Synthesis CuO-ZnO nanocomposite and its application as an antibacterial agent

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Abstract. The synthesis of CuO-ZnO composites and their application as anti-bacterial have been conducted. Nanocomposite CuO-ZnO was synthesized using sol-gel method. The nanocomposite products were characterized by XRD, DR-UV, SAA, FTIR, SEM-EDX. The results of the XRD analysis showed that the CuO-ZnO composite has a nanometer size with the average of 15.99 nanometer. The DR-UV analysis showed that the CuO-ZnO composite has a band-gap of 2.28 eV in the average. The analysis of SAA showed that the CuO-ZnO has a surface area of 23.20 m$^2$/g in average. FTIR investigation revealed that the vibration of ZnO was observed at 432.05 cm$^{-1}$ whereas CuO at 524.64 cm$^{-1}$ and 594.06 cm$^{-1}$. The SEM-EDX analysis showed that the ZnO has a hexagonal structure whereas the CuO has a monoclinic structure. The CuO-ZnO nanocomposite has the ability as an antibacterial against $S.$ aureus as gram-positive and $E.$ coli as Gram-negative bacteria.

1. Introduction
Nanomaterial is a material with the size of nanoscale (1-100 nm). This material has a unique properties and high value for commercial applications. The key factors of nanoparticles are small particle size, narrow size distribution, low agglomeration and high dispersion [1]. Nanomaterial can be applied in various fields such as cosmetics, paints, displays, batteries, medicine, catalysis, gas sensor, food engineering (production, processing, safety and packaging), agriculture, energy (storage and conversion) and construction [2].

ZnO is an excellent antibacterial agent because it has photocatalytic properties. This material can be activated by UV and visible light to form the electron-hole pairs. These holes can split the H$_2$O molecule (from suspension from ZnO) to OH$^-$ and H$^+$. Dissolved oxygen molecules on could be converted to superoxide radical anions (•O$_2^-$) which react with H$^+$ to produce (HO$_2$•) radicals. The collisions of (HO$_2$•) with electrons produce the hydrogen peroxide anion (HO$_2$⁻). These species react with hydrogen ions to produce H$_2$O$_2$ molecules that can penetrate the cell membranes and kill the bacteria [3]

The advantage of ZnO is their photocatalytic ability that can produce radical compounds. This material can be used as an antibacterial agent [3]. However, the ZnO material has large band gap as reported by Vijayakumar et al. [4] which can decrease the photocatalytic properties. Other researchers reported that the ZnO have the band gap of 3.3 eV [5].

The addition of CuO to ZnO could form the CuO-ZnO composite that increased particle size and decrease the band gap energy [6]. The higher concentration of CuO in composites, the smaller band...
gap energy could be obtained. The CuO percentage of 0.5%, 1%, 3%, 5% and 10% on the CuO-ZnO composite resulted in the band gap energy of 3.1, 3.0, 2.95, 2.75 and 2.65 eV respectively. The ZnO band gap energy before impregnated with CuO was 3.20 eV [5]. Other researchers reported [4] that the addition of CuO to ZnO lowered the band gap energy from 3.3 eV to 3.1 eV. It increased the stability of photocatalytic reaction and increased radical species such as superoxide anion radical (\(\bullet O_2^-\)), (HO\(_2\)•) and (HO\(_2\)^–) which can inhibit the growth of bacteria.

Sol-gel is a simple method for nanomaterial synthesis. This method involves two stages of sol and gel formation. Many techniques could be applied in the sol-gel technology such as the changing of initial precursor, time of gel formation, type of catalyst, rate of solution formation, gel formation conditions and gel physical processing. Thus, the sol-gel process enables the formation of solid material through gelation from a solution [7].

The main difference between gram-positive and gram-negative bacteria is that the protein Gram-positive bacteria have thicker cell wall containing many layers (consisting of peptidoglycan and acid teichoic) while protein Gram-negative bacteria have thinner cell wall that contain many layers (consisting only of peptidoglycan). These cause the difference between the gram-positive and gram-negative reaction to an antibiotic. Although the cell walls are thicker, Gram-negative bacteria are more resistant to antibiotics than Gram-positive bacteria because the bacteria can penetrate the lipid layer on the outer membrane of the bacteria [8].

Based on the above description, the authors synthesized the CuO-ZnO nanocomposite using sol-gel method to be applied as antibacterial for the \textit{Staphylococcus aureus} as gram-positive and \textit{Escherichia coli} as Gram-negative bacteria.

2. Experimental

2.1 Materials

Zinc(II) acetate dihydrate (Zn(CH\(_3\)COO)\(_2\).2H\(_2\)O) 98% (Merck), copper(II) sulphate pentahydrate (CuSO\(_4\).5H\(_2\)O) 98% (Merck), ethanol p.a (Merck), NaOH p.a, ethylene glycol p.a (Merck) \(\rho= 1.11\) g/mL (Merck), 99% citric acid (Merck), NaCl, Nutrient agar, \textit{Staphylococcus aureus} and \textit{Escherichia coli}, and distilled water.

2.2 Synthesis of ZnO nanoparticles

Synthesis of ZnO nanoparticles used the sol-gel method [9]. Typically, 4.6751 g of Zn(CH\(_3\)COO)\(_2\).2H\(_2\)O was dissolved in 20 mL ethanol and stirred with a magnetic stirrer for an hour. The mixture was kept for 48 hours to form a gel and washed with distilled water several times. Then, the gel was dried in an oven at 120 °C to constant weight and calcined at 500 °C for 4 hours to obtain the ZnO nanoparticles. These materials were characterized by Diffuse Reflectance-UV (DR-UV) and X-ray Diffraction (X-Ray Diffraction), SAA (BET), FTIR, and SEM.

2.3 Synthesis of CuO nanoparticles

Synthesis of CuO nanoparticles used the sol-gel method [10]. The 20 mL CuSO\(_4\).5H\(_2\)O 0.1M was added to 10 mL of 0.1 M citric acid and stirred with a magnetic stirrer until homogenous. The solution was added by 10 mL of 1 M NaOH drop by drop and stirred with a magnetic stirrer for 1 hour to dark blue. Then, it was stored (aging) for 48 hours and washed with distilled water several times. The gel was dried in an oven at 120 °C to constant weight and calcined at 500 °C for 4 hours to obtain the ZnO nanoparticles. These materials were characterized by Diffuse Reflectance-UV (DR-UV) and X-ray Diffraction (X-Ray Diffraction), SAA (BET), FTIR, and SEM.

2.4 Synthesis of CuO-ZnO nanocomposite

Synthesis of CuO-ZnO nanocomposite used the sol-gel method [11]. Firstly, 25 mL of ethylene glycol was mixed with 5.3247 g of Zn(CH\(_3\)COO)\(_2\).2H\(_2\)O, 25 mL of distilled water and 6.3 g of citric acid with vigorous stirring for an hour. After an hour, 0.4244; 0.6741; 0.9488; 1.2733 g of CuSO\(_4\).5H\(_2\)O were added to the suspension at 60 °C for 3 hours and mixed quickly. The solution was kept in the dark for 48 hours and washed with distilled water several times. The obtained gel was dried at 120 °C to constant weight and calcined at 500 °C for 4 hours to produce the CuO-ZnO nanocomposites. These
materials were characterized by Diffuse Reflectance-UV (DR-UV), X-ray Diffraction (X-Ray Diffraction), SAA (BET), FTIR, and SEM-EDX.

2.5 Antibacterial activity test

2.5.1 Agar medium oblique and bacterial inoculation. All the tools were sterilized by washing them, then wrapped in paper and heated in an oven at a temperature of 170 °C for 2 hours. Agar medium was made by weighing 0.23 g Nutrient agar. All the ingredients were put into the Erlenmeyer and dissolved in 10 mL of distilled water to a boil. Poured each five mL into two test tubes. Then, the solutions were sterilized in an autoclave at 121 °C for 15 minutes and waited for into a warm solution for ±30 minutes to condense at a slope of 30°. On an agar medium oblique, a bacterial suspension was stroked using a needle ose. The medium oblique was incubated at 37 °C for 24 hours for breeding bacteria.

2.5.2 Media Test. Media test was made by Nutrient Agar (NA) 2.3 gram dissolved in 100 mL of distilled water (23g/1000 mL) using Erlenmeyer. The medium was homogenized with the stirrer to boil. The medium that has been homogenized, was sterilized in an autoclave at 121 °C for 15 minutes, and chilled to a temperature of ±45-50 °C.

2.5.3 Preparation of bacterial suspensions. The inoculated test bacteria were taken with a wire loop and suspended in a sterile tube containing 2 mL of 0.9% NaCl solution. Then, the concentration of bacteria was measured using Denis check to obtain Mc Farland standard, 0.5. The same treatment was carried out on any kind of test bacteria.

2.5.4 Testing Antibacterial. Poured 25 mL essential media into a sterile Petri dish. It was left until freeze. It was added the bacterial suspension with a soft cotton until evenly distributed to the media. Then, the paper discs were immersed in the sample solution 10 mg/mL, lifted and aerated briefly. The paper disc was placed on the test medium with a predetermined distance. The petri dish was incubated in an incubator at 37 °C for 24 hours. After that, the clear zone was measured as obstruction growth of bacteria.

3. Results and Discussion

3.1 The synthesis of ZnO, CuO, and CuO-ZnO

The synthesis of ZnO nanoparticles by modifying the sol-gel method was performed by Mallick et al. [9], by mixing Zinc (II) acetate dihydrate and ethanol. They were stirred using a magnetic stirrer for an hour. Ethanol is used as a solvent. The mixture was obtained and stored (aging) for 48 hours to obtain a gel formation. The gel was dried in an oven at a temperature of 120 °C to constant weight to evaporate the solvent ethanol, and calcined at temperatures of 500 °C for 4 hours.

The synthesis of CuO nanoparticles by modifying the sol-gel method was performed by Radhakrishnanet al. [10]. Solution Copper(II) sulfate pentahydrate and citric acid (as a capping agent) were stirred using a magnetic stirrer for 30 minutes, and NaOH was added dropwise and stirred for an hour with the aim of CuO nanoparticles suspension formation [12]. NaOH was used to maintain the solution in a bases condition during the synthesis process. The mixture was stored (aging) for 48 hours to obtain a gel formation. The gel was washed with distilled water to remove impurities from the gel. The gel was dried in the oven at a temperature of 120 °C to constant weight to remove water and calcined at a temperature of 500 °C for 4 hours.

The synthesis of CuO-ZnO nanocomposite by modifying the sol-gel method was conducted by other researchers [11] by mixing up first zinc (II) acetate dihydrate, ethylene glycol, distilled water, and citric acid with a magnetic stirrer for 1 hour. After an hour, copper(II) sulfate pentahydrate solution was added and stirred rapidly at 60 °C for 3 hours to accelerate the reaction. The mixture was stored in dark room (aging) for 48 hours. The gel was washed with distilled water and dried at a temperature of 120 °C to constant weight. Calcination at temperature of 500 °C for 4 hours was to eliminate the organic compound, to decompose CuSO₄·5H₂O into CuO and Zn(CH₃COO)₂·2H₂O into
ZnO, as a result the CuO-ZnO structure was formed. In this synthesis, the polymerization reaction occurred. The nanoparticles can be grown in the polymer matrix and the formation of particle agglomeration can be prevented by maintaining distribution good spatial in a polymer matrix [13].

The function of citric acid is to form the complex compounds with zinc citrate before reacting with ethylene glycol to form a polymerization. The use of citric acid is intended for formation the metal complex compound citrate [14].

3.2 Characterization of ZnO, CuO, and CuO-ZnO

3.2.1. X-Ray Diffraction (X-RD). XRD was used to analyze the size of ZnO, CuO, and CuO-ZnO nanocomposite. The instrument used was XRD (Shimadzu) with Cu radiation at wavelength of 1.54060 Å, 40.0 kV, and a strong current of 30.0 mA. The XRD analysis results of the compound ZnO, CuO, CuO-ZnO nanocomposite can be seen in figure 1.

![XRD spectra of ZnO, CuO, and CuO-ZnO nanocomposites](image)

Figure 1. X-ray diffractograms of ZnO, CuO, 10%CuO-ZnO, 15%CuO-ZnO, 20%CuO-ZnO, and 25%CuO-ZnO.

The result of XRD analysis showed that ZnO diffraction pattern appears in the peak 2θ of 31.47, 34.12 and 35.96. The CuO appears at the peak 2θ of 35.10, 38.34 and 48.36. The XCuO-ZnO nanocomposite (X=10, 15, 20, and 25%) has high peak 2θ at 31, 34, 35, 47, 56 and 67, according to JCPDS 36-1451 that has the ZnO peak at 2θ= 31.7; 34.4; 36.2; 47.5; 56.5; 62.8; 67.9; 69.05 and JCPDS 05-0661 that has the CuO peak at 2θ= 30 to 50 [5].

Based on the diffraction pattern of the nanocomposite XCuO-ZnO, the addition of CuO resulted in a decreased crystallinity of ZnO. The results can be seen in table 1.
Table 1. Intensity of CuO and ZnO in CuO-ZnO.

| Samples       | ZnO intensity around $2\theta = 67$ | CuO intensity around $2\theta = 38$ |
|---------------|----------------------------------|----------------------------------|
| 10%CuO-ZnO    | 275                               | 42                               |
| 15%CuO-ZnO    | 171                               | 45                               |
| 20%CuO-ZnO    | 49                                | 136                              |
| 25%CuO-ZnO    | 47                                | 155                              |

The particle size could be calculated using the Debye-Scherer equation. The results of these calculations can be seen in table 2.

Table 2. Particle size of ZnO, CuO, and X CuO-ZnO XRD analysis.

| Samples       | Particle size (nm) |
|---------------|--------------------|
| ZnO           | 26.83              |
| CuO           | 19.83              |
| 10%CuO-ZnO    | 16.23              |
| 15%CuO-ZnO    | 15.56              |
| 20%CuO-ZnO    | 16.43              |
| 25%CuO-ZnO    | 15.74              |

Based on table 2, it was observed that the CuO had been successfully composit on ZnO. After synthesis, the particle size decreased. The particle size of 16.23 nm, 15.56 nm, 16.43 nm and 15.74 nm was observed in the sample of 10% CuO-ZnO, 15% CuO-ZnO, 20% CuO-ZnO, and 25% CuO-ZnO, respectively. This result is almost similar with other report [11] which has the particle size of 19 nm for 10% CuO-ZnO nanocomposite.

The result of the smaller size might be due to the longer aging process of 48 hours. Moreover, the smaller particle size may be formed as a result of CuO covering the surface of ZnO. Thus, the particle size of CuO-ZnO composite followed the CuO that had smaller size compared to the ZnO.

3.2.2. Band Gap (Spektrofotometer UV-Vis Diffusion Reflectance). The characterization of the band gap energy determination was performed by using UV-Vis diffusion reflectance spectrophotometer. The calculation was performed using the Kubelka-Munk by plotting the $(F(R)h\nu)^{1/2}$ against $h\nu$(eV). The band gap energy of ZnO, CuO and CuO-ZnO nanocomposite can be seen in table 3 and figure 2.

Table 3. The band gap of ZnO, CuO and XCuO-ZnO DR-UV analysis.

| Samples       | Band gap(eV) |
|---------------|--------------|
| ZnO           | 3.39         |
| CuO           | 2.04         |
| 10%CuO-ZnO    | 2.48         |
| 15%CuO-ZnO    | 2.30         |
| 20%CuO-ZnO    | 2.23         |
| 25%CuO-ZnO    | 2.12         |
The addition of CuO decreased the band gap energy of composite. According to another report [5], the smaller band gap energy was caused by the combined transition that enhanced from \( \text{O}_2 \) (2p) to \( \text{Zn}^{2+} \) (3d\(^{10}\)-4s) and to \( \text{Cu}^{2+} \) (3d\(^{9}\)). Other researchers [16] reported that the swift heavy ion irradiation could decrease in the band gap with an increase in the ion fluence. Due to smaller band gap energy, the CuO-ZnO has a better photocatalytic properties compared to the ZnO or CuO a [15]. A decreased band gap energy can facilitate stepping electrons from the valence band to the conduction band and increase the photocatalytic activity through enhancing the radical species such as superoxide anion radical (\( \text{•O}_2^- \)), (\( \text{HO}_2^- \)) and (\( \text{HO}_2 \)) [16].

3.2.3. Surface area (BET). The surface area of ZnO, CuO and CuO-ZnO nanocomposite can be determined using the BET surface area. The method works based on a single gas adsorption at a constant temperature. Nitrogen gas was used as an adsorbate on the surface of ZnO, CuO, and CuO-ZnO.

### Table 4. The surface area of ZnO, CuO, and XCuO-ZnO BET method.

| Samples         | Surface area (m\(^2\)/g) |
|-----------------|---------------------------|
| ZnO             | 9.63                      |
| CuO             | 21.61                     |
| 10%CuO-ZnO      | 22.48                     |
| 15%CuO-ZnO      | 22.07                     |
| 20%CuO-ZnO      | 19.52                     |
| 25%CuO-ZnO      | 28.74                     |

The addition of CuO on ZnO produced a larger surface area of CuO-ZnO composite. The larger surface area of composite possessed better photocatalytic activity compared to the smaller one. According to another report [17], the large surface area of CuO-ZnO more effectively reduced the concentration of Rodhamin B compared to the smaller surface area of ZnO. It was caused by the higher adsorption of CuO-ZnO composite.

The surface area also affected the antibacterial properties. The large surface area of composites can increase the antibacterial properties due to easier to absorb the UV light [17] and generating the radical species. The CuO-ZnO composite could effectively kill the bacterial cells due to increased production of \( \text{Zn}^{2+} \) ions and reactive oxygen species (ROS) [18].
3.2.4. Analysis FTIR spectrophotometer. FTIR spectrophotometer was used to analyze the functional group of ZnO, CuO and CuO-ZnO nanocomposite. The wavelength of 4000-400 cm⁻¹ was used for the analysis of functional groups of samples, and the results can be seen in figure 3.

![FTIR spectra of ZnO, CuO, and XCuO-ZnO nanocomposite.](image)

Functional groups of ZnO, CuO and CuO-ZnO nanocomposite with FTIR spectrophotometer can be seen in figure 3. The -OH functional groups could be observed at the frequency of 3500-3000 cm⁻¹, the peak at 3449 cm⁻¹ could be observed at the sample of ZnO, CuO, and CuO-ZnO (10%, 15%, 20%, and 25%). The C=O functional group could be observed at the wavenumber of 1627.92 cm⁻¹ for ZnO and 10% CuO-ZnO, and 1635.64 cm⁻¹ for CuO, 15% CuO-ZnO, 20% CuO-ZnO and 25% CuO-ZnO. The wavenumber of 2854.65 cm⁻¹, 2862.36 cm⁻¹, 2924.09 cm⁻¹ and 2931.80 cm⁻¹ are the C-H functional group according to the reference [19] that reported the C-H group appeared at wavenumber of 2855.05 cm⁻¹ and 2922.59 cm⁻¹. The C=O and C-H groups appeared because the synthesis used the precursor of Zn(CH₃COO)₂·2H₂O that was not perfectly decomposed to ZnO.

The wavenumber of 432.05 cm⁻¹ is assigned to Zn-O bond similar to another report [19] that the vibration Zn-O appeared at wavenumber of 424.26 cm⁻¹, 471.36 cm⁻¹ and 542.86 cm⁻¹. The wavenumber of 524.64 and 594.06 cm⁻¹ are assigned to Cu-O bond according to reference [20] that the vibrations of the Cu-O are in the range frequency of 700-400 cm⁻¹. By adding the CuO to ZnO, the shift wavenumber at the frequency of 750-400 cm⁻¹ could be observed. The wavenumber of 447.49 cm⁻¹, 462.92 cm⁻¹, 462.92 cm⁻¹ and 478.35 cm⁻¹ was found in the 10% CuO-ZnO, 15%CuO-ZnO, 20% CuO-ZnO and 25%CuO-ZnO respectively. The shift of wavenumber indicated that the addition of CuO may change the structure of ZnO.

3.2.5. SEM-EDX. SEM is a scanning electron microscope that illustrates the sample surface by scanning with a beam of high-energy electrons. X-rays in the SEM can be used to identify the elemental composition of a sample by a technique known as energy dispersive x-ray (EDX) [21]
The surface morphology of ZnO, CuO and 25% CuO-ZnO nanocomposite synthesized by the sol-gel method can be seen in figure 4. The ZnO, CuO and 25% CuO-ZnO have a uniform particle shape and size with low level of agglomeration because they did not form a large cluster. The agglomeration can usually be demonstrated by the formation of large cluster [22].

EDX analysis of 25% CuO-ZnO nanocomposite is expected to having the elements composition similar with the desired composition in the synthesis process.

Table 5. The composition of 25% CuO-ZnO nanocomposite using EDX analysis

| Sample       | CuO  | ZnO  | SO₃  | C    | O    |
|--------------|------|------|------|------|------|
| 25% CuO-ZnO  | 15.53| 68.50| 1.22 | 14.75|      |

Table 5 showed that the composition of CuO measured by EDX in the composite was 15.53%. It is lower than that in the composition of synthesis (25%). It may be due to an inhomogeneous process of composite synthesis such as stirring treatment.

3.3. Antibacterials

The antibacterial test was conducted by the method of the disc. It can be seen that the CuO-ZnO nanocomposite inhibited the growth of gram-positive bacteria (S. aureus) and gram-negative bacteria (E. coli). The experiment used the S.O.S floor cleaner as the positive control because it was proven to inhibiting the growth of bacteria S. aureus and E. coli. The distilled water was used as negative control because it can be used as a solvent of CuO-ZnO nanocomposite.
In this experiment, the sample was irradiated using UV light for only 15 minutes to avoid the bacterial death. When the ZnO, CuO and CuO-ZnO exposed by UV light, the superoxide anion radicals (O$_2^••$) might be formed then reacted with H$^+$ to produce HO$_2$$^•$. The electrons will produce hydrogen peroxide anion (HO$_2$). Then, the HO$_2$ anion reacted with hydrogen ions to form the H$_2$O$_2$ molecules that can serve to kill bacteria.

Other researcher [15] reported that the ZnO-CuO nanocomposite had higher photocatalytic properties than the respective oxides. It can increase the radical compounds and the H$_2$O$_2$ molecule to effectively kill the bacteria. The higher CuO was added, the higher antibacterial activity could be produced. The antibacterial activity of CuO-ZnO nanocomposite is shown in figure 3.5.

![Figure 5](image_url)  
**Figure 5.** The diameter clear zone antibacterial of ZnO, CuO and CuO-ZnO composites against *S. aureus* and *E. coli*.

Figure 5 showed that the ZnO is resistant as antibacterial against *E. coli* and better at inhibiting the growth of bacteria *S. aureus*. The inhibitory of CuO was not so much different between the bacteria *E. coli* and *S. aureus*. Therefore, the CuO-ZnO nanocomposite can be used as inhibitors of the bacterial growth of *E. coli* and *S. aureus*. The antibacterial activity increased by the increase of CuO on the composites, indicating that the CuO increases the photocatalytic properties of composite.

The size of CuO-ZnO nanocomposite of 10%, 15% and 25% CuO were not significantly different. Therefore, the composition has the important role in antibacterial activity. In this experiment, 25% CuO on the CuO-ZnO composite showed the highest antibacterial activity to *S. aureus* and *E. coli*, it is
better than CuO and ZnO. The ZnO was better antibacterial properties against S. aureus whereas the CuO was better antibacterial properties against E. coli.

The surface area of CuO-ZnO nanocomposite may influence the antibacterial activity. In this research the highest surface area of composite showed the highest antibacterial activity. Other researchers [18] reported that the larger surface area of CuO-ZnO will easily enter to the cell and kill the bacteria due to increase of Zn$^{2+}$ ions and reactive oxygen species (ROS).

The smaller band gap energy could also enhance the antibacterial activity because the electrons can be easily exited from the valence band to the conduction band. Therefore, the photocatalytic activity could be more efficient due to high species of superoxide radical formation as inhibitors of bacterial growth.

The size of CuO-ZnO nanocomposite with the CuO content of 10%, 15%, 10% and 25% were not significantly different. However, the antibacterial activity of 25% CuO-ZnO nanocomposite to S. aureus was better than ZnO, CuO and other CuO contents of CuO-ZnO nanocomposites. The CuO-ZnO composite of 15-25% CuO was better antibacterial activity than ZnO and CuO to E. Coli. The ZnO is better antibacterial properties against S. aureus, whereas the CuO is better antibacterial properties against E. coli.

The larger surface area of CuO-ZnO nanocomposite, the higher antibacterial activity was observed. The 25% CuO-ZnO nanocomposite showed the highest antibacterial activity against S. Aureus due to high surface area. Other researchers [18] reported that the CuO-ZnO with large surface area could be easier to get bacterial cells and kill them due to increase of Zn$^{2+}$ ions and reactive oxygen species formation.

4. Conclusion
The composites of CuO-ZnO was successfully synthesized using sol-gel method. The particle size of 16.23 nm, 15.56 nm, 16.43 nm and 15.74 nm were observed in composite for the CuO content of 10%, 15%, 20% and 25% respectively. Addition of CuO reduced the value of the band gap energy of ZnO i.e.: 2.48 eV (10%), 2.30 eV (15%), 2.23 eV (20%) and 2.12 eV (25%). The synthesis of composite increased the surface area up to 28.74 m$^2$/g for 25% CuO-ZnO. The morphology of ZnO, CuO and 25% CuO-ZnO has a uniform shape and size. The composite of 25% CuO-ZnO showed the best antibacterial activity with the clear zone against S. aureus of 2.1 mm and 2.3 mm for E. coli. Photocatalytic properties of CuO-ZnO with the band gap of 2.12 eV is better than ZnO or CuO which is having the band gap energy of 3.39 eV and 2.04 eV, respectively.

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