

RESEARCH PAPER

Unveiling The Innovative Applications of Nano-binary Oxide ZnO/SiO₂ Antibiotics Medical Ointment Apply on Wound Dressings

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ABSTRACT

Current research in this field aims to tackle the issue of antibiotic resistance by focusing on the role of pure nanocomposites in health applications. in an eco-friendly manner, depending on the solution gel route used to prepare nano binary oxide ZnO/SiO₂. The characterization of the nano-binary oxide ZnO/SiO₂ included), x-ray diffraction (XRD), Brunauer-Emmett-Teller surface area design (BET), Energy Dispersive X-ray (EDX), Field Emission Electron Microscopy (FE SEM, and microplate reader (ELISA). Results show higher activity of the value 500µg/ml nano binary oxide ZnO/SiO₂ against Gram-negative microorganism *Escherichia Coli* (*E. Coli*). With a large surface area and pore circulation, the nano binary oxide ZnO/SiO₂ exhibits high activity. In this research, a nano-medical ointment was developed using a ZnO/SiO₂ composite with an average particle size 14 -50 nm to enhance the antibacterial efficacy and accelerate the healing of wounds and burns. Results from the medical ointment against Gram-negative bacteria (*E. Coli*) were promising, with reduced toxicity of ZnO/SiO₂ nanoparticle ointment, offering an innovative solution as a broad-spectrum topical antibiotic, with accelerated tissue healing and excellent safety.

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INTRODUCTION

Innovation is essential in the field of medicine and healthcare, the use of nano-binary oxide antibiotics in wound dressings is one such ground-breaking invention [1]. These minuscule particles have demonstrated remarkable efficacy in combating infections and accelerating wound healing [2]. To understand the role of antibiotics in wound dressings, therefore in this research paper diving into the specifics of nano-binary oxide ZnO/

SiO₂ antibiotics. Antibiotics are substances that either completely eradicate or destroy growth of microorganisms. When used in wound dressings, antibiotics help prevent infections and promote faster healing. Nano-binary oxide ZnO/SiO₂ is a special blend of nanoparticles consisting of silicon and zinc nanoparticles are perfect for use in wound dressings because of low toxicity and their demonstrated strong antibacterial qualities

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[3]. Furthermore, since nanoparticles (NPs) are usually small in size between 1-100 nm, this helps them penetrate the cell wall of microorganisms and destroy them easily.[4]. The harmful effects that nanoparticles may have on tissues or cells are referred to as cytotoxicity. Research indicates that although zinc and silica nanoparticles antibiotics are typically safe to use, one must be cautious when determining the concentration and duration of exposure to minimize any possible risks [5]. In light of the growing global challenges of antibiotic resistance and the side effects of traditional disinfectants. ZnO/SiO₂ nanoparticles were prepared using a sol-gel method as a revolutionary solution for topical pharmaceutical engineering. This hybrid composite—combining the properties of zinc oxide (ZnO) and silicon dioxide (SiO₂) offers unique multi-pathway mechanisms of action against bacteria while promoting tissue healing [6]. This study represents a quantum leap toward translating the exceptional physicochemical properties of this composite into safe and effective clinical applications [7]. The medical ointment prepared from a nanocomposite represents a radical shift in the specifications of therapeutic ointments by overcoming some challenges, such as increasing the penetration of the active ingredient through the skin layers thanks to the nano-particles size [8,9]. Zinc oxide impact biological processes depends on its shape, particle size, exposure time, concentration, pH, and biocompatibility [10,11]. Zinc oxide nanoparticles are more effective against some microorganisms, such as *Staphylococcus aureus*, *Escherichia Coli*, and *Pseudomonas* [12,13]. Among these inorganic

metal oxides, zinc oxide nanoparticles meet all of the previously specified requirements, allowing for safe use as an antibacterial agent, package preservative, and medicine. Oxidative stress damages DNA, lipids, proteins, and carbohydrates. It also alters the cell membrane, which in turn affects vital biological functions. [12,14,15]. However, external H₂O₂ production is necessary for bulk zinc oxide suspension. [16]. Additionally, the toxicity of nanoparticles that release harmful ions has been taken into account. Zinc oxide reacts with both acids and alkalis to form Zn⁺² ions because it is amphoteric [17]. When creating mesoporous silica nanoparticles (MSNS), tetraethyl orthosilicate (TEOS) is the most often used silicate precursor. Although TEOS is preferred due to its apparent ease of control over the TEOS reaction output, several studies also employ Tetra Propyl Ortho Silicate (TPOS) and Tetra Methyl Ortho Silicate (TMOS) as alternatives [18]. Sol-gel method was chosen because this method is good for controlling the size of the nanoparticles, the structural composition, and the particle size. It also produces nano materials with high porosity and purity, as well as ensuring the homogeneity of the mixture to improve the physical properties of the composite, such as solubility and stability. This method does not require high calcination temperatures for the calcination process. Therefore, it is considered an economical method compared to traditional preparation methods [19].

MATERIALS AND METHODS

Zinc and silica precursors to be used, zinc acetate dihydrate (Zn(CH₃COO)₂•2H₂O), purity



Fig. 1. a) Photos of nano binary oxide ZnO/SiO₂ by the Sol-Gel method before calcination and after calcination (b).

≥99.0% and TEOS (Tetraethyl Ortho Silicate) with purity >98%, were purchased from Sigma-Aldrich®, respectively. Nitric acid HNO₃ SCIENCE company, ethanol with purity 99.9% and water that was ultra-pure (Deionised) were created by a water distiller model DESA, Nutrient broth, and Miller Hinton agar were utilized.

Preparation of nano- binary oxide ZnO/SiO₂

Nano-binary oxide ZnO/SiO₂ was synthesised by the Sol–Gel method. To synthesise ZnO/SiO₂ core–shell nanomaterials, preparation mixture from solution one, 8 ml of TEOS (Tetraethyl Ortho Silicate) was added to 40 ml of ethanol with a stirrer for 60 min, then preparation solution two, 6 ml nitric acid was added to 300 ml of deionized water, solution two added gradually in drops to solution one to form precursor. 40 ml of ethanol was used to dissolve 6 g of Zinc acetate dihydrate (Zn(CH₃COO)₂·2H₂O) with stirring. 20 ml of nitric acid was then added to the precursor prepared in step one; mixture was stirred for 2 h at 60 °C. A white gel was obtained after 2 hours. Gel product drying in oven at 100 °C for 24 hours. nano-binary oxide ZnO/SiO₂ was formed by calcination at 600 °C over 4 hours. Nano-binary oxide ZnO/SiO₂ was allowed to cool to ambient temperature before being stored in a container. [20,21]. Fig. 1a and b show photos of nano-binary oxide ZnO/SiO₂ before and after calcination.

Antibiotic activity determination

Disc diffusion susceptibility test on Mueller-Hinton solid agar. This method depends on the preparation of the culture of bacteria with a concentration of 1.5*10⁸ CFU/ml. Preparation of Muller Hinton agar solution by weighing 38 g in 1000 ml of distilled water and sterilising in an autoclave for 15 min at 121 °C and 1 atm, after cooling to 35 °C, pour into Petri dishes and wait for it to solidify. Then preparation stock solution of nan binary oxide ZnO/SiO₂ was also sterilised in an autoclave for 20 min at 121 °C. Stock solution sonication for four hours. After that, holes are made in the dish and these holes are filled with antimicrobial nan binary oxide ZnO/SiO₂ prepared in different concentrations (500, 350, 250, and 150) µg/ml using DMSO solvent. Petridishes are incubated for 24 hours at 37 °C. The next day observed inhibition percentage growth (zone inhibition) was measured for the samples. This standard method has been used to measure the

activity of the antibiotic nan binary oxide ZnO/SiO₂ against bacteria E.Coli [22]. ZnO/SiO₂ oxide powder activity was assessed using the minimum bactericidal concentration (MBC) and minimum inhibitory concentration (MIC) tests. In a sterile saline solution, E. Coli was cultivated to 0.5 McFarland (1.2*10⁸ CFU/ml). The ZnO/SiO₂ nano binary oxide powder was evaluated at 500, 350, and 150 µg/ml. Petridishes were incubated for 24 hours at 37 °C following the application of nano binary oxide ZnO/SiO₂ on wound dressings [23].

Preparation of nano-medical ointment

ZnO/SiO₂ nano binary oxide composition for medical ointment, active substances manufactured from it, and their use on medical gauze. The process of creating an ointment base consists of multiple steps. It is divided into two stages: an aqueous phase and an oil phase with an emulsifier substance. The oil phase, which is in a ceramic container in a water bath at 60 °C, contains 65 ml of paraffin oil and 13 g of white beeswax. Next, paraffin, or mineral oil, is added and thoroughly blended. In a water bath set at 60 °C, 1g of borax is dissolved in water to create an aqueous phase (both liquid phase and oil phase at the same temperature). The water phase is progressively added to the oil phase while being continuously stirred once the oil phase has finished melting [24]. In addition to its antibacterial properties, benzoic acid (0.1%) is used as a preservative [21,22]. The toxicity of benzoic acid alone is minimal [25]. Following preparation, 1g of the ointment base from the emulsions was combined with 0.7 g of ZnO/SiO₂ nano powder. To ensure that the emulsion (ointment base) and the active ingredient are homogeneous.

RESULTS AND DISCUSSION

ZnO/SiO₂ Characterisation of nano binary oxide

Using a diffraction meter (X'Pert HighScore PANalytical), x-ray diffraction using Cu-K radiation 1.54056 Å at room temperature were used to identify the phase structure of synthesized nano binary oxide ZnO/SiO₂ crystalline phases. Scanning at 2θ (theta) range (10- 80) degrees. Fig. 2a shows the diffraction peak of silica oxide is observed at 2θ range (10-30) degrees, broad peak indexes for amorphous silica oxide [26]. Fig. 2b shows the diffraction peak of the Hexagonal crystalline phase of ZnO appearance of sharp peaks at 2θ (31.419, 34.097 and 35.892) degrees, which confirms the

hexagonal wurtzite structure [27]. Without the contaminants, all of the ZnO peaks agreed well with the standard patterns (JCPDS 36-1451) [28]. Fig. 2c displays the diffraction peak of the ZnO/SiO₂ nano binary oxide, which is orthorhombic and appears at 2θ values as indicated in (Table 1). Fig. 2c shows broad peak indexes for amorphous silica oxide, which is found in the crystal structure of nano binary oxide ZnO/SiO₂, at 2θ (10-30), amorphous silica improves zinc ion release and reduces toxicity [29] Also, observe shift peak at 2θ (31.930, 34.545 and 36.490) degrees this suggests that zinc oxide and silica overlap to create the nano binary oxide ZnO/SiO₂ with novel physicochemical characteristics. The Scherrer equation can be used to determine the average crystal size of ZnO/SiO₂.

$$L = k\lambda / \beta \cos \Theta$$

L = Thickness of crystallize (mean crystal size), K= Scherrer s constant depends on crystal shape (0.94 is spherical shape) λ= is the wavelength (0.1540 nm), β= FWHM * π/180 and Θ = is the Bragg angle [30,31].

Particle size is in the nano range (< 50 nm), as shown in (Table 1), which enhances its antimicrobial properties in ointments.

Nano binary oxide ZnO/SiO₂ characterization by EDX and FE-SEM using a model (MAG 400 Kx Germany) scale bar 200 nm with magnification (100,000×) can analyze the surface's morphology. The ability to produce high resolution imaging is one of FE-SEM's advantages. Very small features

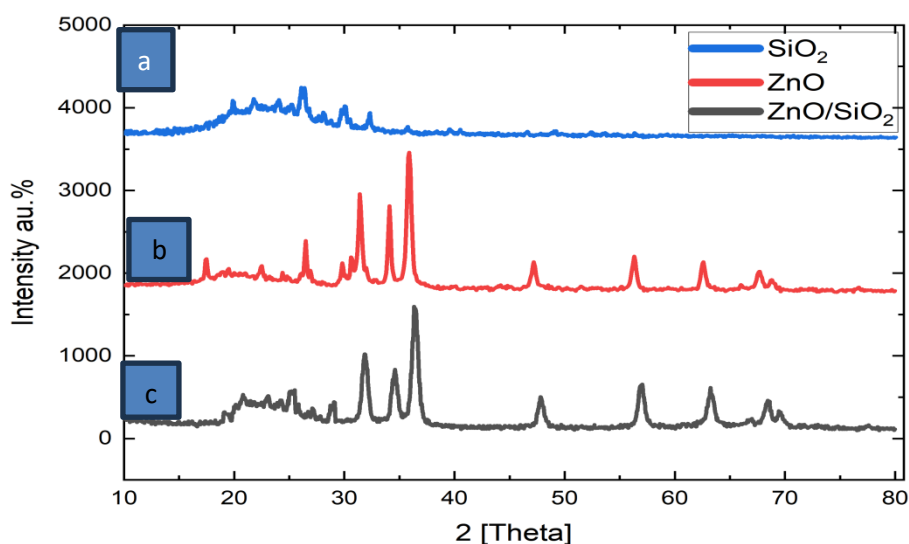


Fig. 2. X-ray diffraction of patterns a.SiO₂ NPs ,b.ZnO NPs ,and c. nano binary oxide ZnO/SiO₂.

Table1. The crystal size, FWHM (Full Width Half Maximum), and d-spacing [Å] of nano binary oxide ZnO/SiO₂

NO	Pos. [°2Th.]	Height [cts]	FWHM Left [°2Th.]	d-spacing [Å]	Crystal size nm
1	31.849(4)	573(10)	0.59(1)	2.80750	14.395
2	31.930(4)	286(10)	0.59(1)	2.80750	14.558
3	34.545(5)	420(9)	0.61(2)	2.59431	14.239
4	34.634(5)	210(9)	0.61(2)	2.59431	14.242
5	36.397(3)	947(13)	0.642(6)	2.46647	13.590
6	36.490(3)	473(13)	0.642(6)	2.46647	13.603
7	47.808(7)	222(6)	0.63(2)	1.90100	14.407
8	47.935(7)	111(6)	0.63(2)	1.90100	14.599
9	56.909(5)	371(9)	0.60(2)	1.61670	15.715
10	57.064(5)	186(9)	0.60(2)	1.61670	15.734
11	63.208(8)	301(9)	0.69(3)	1.46992	14.089
12	68.581(9)	113(8)	0.71(3)	1.37066	14.139

with dimensions of several nanometers can be seen using the scanning electron microscopy FE-SEM imaging technology. It uses a focused electron beam to scan the sample's surface. Details about the surface topography are revealed by secondary electrons produced when the electron beam interacts with the substance. Sometimes, variations in sample composition can be ascertained using back scattered electrons [32,33]. The image's FES-EM displays the nanocomposites' structural morphology. The prepared ZnO/SiO₂ antibiotic appears as particles in nano scale, particle grain size (41.664 nm) and heterogeneous as seen in Fig.

3a,b. Nano binary oxide ZnO/SiO₂ nanoparticles that were prepared by the sol-gel method and analyzed by FES-SEM exhibit a nano-spherical shape distributed almost uniformly on a rough surface, with moderate surface agglomeration. This morphology indicates successful nanoparticle growth, which is suitable for applications related to catalysis, antibacterial, or insulation [34]. This result is consistent with the x-ray characterization, which revealed crystalline size in the nanoscale, as indicated in (Table 1). The EDX values for the nano binary oxide ZnO/SiO₂ that were studied are rather close to what was predicted theoretically,

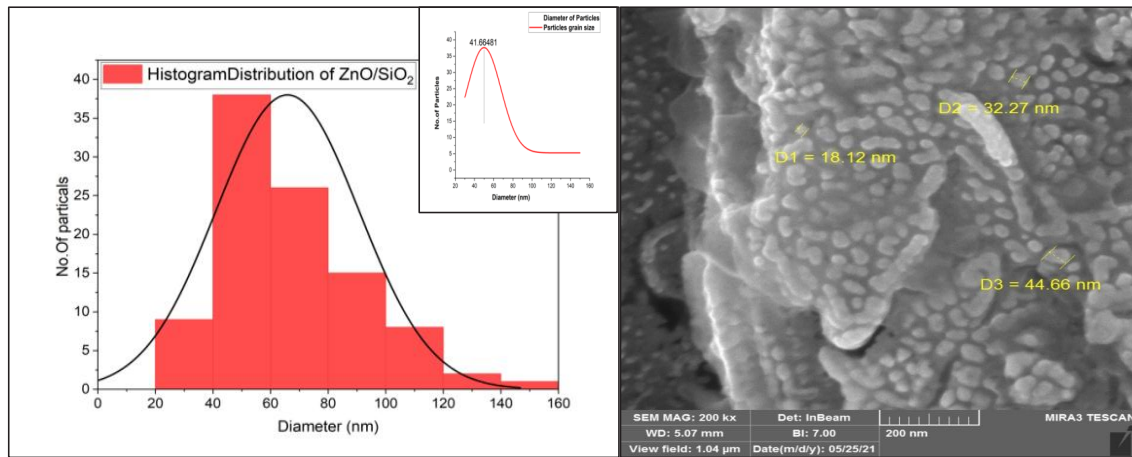


Fig. 3. a) FE-SEM image of nano binary oxide ZnO/SiO₂ b) The average particle diameter of the composition particles grain size.

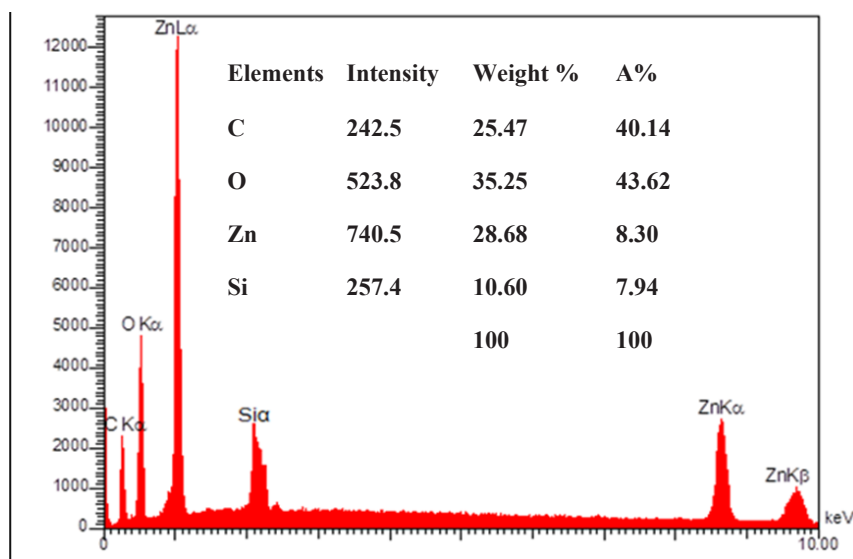


Fig. 4. EDX of nano binary oxide ZnO/SiO₂ with percentage weight of element content in a sample.

suggesting that there is information on the concentration of particular elements in a sample, as indicated in Fig. 4. The adsorption and desorption isotherms of N₂ on nano binary oxide ZnO/SiO₂ nanomaterials are indicated in Fig. 5. The particle size and surface area are linked through the use of BET measurements. Additionally, similar to how the adsorption isotherm's shape aids in pore size classification, this metric serves a similar purpose.

BET calculations, the specific surface area of nano binary oxide ZnO/SiO₂ was found to be 66.4053 m²/g, this material was synthesised by the sol-gel method.. The total volume of pores with a width of 1.7000–300,000 nm for BJH adsorption is 98.2636 m³/g. 10.4156 nm is the adsorption average pore diameter (4V/A by BET). 11.983 nm is the average pore diameter for desorption (4V/A via BET).

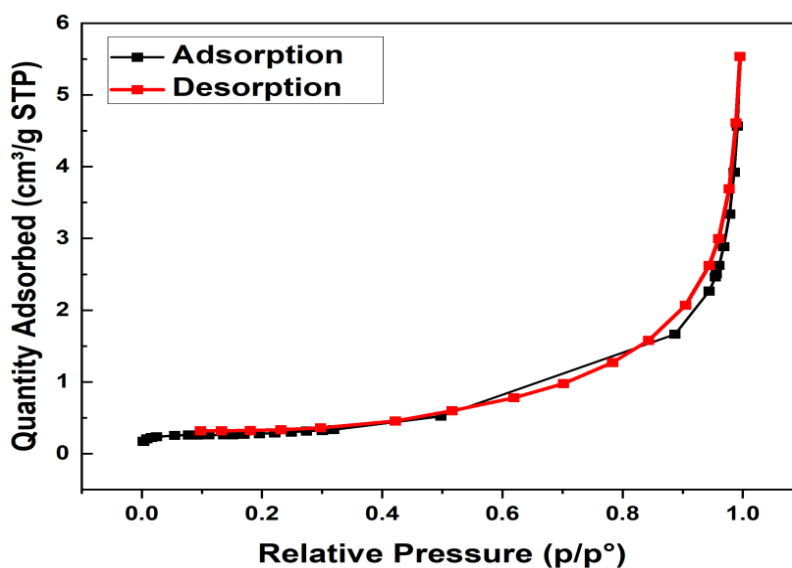


Fig. 5. Nitrogen adsorption-desorption isotherms for nano binary oxide ZnO/SiO₂.

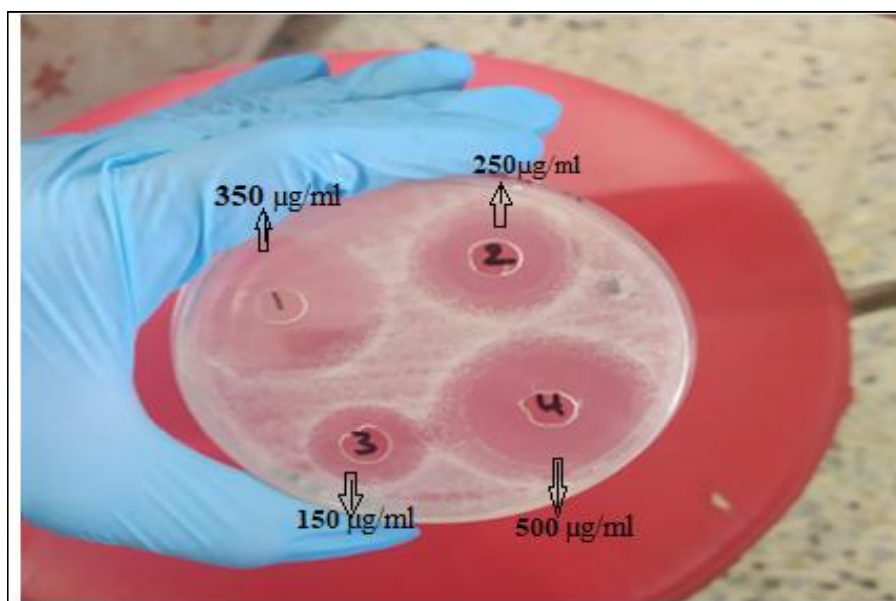


Fig. 6. Test results of antibacterial activities of nano binary oxide ZnO/SiO₂ for *E. coli*.

Antibacterial activity

To demonstrate the effectiveness of nano binary oxide ZnO/SiO₂ in eliminating E.Coli bacteria, the growth of gram-negative E.Coli was studied in a medium containing different concentrations of nano binary oxide ZnO/SiO₂. Fig. 6 shows the effect of nano binary oxide ZnO/SiO₂ dosage on the removal of gram-negative E. coli. Fig. 6 and (Table 2) indicate that the removal of Gram-negative E. Coli increased with the increase of nano binary oxide ZnO/SiO₂ concentration. The antibacterial activity of nano binary oxide ZnO/SiO₂ nanoparticles was much higher at the concentration of 500 µg/ml. Controlling the size and form of the produced nanoparticles as well as the electrostatic interactions between the bacterial cell wall and the manufactured nanoparticles' outer shell, will increase the effectiveness of stopping the growth of E. Coli bacteria. [35,36]. Nano binary oxide ZnO/SiO₂

works to remove E.Coli bacteria through several stages. The first stage includes the adhesion of nanoparticles through an electrostatic interaction between the surface of the negative bacterial wall and the positive charge of the nanoparticles. The release of Zn⁺² and ROs ions which damage the outer layer of the cell, the third stage destroys the cell components through the interaction of Zn⁺², Si⁺² ions with proteins and DNA inside the cell [37]. These ions Zn⁺², Si⁺² and ROS oxidized lipids in the cell membrane [38]. The small size of the nanocomposite within the range (14-50) nm helps increase the inhibition efficiency, as the smaller the nano size, the better the permeation and penetration efficiency through the bacterial cell wall. In (Table2) designation of (MIC and MBC) minimum inhibition concentration and minimum bacterial concentration values respectively of nano binary oxide ZnO/SiO₂ the results of this study indicated that nano binary oxide ZnO/SiO₂

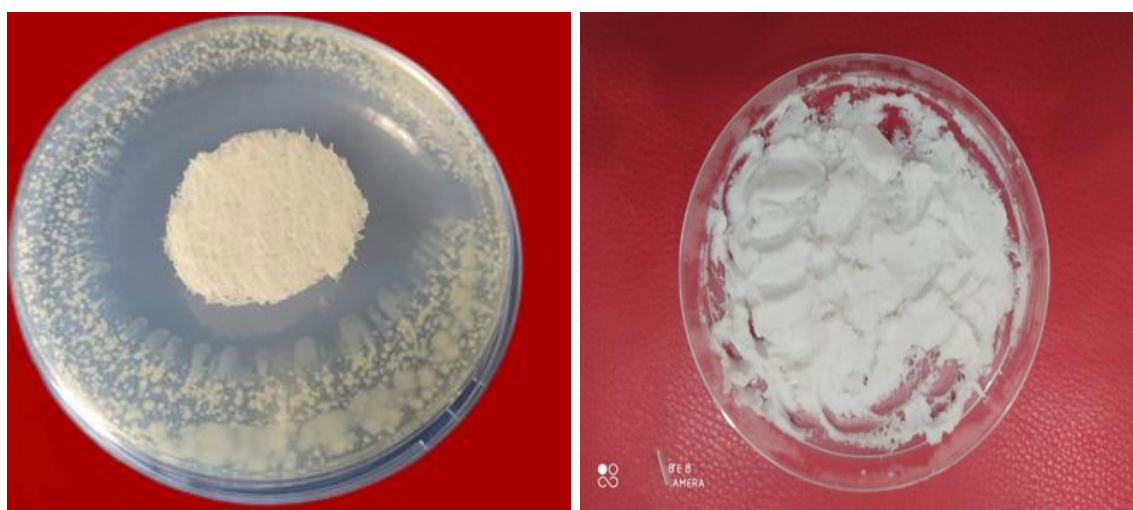


Fig. 7. a) Medical ointment cream preparation from nano binary oxide ZnO/SiO₂ b) Inhibiting microbial growth of the ointment cream on *E. coli*.

Table 2. The effect of nano binary oxide ZnO/SiO₂ dose on the zone inhibition growth of *E. coli*.

Concentration µg/ml	Zone inhibition/mm
500	24
350	22
250	18
150	5.5

has antibiotic activity with 500 µg/ml and 150 µg/ml, respectively, against gram-negative *E. Coli*. [39].

Effect of the activity of a medical ointment on E. Coli

The antibacterial activity of nano binary oxide ZnO/SiO₂ nanoparticles as a medical ointment was evaluated by taking the percentage weight of nano binary oxide ZnO/SiO₂ 7 % mix with 1g of medical ointment prepared as shown in Fig.7b. This study was against Gram-negative bacteria *E. Coli*. The medical ointment is applied to wound dressings. The assay results of antibacterial activity show clear inhibition zones against Gram-negative bacteria *E. Coli* such as shown in Fig. 7a. Nano binary oxide ZnO/SiO₂, because of its small size and applicability, has prompted a lot of interest. By preventing microbial growth, the medical ointment's results for the nano binary oxide ZnO/SiO₂ contribute to a healthy environment and aid in wound healing. Thus, the nano ointment has antibacterial and wound-healing properties, particularly considering that the ZnO/SiO₂ nano binary oxide NPs had a low toxicity assessment. Because of its antibacterial properties, nano binary oxide ZnO/SiO₂ has become a novel treatment for bacterial illnesses [40]. In this work, we created an ointment to treat cutaneous wounds infected with *E. Coli*.

CONCLUSION

The use of antibiotics with nano-binary oxide ZnO/SiO₂ in wound dressings is revolutionizing the medical industry. They are a useful contribution to contemporary medicine because of their antibacterial qualities, production method, and general efficacy. The sol-gel process yields pure nano binary oxide ZnO/SiO₂ NPs, x-ray diffraction is used to characterize and EDX show that. The FE-SEM scan determined the average particle size (41.664 nm). For nanocomposites, FESEM clearly shows the surface morphology and the distribution of particle sizes at the nanoscale. Nano binary oxide. ZnO/SiO₂ at a dosage of 500 µg/ml, exhibits high zone inhibition and promising antibiotic action against the bacterium *E. Coli*. By examining how these ointments affect the bacteria that cause burns and wounds, nano binary oxide ZnO/SiO₂ demonstrated extremely effective results and a potential effect for the creation of topical medical preparations with therapeutic efficacy.

By examining the impact of these ointments on the bacteria *E. Coli*, the study also included the preparation of medical ointments from prepared nano binary oxide ZnO/SiO₂ NPs, which demonstrated extremely effective results and a promising effect for the production of topical medical preparations with therapeutic efficacy. They slow down the healing process and are found on the skin's surface where burns or wounds have occurred. In addition, the ointment's physical texture is modified thanks to the properties of amorphous silica, which acts as a smart thickener that improves the ointment's adhesion to abraded skin. In this study, the sol-gel method was used to prepare a nano binary oxide ZnO/SiO₂ antibiotic to provide nano material properties that make it ideal for preparing a medical composite.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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