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Anti-bacterial Activity of Copper Oxide Nanoparticles Biosynthesized by Gum Arabic extract

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Abstract

Copper oxide NPs produced using Gum Arabic extract and employed as anti-bacterial and anti-fungal agents in this work. The UV–visible absorption spectra revealed that the absorbance peak is around 224 nm, and the vibrational modes of phytochemicals in the extract analyzed using the FT-IR technique, which allows for material identification and information. The shape of copper oxide, which has a spherical nanoparticle and semi-spherical were really created with average diameter 36.47 nm through results FE-SEM. As-produced CuO nanoparticles being in the mixed crystalline phases of CuO and Cu_2O with a predominant percentage of the CuO phase, according to an XRD analysis. Four bacterial strains and one fungal species were looked at using CuONPs. The results show activation regions with diameters (20,21,22) mm this confirms the effectiveness of nanomaterial against bacterial and fungal activity.

Introduction

The twenty-first century has seen a scientific revolution in nanotechnology. Due to their distinctive characteristics, which are crucial to contemporary research, nanotechnology is increasingly being studied. Due to their high potential in a number of fields, CuO nanomaterials are regarded as one of the most significant transition metal oxides because of their intriguing properties. Due to its ease of use, environmental friendliness, and affordability, its synthesis using green chemistry principles is becoming more significant as a source of next-generation antibiotics. CuO materials have band gaps between 1.2 and 2.0 eV [1].

Copper (Cu) and copper oxide (Cu_2O) nanoparticles have garnered a lot of interest due to their significance in contemporary technology and inexpensive price. Copper nanoparticles are gaining popularity due to their abilities in optics, catalysis, mechanics, and electricity [2-5]. Additionally, due to their anti-bacterial qualities, CuO nano-materials make great candidates for use as therapeutic agents. To address drug resistance, researchers are currently up against a significant hurdle in the healthcare industry. Various advanced synthesis approaches are being created every day in this field, including physical, chemical, and biological processes. It is still challenging to obtain stability using CuO nanomaterial, despite the fact that its synthesis is less expensive than that of silver (Ag), gold (Au), and platinum (Pt) nanoparticles [6-12]. CuO nanomaterial has been produced using a variety of techniques, including vapor deposition, electrochemical reduction, radiolysis reduction, thermal breakdown, and chemical reduction. These techniques, however, are linked to pollution problems and detrimental to both ecosystems and public health. Therefore, "green chemistry," which refers to using natural resources like plants and microbes for the synthesis process, may prove to be a viable solution to deal with these problems. Plant extract and metal salt solution are blended to produce the first nanoparticles.

The biological reduction of the metal salt causes the reaction's color to shift. The manufacture of nanoparticles involves a variety of plants and plant components. Plant extracts contain a variety of phytochemicals and secondary metabolites, including flavonoids, alkaloids, proteins, polysaccharides, cellulose, and phenolic compounds. Different shape, size, and morphological nanoparticles are produced from plant extracts depending on the type and amount of reduction agents used. By changing synthesis parameters such pH, metal salt concentration, temperature, plant extract concentration, and reaction duration, researchers have demonstrated a considerable impact on nanoparticle generation as well as changes in size, shape, and morphology [12,13].

The current study focused on the synthesis, characterization, and assessment of the anti-bacterial and fungal potential of CuO nanoparticles generated from gum Arabic extract.

Experimental part

Gum Arabic was added 1g per 100 ml of deionized water. To obtain a pure aqueous extract and put on a magnetic stirrer at 60 °C for half an hour and filtered three times with cotton after chilling. 100 ml of deionized water was mixed with 1.8 gram of copper nitrate ($Cu(NO_3)_2$) and heated to 60 °C for 30 min. Following that, 10 ml of the Gum Arabic extract and 100 ml of the copper nitrate solution at 60 °C were blended for one hour at normal atmospheric pressure while constantly stirring, it observed the color shift demonstrated and formation of copper oxide nanoparticles as shown in Figure.1, Then the product is deposited by drop casting (4 drops) on glass substrates and leave it to dry for the purpose of testing them.

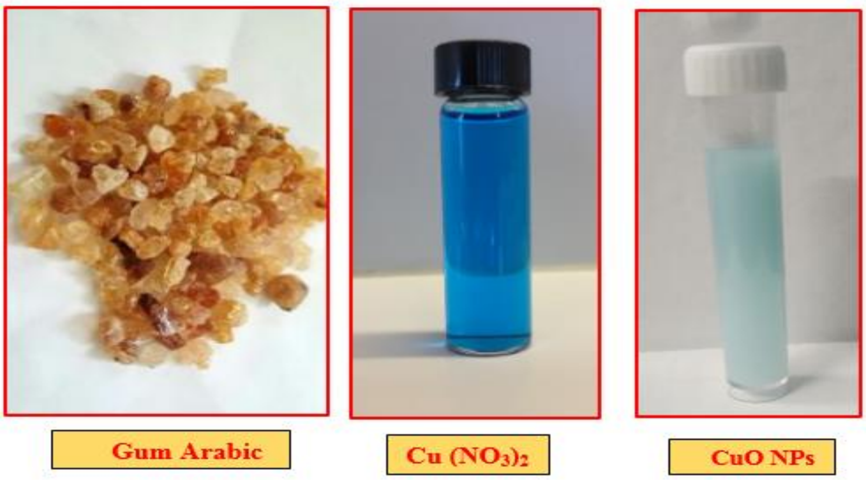

Fig.1: shows the stage of preparation of CuO nanoparticles.

Result and Dissection

Structural properties

The X-ray diffraction pattern of the produced CuO nanoparticles that deposited by drop casting (4 drops) on glass substrate as shown in Figure 2. According to JCPDS no. 41-0254, the diffraction peaks located at 2 theta= 35.3, 38.5, 52.3, and 61.2 correspond to the (111), (111), (020), and $(\bar{1}13)$ planes of the crystalline phase of monoclinic (CuO). The (111) and (220) planes of the cubic cuprous oxide (Cu_2O) crystalline phase are where the peaks at 2theta 16.8, 21.3, and 32.3 are located (JCPDS no. 34 1354). As-produced CuO nanoparticles are in the mixed crystalline phases of CuO and Cu_2O, with a predominating proportion of the CuO phase, according to the XRD analysis with average crystalline size 24.62 nm [14,15].

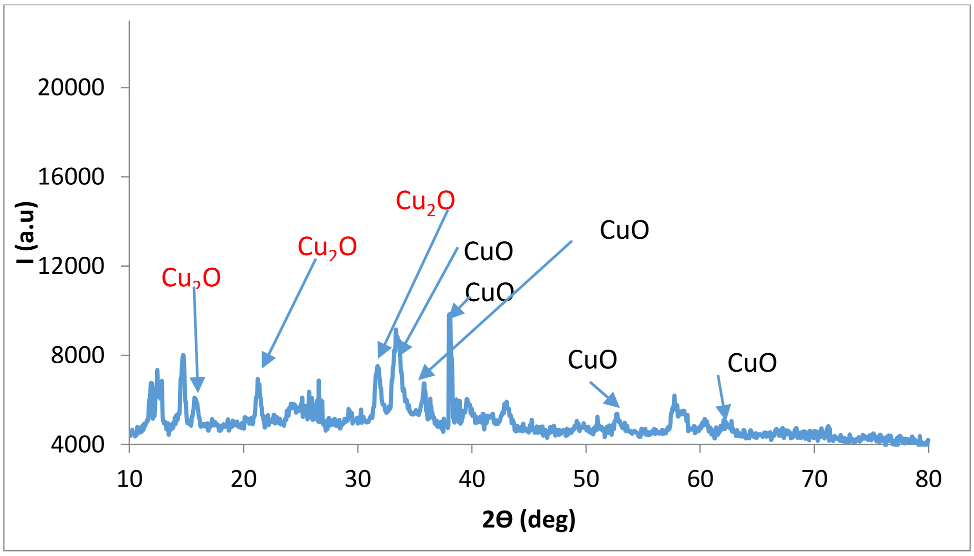

Fig.2: XRD analysis of copper oxide.

Fourier transform infrared spectroscopy (FT-IR) is a method for measuring the vibrational frequencies of molecules' bonds. At room temperature, CuO nanoparticles were scanned using FT-IR spectroscopy in the range 4000-400 cm^{-1}. Figure 3 depicts the FT-IR spectrum of CuO nanoparticles. The detected peaks at 412, 810 (1/cm) correlate to the stretching vibration properties of the Cu-O bond and Cu_2O [16]. The adsorbed water molecule causes the wide absorption peak at approximately 3271 (1/cm) because nano-crystalline materials with a high surface to volume ratio absorb moisture. C-H, OH, C=O, and C-O bonds cause a wide absorption peak at 2357,1639,1411,1296 and 1041 (1/cm). Thus, the presence of two phases of CuO nanoparticles (CuO and Cu_2O NPs) confirmed by Fourier transform infrared spectroscopy analysis [17-20].

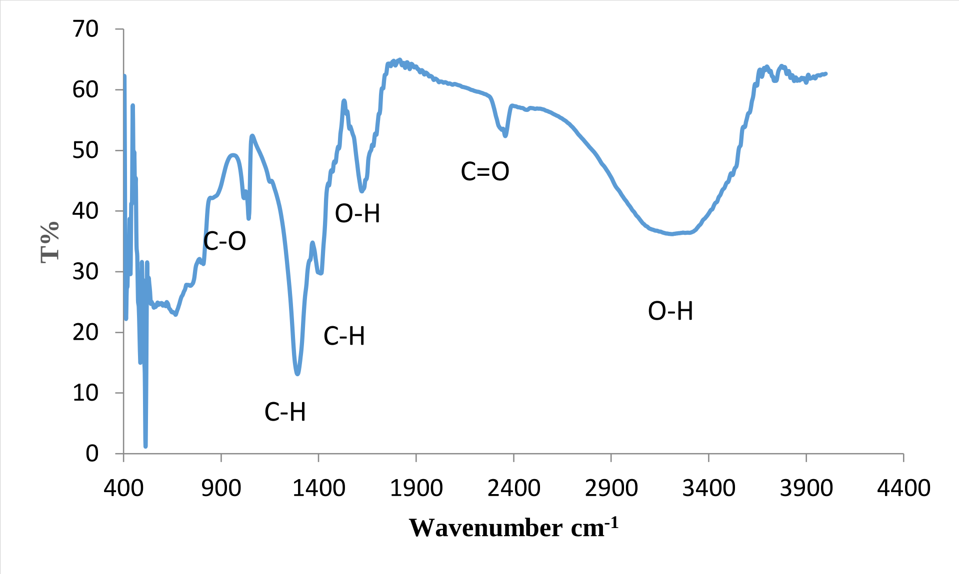

Fig.3: FT-IR spectrum of CuO nanoparticles.

FE-SEM was used to study the morphological characteristics of the CuO nanoparticles that deposited on glass substrate as in Figure 4. The resulting nanoparticles exhibited diverse structures and nanometer-sized dimensions. This picture demonstrates how few spherical nanoparticles and semi-spherical were really created with average diameter 36.47 nm, to benefit from the effectiveness of its absorption by bacteria and fungi. The majority of the nanoparticles were agglomerated, although others were not. Thus, the SEM results confirmed the produced particles' behavior in a nanostructure. The results are similar with those of earlier publications With a few slight changes brought on by chemical composition [21,22].

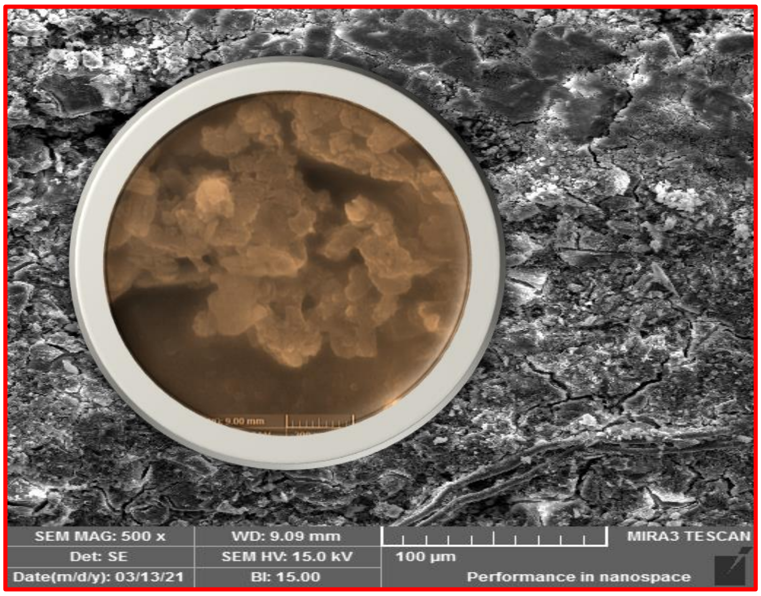

Fig. 4: FE-SEM image of the synthesized CuO nanoparticles.

Optical properties

CuO nanoparticles as-produced have a strong absorption peak at 224 nm in UV-VIS absorption spectra as in Figure 5. The existence of the cuprous oxide (Cu_2O) phase is responsible of this absorption peak. In Figure 5, there is also slight increases in the absorption at 650 nm; the cupric oxide (CuO) phase is what is responsible for increases in the absorption in this region. The presence of the CuO and Cu_2O phases therefore confirmed by the UV-visible absorption spectra of the CuO nanoparticles. Plotting absorptivity $(hv)^2$ as a function of photon energy to determine the band gap of CuO nanoparticles. The band gap energy of the CuO nanoparticles was 4.8 eV, which is larger than energy gap of bulk CuO (2.1 eV) as shown in figure 6. This estimate of the energy of the band gap for CuO nanoparticles is pretty close to earlier observations, although being a bit bigger. The smaller particle size caused by the greater band gap. Quantum confinement takes place when the size of nanocrystals is less than the Bohr radius of the excited electron-hole pair, and by increasing energy gap, the size of the nanoparticles decreases which enables it to penetrate into the bacterial cell to kill it [23,24].

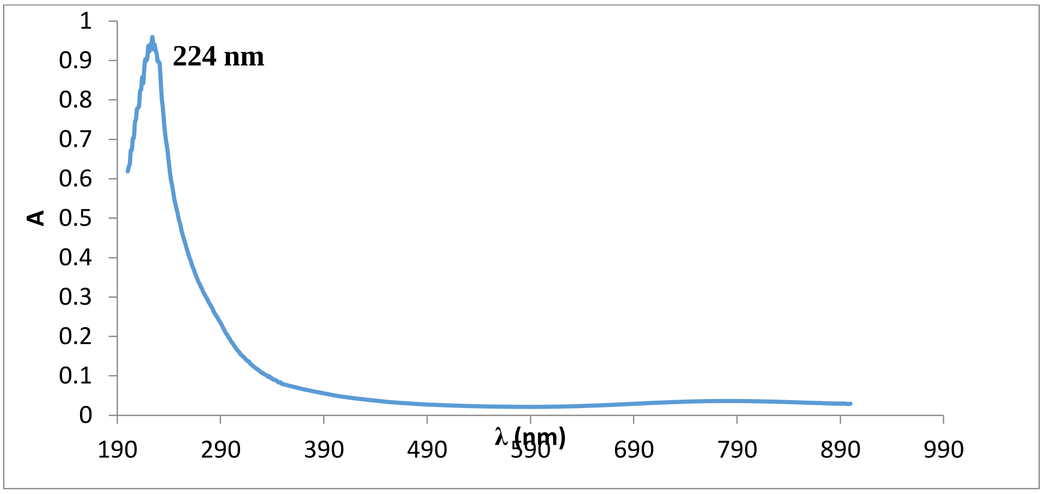

Fig. 5: UV-visible absorption spectrum of copper Oxide nanoparticles.

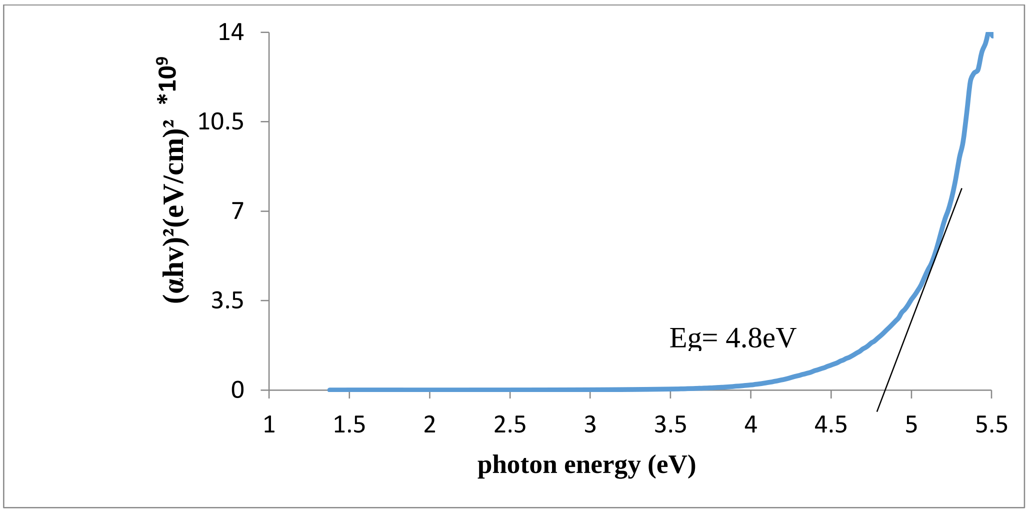

Fig. 6: Shows the energy band gap of CuO nanoparticles.

According to previously published investigations, the anti-bacterial preventive and anti-fungal curative efficacy of green produced CuO NPs examined in the present study utilizing the agar well diffusion method [25,26]. By evaluating the zones of inhibition as shown in figure 7, the anti-bacterial activity of CuO NPs was assessed against both Gram-positive and Gram-negative multidrug resistant bacterial strains. The highest efficacy observed against Sta. aureus with a 22 mm zone of inhibition. The findings for anti-fungal activity for Candida were likewise excellent was 21mm, which regarded as fairly significant as shown in Figure 8. Previous studies reported, CuO NPs enter bacterial cells by alterations in membrane shape, which sharply increase cell permeability and interfere with transport across the plasma membrane, both of which lead to cell death [27]. Different processes have been identified as the cause of CuO NPs ' anti-bacterial action to date. These include the production of reactive oxygen species, protein and lipid oxidation, cell membrane disintegration, DNA degradation, and reactive oxygen species. Additionally, the shape, size, and oxidation number of nanoparticles affect their anti-bacterial effectiveness [28]. Nanoparticles in the current study have a high surface-to-volume ratio, which allows them to engage with microbe cell membranes and stop their growth [29-31].

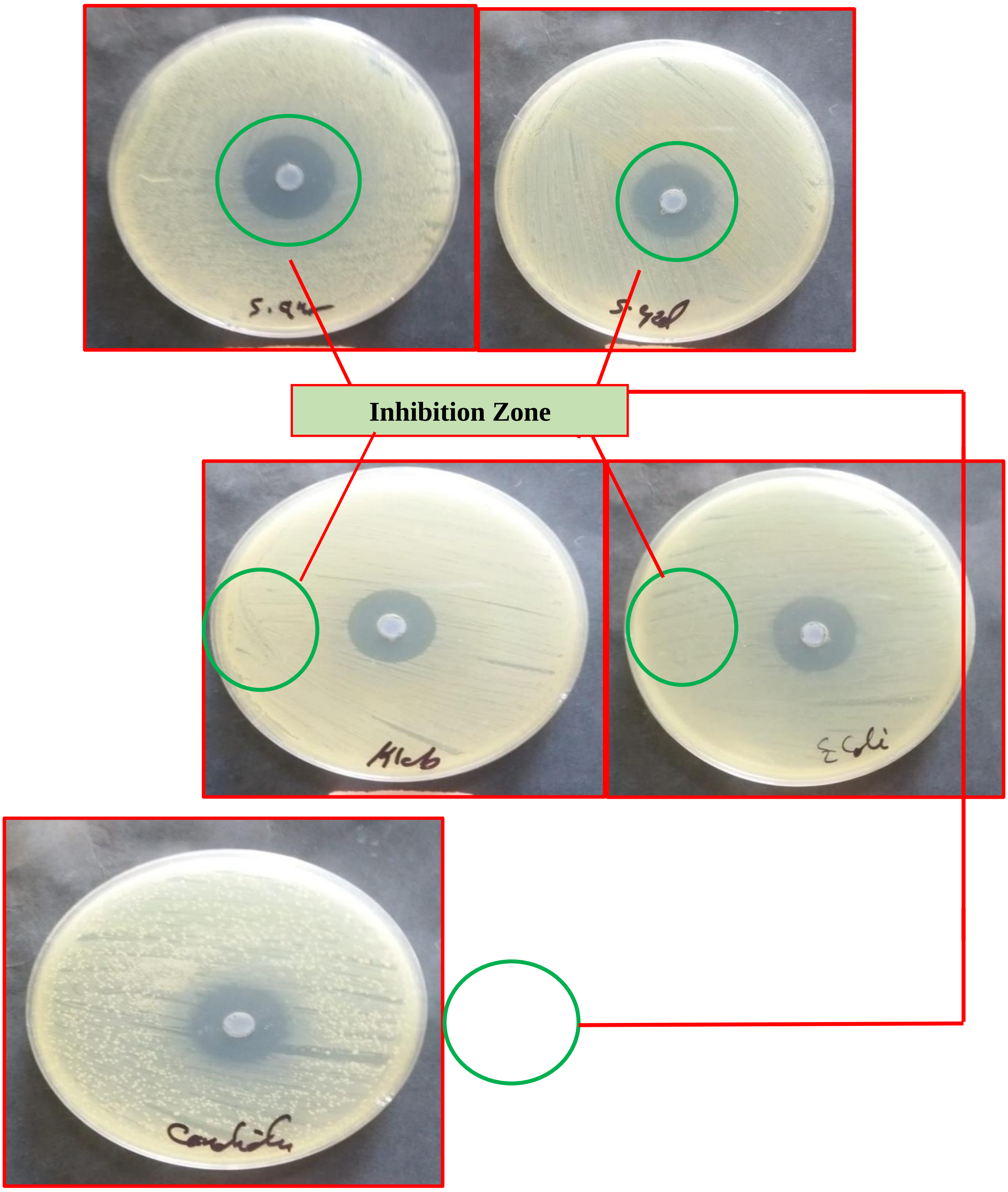

Fig. 7: Anti-bacterial and anti-fungal activity of CuO NPs

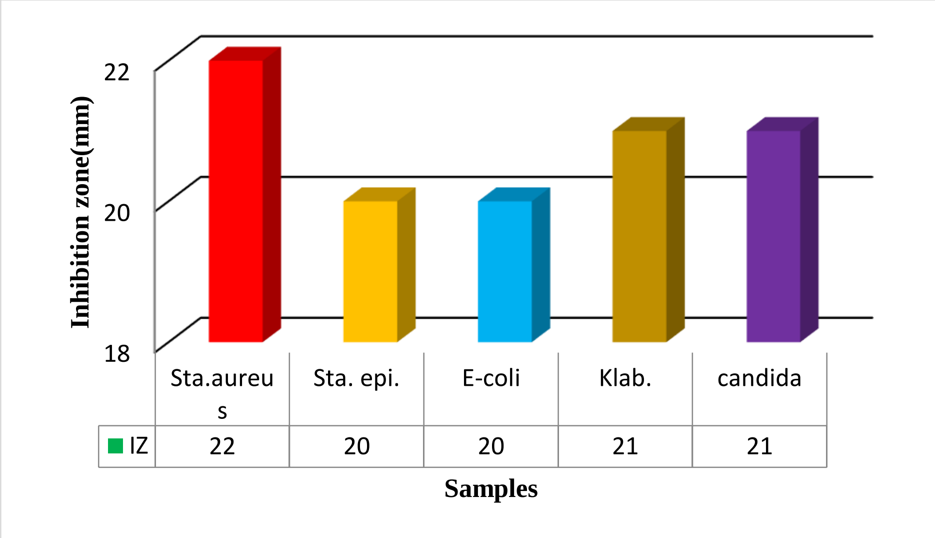

Fig.8: Diameter of inhibition zone of CuO NPs.

Conclusion

We have succeeded in synthesizing nanoparticles of CuO using Gum Arabic extract. This method is simple and environmentally friendly. It also saves a significant number of nanomaterials, where CuO has demonstrated its efficiency as an antibiotic as demonstrated by the findings of this study. Based on the current findings, green produced CuO NRs might have potential uses in the realm of nanomedicine. Through the results obtained, CuO NPs can be used as window layer in solar cell applications.

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النشاط المضاد للبكتريا لجسيمات اوكسيد النحاس النانوية المحضرة بطريقة التخليق النباتي بواسطة مستخلص الصمغ العربي

عماد كاظم خضير

وزارة التربية، مديرية تربية بغداد الكرخ /2، العراق

معلومات البحث:

تأريخ الاستلام: 2023/01/30
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الكلمات المفتاحية:

الجسيمات النانوية لاوكسيد النحاس، مستخلص الصمغ العربي، مضاد للبكتريا

معلومات المؤلف

الايميل:

الخلاصة:

يتم انتاج الجسيمات النانوية لاوكسيد النحاس باستخدام مستخلص الصمغ العربي ويعمل كمضاد للبكتريا ومضاد للفطريات، بينت اطياف الامتصاص المرئي للاشعة فوق البنفسجية ان ذروة الامتصاص تبلغ حوالي (224) نانومتر وكذلك انماط الاهتزاز للمواد الكيميائية النباتية في المستخلص والتي تسمح بتحديد المواد التي تم تحليلها باستخدام تقنية (FT-IR). تم تحديد شكل اوكسيد النحاس الذي يحتوي على جسيمات نانوية كروية وشبه كروية بمتوسط قطر يبلغ (36,47) نانومتر من خلال نتائج ال FE-SEM. وان جسيمات اوكسيد النحاس النانوية المنتجة في المراحل البلورية المختلطة من CuO, Cu_2O مع نسبة سائدة من طور CuO وفقا لتحليل XRD. تم دراسة أربع سلاسل بكتيرية ونوع فطري واحد باستخدام الجسيمات النانوية لاوكسيد النحاس أظهرت النتائج مناطق تنشيط بأقطار (22, 21, 20) ملم، وهذا يؤكد فعالية المادة النانوية ضد النشاط البكتيري والفطريات.