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Comparison of Antibacterial Properties of Magnesium Oxide and Copper Oxide Nanopowders: Green Synthesis Approach

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Abstract*—Magnesium oxide (MgO) and copper (Cu) tiny particles were made using a green method that is good for the environment. Making the particles uses natural materials and does not involve harmful chemicals. This method uses plant extracts to help make and keep substances stable, showing a valuable and eco-friendly alternative to traditional ways of making them. In this study, we looked closely at the structure, shape, and light properties of the MgO and Cu nanoparticles we made, using different methods to investigate them. X-ray diffraction (XRD) analysis showed that the nanoparticles were successfully made and had no impurities. The FE-SEM images showed that the nanoparticles were smaller than 100 nanometers, which means they are very tiny. Also, energy-dispersive X-ray spectroscopy (EDX) helped identify the elements in the nanoparticles, confirming that magnesium, oxygen, and copper are present. We used Fourier-transform infrared (FTIR) spectroscopy to find diverse groups of atoms in each sample, which helped us understand their chemical bonds and molecular structure. We used UV-Vis spectroscopy to examine the light properties, showing the unique absorption peaks of MgO and Cu nanoparticles. The antibacterial effects of the MgO and Cu nanoparticles were tested and compared with those of different types of bacteria. The results showed that both kinds of nanoparticles have strong antibacterial effects. They could be used in coatings that fight germs, medical devices, and other areas that need protection against microbes. This study shows the benefits of using green methods to make eco-friendly nanoparticles that work well against bacteria. This approach helps create sustainable and valuable materials.

***Keywords*—Nanoparticles; green synthesis; magnesium oxide; antibacterial properties; copper nanoparticles; UV-Vis spectroscopy.**

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I. INTRODUCTION

These days, nanomaterials are used for numerous applications. Nanotechnology can be used in many fields, such as health care, biology, physics, chemistry, and technology [1]. These microscopic particles are one of a kind because they have a lot of surfaces contrasted to their dimensions. Due to such characteristics, they can make progress in lighting, electricity, the biological sciences, sensing, and catalysis [2], [3], [4]. Things about copper nanoparticles differ from those about copper in substance [5]. The CuO nanoparticles are p-type semiconductors with a discrepancy of 1.7 eV [6]. They are capable of being employed as superconductivity [7], gas monitoring [8], catalysts [9], within the framework of organic-inorganic nanostructure components [10], in capacitors [11], and they can help make electrical via starlight [12]. It shows that the nanoparticles may also have applications in continuing to fight sickness and cancer [13].

Parts are increasingly crucial in many areas, such as biological sciences, petroleum science, and health science [14]. Pigments, fiber boards of directors, electronics, catalysis, and petroleum-based chemicals are all things that use them. Nanomaterials are helpful in many ways for health and life. They carry drugs and can also identify DNA, which kills pathogens and breaks down downward colors [15, 16]. Plus, these things can be used as screens in vision and medical supplies. Nanotechnology can be helpful in these ways because it is very compact and has much of the needed area compared to volume. Nanostructured compounds can be made in many ways, including biological, chemical, and physical approaches [17], [18].

Details particles, heat, sol-gel, precipitation, and pyrolysis techniques [19], [20] are all terrible ways to make harmful chemicals for people and the world. It seems that both negative impacts could be lessened by green output. People, plants, algae cells, and many other living creatures are used in environmentally friendly chemical processes [21]. A lot of individuals do it like this because it is simple, cheap, and does not involve any harmful substances or substances [19], [20], [22], [23]. It could potentially be workable to make man-made oxides of metal purely, just like magnesium oxide, which has been generated in a green way. Inorganic Metals, while alloys made of them, have gotten an excessive amount of your time lately as they can handle tough working situations [24], [25]. Magnesium oxide is different because it stays fixed even when matters get tough [26]. It is also thought to fall apart when safe for humans and pets. It has been established that magnesium oxide kills germs much better than its natural cousins [27], [28], [29].

Several chemical methods can be used to create nanoparticles made from magnesium oxide [30]. On the other hand, the techniques above apply compounds that are bad for humans and the Earth. There are several methods to create metal oxide nanoparticles, including the technique known as sol- the approach known as co-precipitation and the way-out burning method. Hydrothermal method, some environmentally friendly techniques that are healthy for the earth, solvent methods, and the micro-assisted sol-gel method [31]. The "green" synthesis process is one of the best ways to make metal oxide nanostructures. Subsequently, it costs less and employs fewer ingredients that aren't bad to feed them. The substances and chemicals produced are also safe to feed the planet [32]. Biological activity is only one of many activities for which ecologically friendly nanoparticles might be employed. This implies that they can go once tumors and attack illness. They additionally have the potential to attack pathogens and make you feel better. Nano is also not only used to study creatures that live.

Aside from that, they serve as components for transistors that anticorrosive films, substances, and microchips [18], [33], [34], [35], [36], [37]. Some constituent components in plants used to make new knowledge are their roots, stems, blossoms, leaves, and seeds. The phytonutrients in these foods are very different. They include flavonoids, alkaline compounds, phenolics, and other chemicals with a lot of hydrogen, nitrogen, and carbon [38]. When metal salts and plant-based substances are mixed, they make tiny bits that have multiple dimensions, shapes, and surfaces. Nanoparticles and metal oxide nanoparticles can be made from seeds in leaves, flowers, tubers, and stems, among other plant parts. However, leaves are the best source as they can be used again and are preferable to algal, bacterial, or the rest of the plant because leaves do not hurt plants [39]. The extracts of leaves are also great because they clean up contamination much faster than bacteria or algae [40].

II. Materials and Method

A. Preparation of MgO NPs from Coffee

Magnesium oxide Nanopowders from coffee were prepared in several steps:

1) The first step: Pour 5 grams of coffee powder into 50 ml of double-distilled water and stir at room temperature for 1 hour. Leave it for 24 hours at room temperature, head closed, and stir at a medium temperature between 70 and 80 °C. Then, filter the powder and let it cool.

2) The second step: We dissolve 5 mg of magnesium nitrate in 10 ml of double-distilled water. Then, we add the extract little by little and let the water evaporate at 70 to 80 °C.

3) The third step: We dry the powder above 120 degrees and then calcinate it at 500 °C for two hours.

4) Final step: After collecting the powder, we wash it with distilled water twice until the resulting salts dissolve and magnesium oxide remains. We dry the resulting powder, put it in a tube, and send it for testing to ensure the formation of the nanomaterial of MgO NPs.

B. Preparation of Copper/copper Oxide Nanoparticles from Coffee.

Cooper oxide nanoparticles from coffee were prepared in several steps:

1) The first step: Pour 5 grams of coffee powder into 50 ml of double-distilled water and stir at room temperature for 1 hour to remove water-soluble substances. Leave it for 24 hours at an ambient temperature, with the head closed, and stir at a medium temperature between 70 and 90 °C. We filter the powder and let it cool.

2) The second step: We dissolve 5 mg of copper nitrate into 10 ml of double-distilled water. We add the extract gradually and let the water evaporate at 70 to 90 °C.

3) The third step: We dry the powder above 120 degrees and then calcinate it at 500 °C for two hours.

4) Final step: After collecting the powder, we wash it with distilled water twice until the resulting salts dissolve and copper oxide remains. We dry the resulting powder, put it in a tube, and send it for testing to ensure the formation of the nanomaterial copper oxide.

III. Results and Discussion

Figure 1 shows the XRD pattern of MgO nanoparticles made using coffee extract. It shows that our sample had five peaks at angles of 36. 92°, 4289°, 6223°, 7458°, and 7850°These peaks matched the standard JCPDS card number. The ID 01-075-1525 is for the cubic form of magnesium oxide (MgO) with the Fm-3m structure. It relates to the (111), (200), (220), (311), and (222) crystal planes. The Debye-Scherrer formula was used to determine how big the MgO nanoparticles are. This involves using the wavelength of X-rays, the angle of the peak in the diffraction pattern, and the broadness of the lines. The formula is written as:

$$D = \frac{k\lambda}{\beta \cos \theta} \tag{1}$$

In this equation, D is the size of the crystals, k is a factor that describes their shape, λ is the wavelength of the X-ray, β is the width of the peak at half its height (measured in radians), and θ is the angle used in the Bragg equation. The shape factor, k, is related to how the material is arranged on a tiny level and shows the shape of the crystal pieces. The size of the MgO nanoparticles (D) was determined using the Scherrer equation based on the strongest peak from the MgO (200) plane. The size of the MgO tiny particles was found to be 8 nanometers. The XRD details are shown in Table 1.

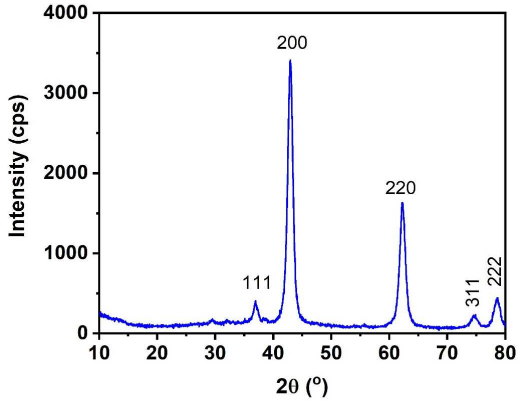

Fig. 1 XRD patterns of MgO nanoparticles synthesized using coffee extract.

It can be seen in Diagram 2 that a caffeine extract was used to make CuO nanoparticles. Two significant summits were at 35.65°, 38.84°, and 39.04°.49.03°, 53.74°, 58.44°, 61.67°, 66.27°, and 68.27°, which matched with The copper dioxide structure is monoclinic, has the C2/c space group, along with the (11), (111), (02), (020), (202), (13), (022), along with (220) planes are shown on JCPDS card no. 00-001-1117 [44], [45], [46]. The ceramic nanoparticles were mostly 17 nm large. The XRD scan values are shown in Table 1.

TABLE I
THE XRD PARAMETERS OF ALL SAMPLES

Sample	2θ [°]	FWHM [°]	d-spacing [Å]	D (nm)
MgO	42.89	1.056	2.10682	8
CuO	35.65	0.502	2.52221	17

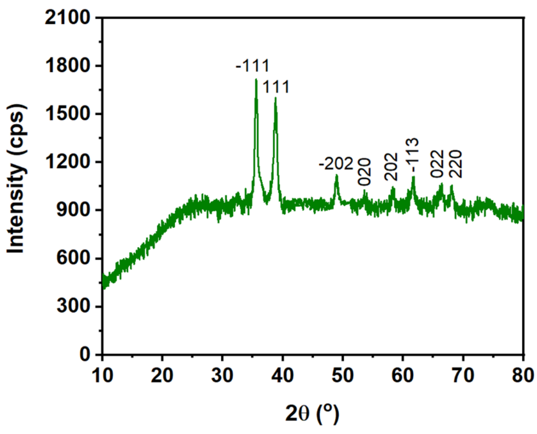

Fig. 2 XRD patterns of CuO nanoparticles synthesized using coffee extract.

A. FESEM images

Figure 3 shows the SEM image of the MgO sample prepared using coffee extract. According to the SEM images, the synthesized manganese oxide material exhibits a variety of morphologies. Notably, there are sheet-like structures referred to as nanosheets. In addition to these nanosheets, the SEM images also reveal the presence of nanoneedles [47]. The typical sizes of the nanoneedles at their tips are around 20 nm, and their lengths are approximately 100 nm.

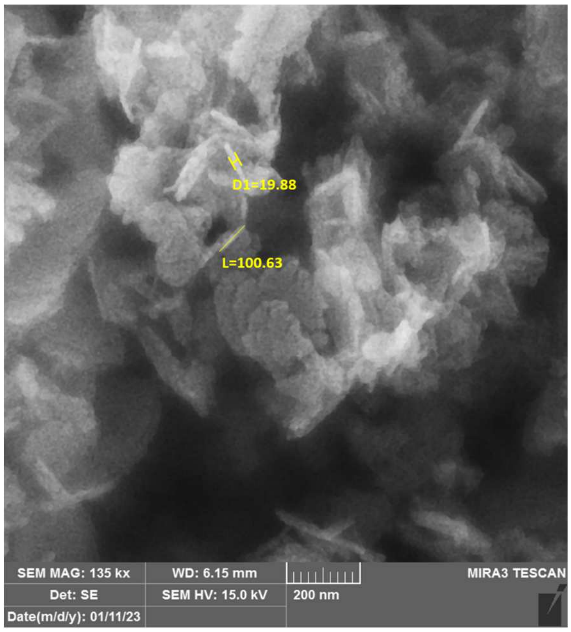

Fig. 3 The SEM images of MgO nanoparticles synthesized using coffee extract.

The SEM image of CuO nanoparticles is presented in Figure 4. Upon examination of this image, it becomes evident that the CuO nanoparticles possess a monoclinic crystal structure [48]. Three axes of unequal lengths characterize a monoclinic crystal structure. Furthermore, one pair of these axes is not orthogonal, meaning they do not intersect at right angles. The CuO nanoparticles exhibit this unique structural characteristic. The observation made in this study aligns with the results obtained from the X-ray diffraction (XRD) analysis. The XRD results revealed the presence of a monoclinic structure in the copper oxide.

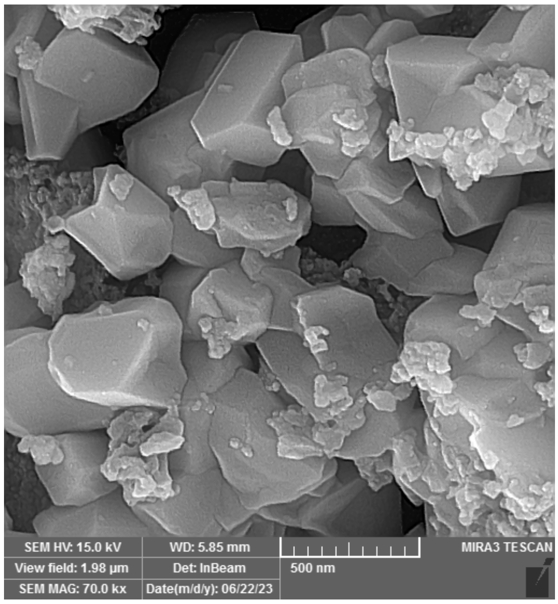

Fig. 4 The SEM images of CuO nanoparticles synthesized using coffee extract

The EDX technique is a science technique that can be employed to determine which compounds are in a substance. The previous EDX test allowed us to work toward the forms that contain components in the FeO (MgO) and CuO (CoO) nanoparticles. The magnesium dioxide and copper dioxide samples, created from coffee grinds, have EDX profiles shown in pictures 5 and 6. The EDX test showed that the magnesium oxide sample contained magnesium and oxygen. Copper and oxygen were present in the Copper Oxidation sample as well.

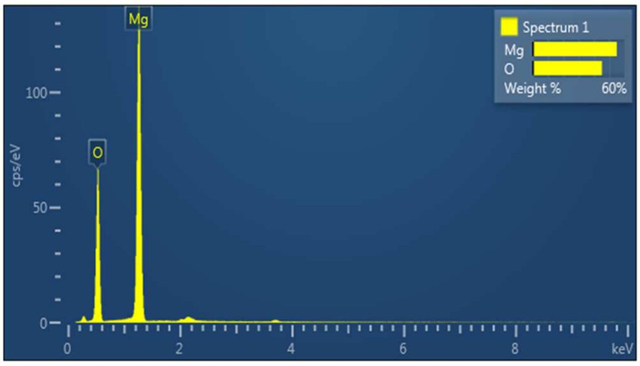

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Fig. 5 EDX diagrams of MgO nanoparticles synthesized coffee extract

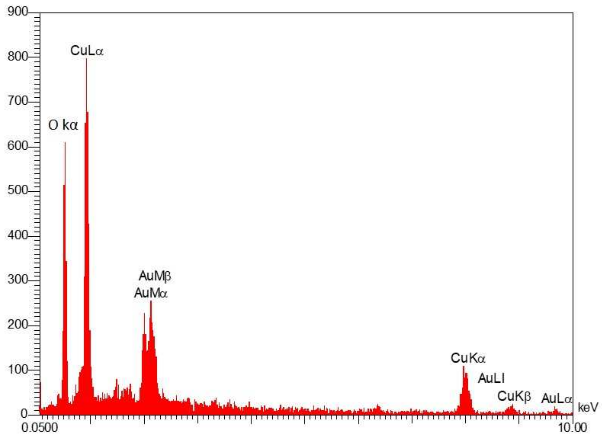

Fig. 6 EDX diagrams of CuO nanoparticles synthesized coffee extract

B. UV-Vis

The company's UV-visible infrared absorption test determined what coffee extract-made MgO and copper oxide nanoparticles could be absorbed. Spectroscopy was carried out between 200 and 1100 nm, and the absorption data for the MgO sample can be seen in Figure 7. A UV-visible spectrum edge can be seen in number seven for the material being looked at. It is at 297 nm. The rise in this level is a crucial sign that exceedingly small iron oxide (MgO) crystals have formed. The value recorded at 297 nm shows that the material has oxide chemicals. As further evidence that nanoparticles made of magnesium oxide exist [49], [50], [51], [52], this peak is a perfect match for the pinnacle that is usually seen for them. Figure 8 shows that copper oxide nanoparticles were made from coffee extract. It has an apparent zenith at 345 nm in the Ku-V region of the copper dioxide particle. This peak makes it highly likely that the nanoparticles of CuO were made [53], [54].

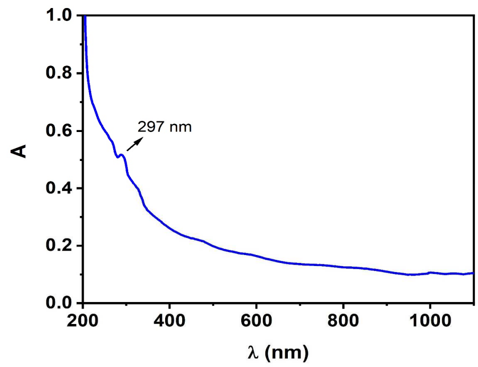

Fig. 7 Absorbance spectra of MgO nanoparticles synthesized using coffee extract.

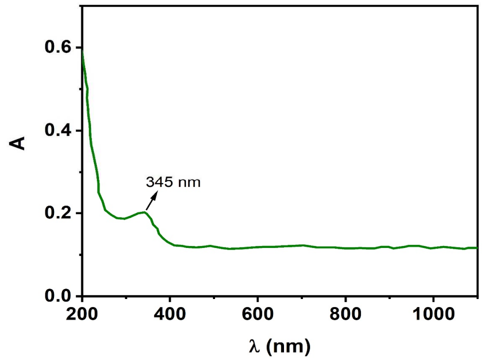

Fig. 8 Absorbance spectra of CuO nanoparticles synthesized using coffee extract.

C. FTIR

The Fourier transform inf of the coffee extract-made MgO nanoparticles is shown in Figure 9. You can see two prominent peaks at 1443 millimeters^{-3} and 3469 cm^{-3}. These peaks show that it has hydroxide (-OH) groups. The groups with -OH make the 1443 cm^{-3} and 3469 cm^{-3} peaks. These communities are what make the waves that bend. It turns out that H2O molecules are sticking to the MgO nanoparticles' surface. This occurs when particles are generated, which can change how the nanoparticles work. Another set of rings at 421 cm^{-3} and 6 cm^{-3} can be seen on the topping of these -OH peaks. The bands in this picture show whether things change throughout the magnesium oxide group. These spectra give more proof that coffee extraction was used to make mica particles [49], [55], [56], [57]. They show that magnesium dioxide formed in the sample.

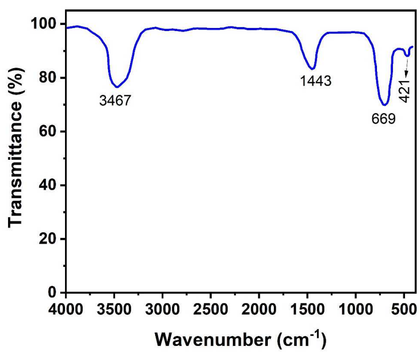

Fig. 9 The FT-IR spectrum of MgO nanoparticles synthesized using coffee extract.

Figure 10 shows that NPs made from CuO were made from hazelnut extract. The coffee extract was used to produce copper oxide nanoparticles. Some of the spots on the FT-IR band can be linked with various functional groups. The highest level at 3429 cm⁻² might be caused by water molecules or hydroxyl groups [58], [59].

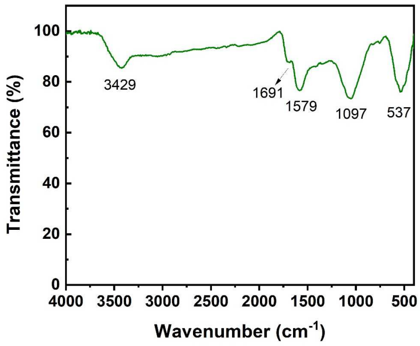

Fig. 10 The FT-IR spectrum of CuO nanoparticles synthesized using coffee extract

Because groups of carbonyls are present, the height peak at 1691 cm^{-1} is linked to the C=O bending wave [19]. This peak at 1579 cm^{-3} is likely caused by the C=C bending wave [59] since it is made up of aromatic chemicals or hydrocarbons, which are The prominence at 1097 cm^{-1} is caused by the C–O–C link [18], [19]. A lot of the time, this point in time at 537 inches^{-3} is connected to Cu-O waves that stretch. This proves that copper oxide exists [58], [59].

D. Antibacterial Properties

They used two kinds of bacteria, markers, to see how much MgO and copper dioxide nanoparticle solutions killed them. Bacteria such as Escher, the American Type Culture Collection25922, were used while participating in the pathogen Sta ATCC25923 (S. aureus for short). The E. coli gene is Gram-negative, while the S. aureus gene is Gram-positive. Researchers use these categories a lot to figure out how both microbes talk among themselves and what characteristics they share. Since the aggressive disease, S. aureus, the American Type Culture Collection25923 is often used for researching how it affects individuals differently. It is a model for studying S. aureus infections, including virulence factors and antibiotic resistance. E. coli ATCC25922 is a widely used Gram-negative bacterium representing both beneficial and pathogenic strains of E. coli. It is used to understand genetics, physiology, virulence factors, and antibiotic resistance. ATCC25922 helps examine antimicrobial agents and develop interventions against E. coli infections. The comprehensive results of our analysis of the antibacterial activity of MgO and CuO nanoparticles against S. aureus and E. coli are detailed in Table 2.

TABLE II
ANTIBACTERIAL ACTIVITY OF MGO AND CUO NANOPARTICLES AGAINST REFERENCE BACTERIAL STRAINS

Sample	**Microorganism**	**Number of inoculated microorganisms at zero time (CFU/ml)**	**Sample concentration**	**Exposure Duration**	**Results (CFU/ml)**	**Percentage reduction**
MgO	S. aureus	3.5×10^5	0.3 mg/ml	24 h	5.12×10^7	68.39%
	E. coli	1.72×10^5	0.3 mg/ml	24 h	1×10^8	68.75%
CuO	S. aureus	3.1×10^5	0.3 mg/ml	24 h	< 10	> 99.999%
	E. coli	1.78×10^5	0.3 mg/ml	24 h	< 10	> 99.999%

The results indicated that the MgO and CuO nanoparticles exhibited a different level of effectiveness in reducing the number of microorganisms. Also, Figures 11 to 14 presented the dilution series of MgO and CuO nanoparticles synthesized using coffee extract against the two microorganisms. A dilution series refers to solutions with decreasing concentrations of the substance being tested. Based on the results in Table 2, we can draw several conclusions about the antibacterial activity of MgO and CuO nanoparticles.

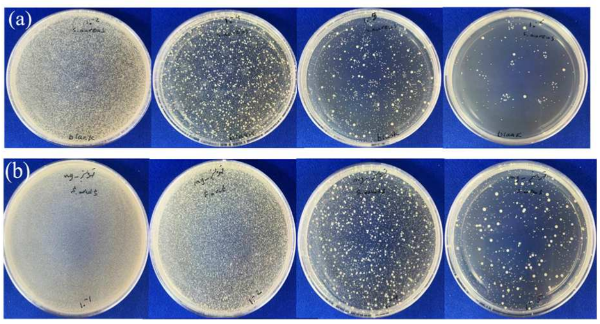

Fig. 11 Dilution series of MgO nanoparticles synthesized using coffee extract, tested against S. aureus: (a) Blank series and (b) Sample series

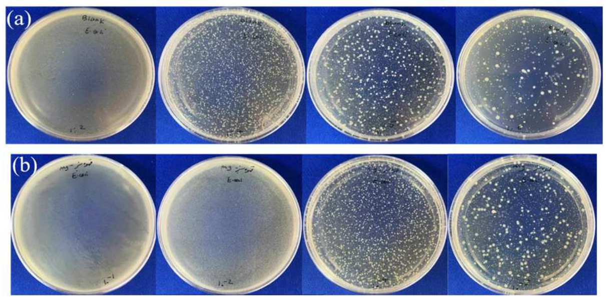

Fig. 12 Dilution series of MgO nanoparticles synthesized using coffee extract, tested against E. coli: (a) Blank series and (b) Sample series

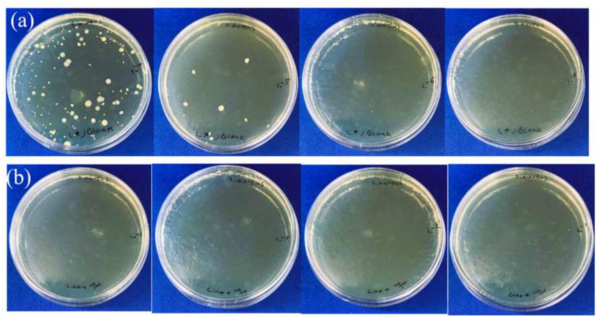

Fig. 13 Dilution series of CuO nanoparticles synthesized using coffee extract, tested against S. aureus: (a) Blank series and (b) Sample series

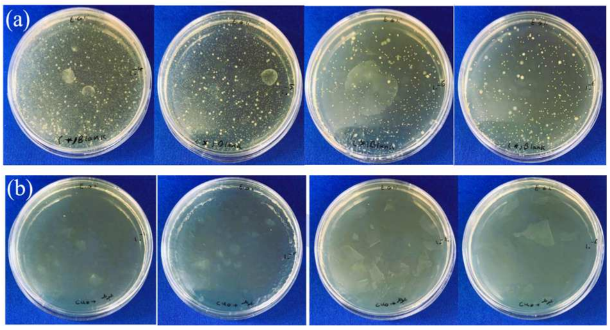

Fig. 14 Dilution series of CuO nanoparticles synthesized using coffee extract, tested against E. coli: (a) Blank series and (b) Sample series

When exposed to S. aureus for the MgO nanoparticles, the colony-forming units per milliliter (CFU/ml) increased from 3.5×10^5 to 5.12×10^7 after 24 hours of contact at a sample concentration of 0.3 mg/ml. This corresponds to a reduction percentage of 68.39%. Similarly, for E. coli, the CFU/ml increased from 1.72×10^5 to 1×10^8 with a reduction percentage of 68.75%. On the other hand, the CuO nanoparticles demonstrated a significantly higher antibacterial effect. For both S. aureus and E. coli, the CFU/ml decreased to less than 10 after 24 hours of contact at the same sample concentration of 0.3 mg/ml. This corresponds to a reduction percentage of more than 99.999%. In summary, while both MgO and CuO nanoparticles exhibit antibacterial properties, the CuO nanoparticles appear to be significantly more effective in reducing the bacterial population of both S. aureus and E. coli. This could be due to numerous factors, such as the difference in the reactive surface area, the release rate of ions, or the interaction between the nanoparticles and the bacterial cell wall. These results suggest that CuO nanoparticles could be more suitable for applications with strong antibacterial properties.

IV. Conclusion

This research synthesized manganese oxide and copper oxide nanoparticles using a green synthesis method with coffee extracts. The green synthesis method is eco-friendly and uses natural resources to produce nanoparticles, avoiding toxic chemicals. Using coffee extract as a reducing and stabilizing agent in synthesizing manganese oxide and copper oxide nanoparticles is an effective and sustainable approach. The XRD analysis showed that MgO and CuO nanoparticles were successfully synthesized using coffee extract, exhibiting distinct crystalline phases. The SEM images revealed distinct morphologies of the synthesized MgO and CuO nanoparticles using coffee extract. The MgO sample exhibited nanosheets and nanoneedles with lengths of approximately 100 nm and tip sizes of around 20 nm. On the other hand, the CuO nanoparticles possessed a monoclinic crystal structure characterized by three axes of unequal lengths and one pair of axes not intersecting at right angles. The EDAX analysis confirmed the presence of Magnesium and Oxygen in the MgO sample and Copper and Oxygen in the CuO sample, both synthesized using coffee extracts. Based on the UV-Vis spectroscopy, the MgO sample displayed a peak at 297 nm, confirming the formation of nanosized MgO particles.

Similarly, the CuO sample peaked at 345 nm, indicating the successful synthesis of CuO nanoparticles. These peaks are characteristic of their respective oxide compounds. The FTIR spectra revealed specific peaks corresponding to the vibrational frequencies of the bonds between manganese and oxygen in MgO, and copper and oxygen in CuO, thereby confirming their successful synthesis. Based on the antibacterial properties, both Manganese Oxide and Copper Oxide nanoparticles showed antibacterial activity against S. aureus and E. coli. However, the CuO nanoparticles were significantly more effective in reducing the bacterial population. In contrast, the MgO nanoparticles also demonstrated antibacterial activity, but to a lesser extent. This suggests that while both types of nanoparticles have antibacterial properties, CuO nanoparticles may be more suitable for applications requiring vigorous antibacterial activity.

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