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Antibacterial Activity of Manganese Oxide Nanoparticles Prepared by Sol-Gel Method

In this study, nanoparticles manganese oxide was prepared by the sol-gel method where solution prepared by dissolving manganese nitrate in distilled water. Urea added to the solution and heated at 140°C for 1 hour to produce MnO_2 gel. The gel dried at 250°C for 1 hour to produce manganese oxide powder. The powder showed that the crystalline system is quaternary with crystallite size of 33 nm. The antibacterial activity of MnO_2 nanopowder was studied against two kinds of bacteria (*Escherichia coli and Klebsiella*). MnO_2 nanopowder showed good antibacterial activity.

Keywords: Manganese oxide; Nanopowders; Sol-gel; Antibacterial activity
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1. Introduction

One of the biggest public health issues facing the globe today is bacterial infections, which are estimated to affect hundreds of thousands of people annually [1,2]. Antibacterial medications are frequently used to address this issue, and the misuse of conventional antibiotics results in antibiotic resistance, which makes treating these infections more challenging. These days, because of their superior physicochemical qualities and large specific surface area, nanoparticles are receiving more and more attention as novel antibacterial agents [3-7]. The nanomaterials that have been found to exhibit some level of antibacterial action can be broadly classified into two groups as of yet: (i) materials in two dimensions (2D) (GO, rGO, MoS_2, WS_2) [8,9]. In addition to (ii) metal nanoparticles and metal oxide nanoparticles (AgNPs, ZnO, AuNRs, TiO_2) [10-12]. The most promising antibacterial materials among them are 2D materials with a thickness at the nanoscale.

Manganese dioxides are quite popular because of their excellent physicochemical properties, wide structural variety, low cost, and environmental friendliness. [13] They find numerous potential applications in ion exchange, molecular adsorption, catalysis, and electrochemical energy storage and conversion [14,15]. The polymorphic forms of manganese dioxides, which include alpha, beta, delta, and gamma, are due to differences in the bonds between the octahedra that make up the fundamental unit [MnO_6]. It has been demonstrated that different architectures exhibited distinct behaviors and, consequently, a range of applications [16]. Pathogenic bacteria, such as *Escherichia coli*, *Klebsiella* pneumoniae and *Pseudomonas* aeruginosa, can affect people with compromised natural defences and cause extreme systematic disease [17]. Clinical manifestations include nosocomial or healthcare-related infections, such as pneumonia, urinary infections, surgical wound infections, joint infections and septicaemia, as well as common community infections, such as intestinal, skin, soft tissue and otitis externa infections [18]. Antibiotic resistance and biofilm formation are global public health problems that lead to high morbidity, mortality and healthcare costs [19,20]. Metal oxide nanoparticles have the potency to contend antibacterial resistance by many mechanisms. Nanoparticles can penetrate biofilms and bacterial cell walls and cause cytotoxic effect owing to their nanoscale size; they can increase the effectiveness of current antibiotics by protecting them from detection and supply a means of targeted delivery to microorganisms to maximise the topical concentration and bactericidal impact of the agent [21].

2. Experimental Part

Sol-gel method used to prepare manganese oxide nanoparticles by dissolving manganese nitrate (35g) in 35 mL distilled water and placed on magnetic stirrer to get the solution, then urea added to the solution. The solution was heated for one hour at 140°C to obtain the gel, which was dried at 250°C for one hour also to produce manganese oxide powder. The resulting material was tested by X-ray diffraction (XRD) and field-emission scanning electron microscopy (FE-SEM).

A 38 g of Molar Hinton agar was dissolved in 100 mL of distilled water using a hot plate until it boils, then the solution is sterilized by an autoclave at 121°C. After the solution cools to 45-50°C, it is poured into petri dishes in an amount of 8-10 mL, then left in ultraviolet light to ensure no contamination for half an hour. After that, the bacteria (*Escherichia* and *Klebsiella*) are grown on them. Then we choose a section of dishes to put a capsule of manganese oxide nanopowder in it to study its effect on the growth of bacteria. Then all the dishes are placed in the incubator for 24 hours at 37°C, so that a comparison

can be performed between the dishes before and after adding the nanopowder.

3. Results and Discussion

Figure (1) showed that the prepared material is manganese oxide (MnO_2) after matching with JCPDS card no. 00-044-0141 and the crystal system is quadruple, where the positions of peaks at 2θ = 12.7°, 25.7°, 28.8°, 36.6°, 39.01°, 41.2°, 47.3° and corresponding Miller indices of (110), (220), (310), (400), (330), (420), and (510), respectively, were assigned. The trend of growth is (110) and the crystallite size (D) is 33 nm according to Debye-Scherrer equation:

$$D = \frac{k\lambda}{\beta cos\theta} \quad (1)$$

where k is the shape factor and equals to 0.9, λ is the x-ray wavelength (0.154 nm), β is the full-width at half maximum (FWHM) of the diffraction peak at diffraction angle (θ)

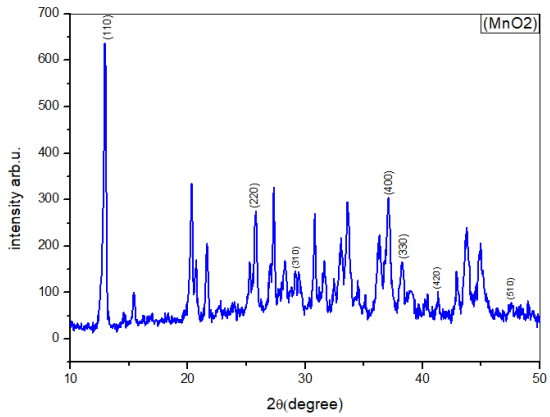


Fig. (1) XRD pattern of MnO_2 nanopowder sample

The surface morphology of MnO_2 nanopowder prepared in this work was examined by FE-SEM. The surface morphology of MnO_2 tends to be dense packed with pinholes. Also, the grains have different sizes. Figure (2) shows that the prepared material consists of non-homogeneous agglomerates with some holes, cracks, and defects.

After preparing MnO_2 nanopowder, the biological effectiveness was tested against (*Eshereshia coli* and *Klebsiella*). The manganese oxide (MnO_2) worked as an antibiotic against the bacteria. In Fig. (3), circular distance was formed around the plate of MnO_2, which means no growth around the plate and success the substance as an antibacterial against *Escherichia coli* because MnO_2 has a high potential to cause cell membrane damage to living organisms. The results also showed that MnO_2 nanopowder was the main cause of increasing the permeability in the cytoplasmic membrane of bacteria. In addition, the cytoplasmic membrane of bacteria acts as a barrier to prevent leakage of ions [22].

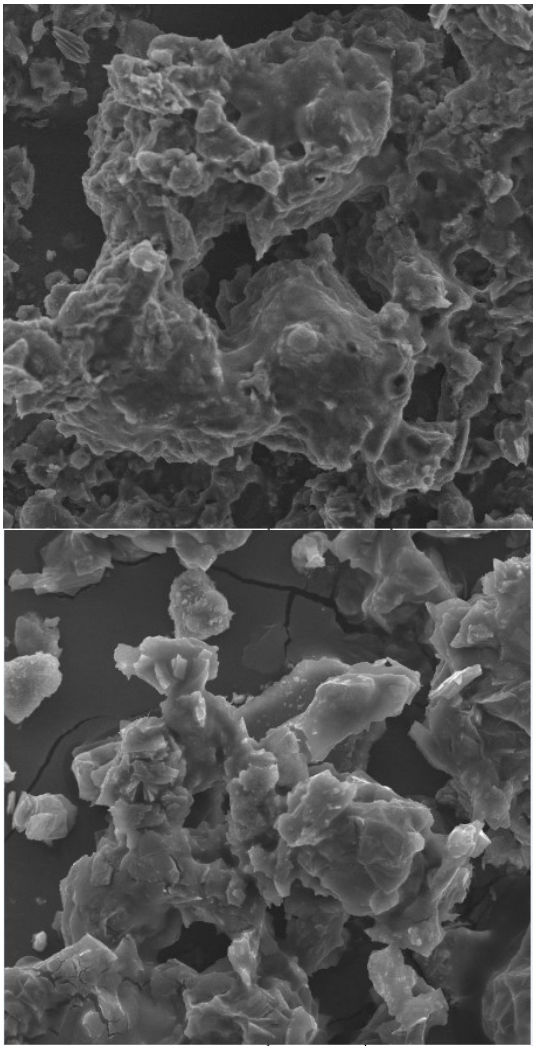
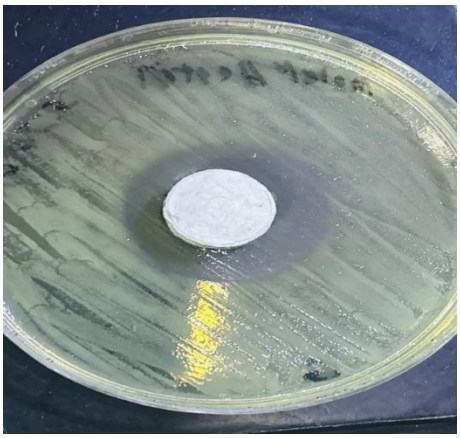


Fig. (2) FE-SEM images of MnO_2 nanopowder prepared in this work

Figure (4) shows an increase in the diameter of the inhibition zone after adding MnO_2 nanopowder, which means that the nanomaterial is much more effective on *Klebslla* bacteria than *Escherichia coli.*



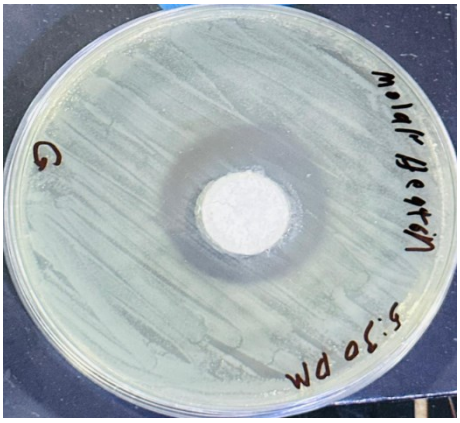


Fig. (3) Antibacterial Activity of MnO_2 nanopowder against *Eshireshia coli*

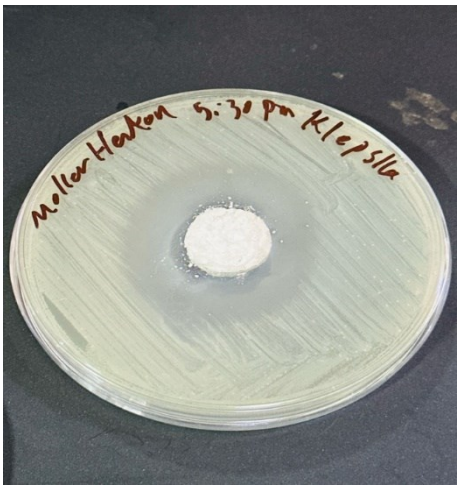


Fig. (4) Antibacterial Activity of MnO_2 nanopowder against *Klebsila*

4. Conclusion

Manganese oxide nanoparticles are good antibacterial material against two types of bacteria (*Escherichia coli* and *Klebsiella*). The effectiveness of manganese oxide nanopowder against *Klebsiella* bacteria is higher than its effectiveness against *Escherichia coli* as an antibacterial material.

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