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Antibacterial Activity, Characterizations, and Biological Synthesis of Manganese Oxide Nanoparticles using the Extract of *Aloe vera*

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Abstract

Green nanotechnology is relatively new branch of science and technology with many interesting applications. This technology involves in the synthesis of inorganic nanoparticles (NPs) through green synthesis using extracts of plant-derived materials. Green synthesis of metal and metal oxide NPs is a good alternative over the other conventional physical and chemical methods. This study deals with the green synthesis of manganese oxide (MnO_2) NPs using the extract of *Aloe vera*. The green synthesized MnO_2 NPs have been synthesized using various analytical methods such as Fourier transform infrared, X-ray diffraction, and field emission scanning electron microscope. MnO_2 NPs were tested for antibacterial activities against *Escherichia coli*, *Streptococcus mutans,* and *Staphylococcus aureus* using well diffusion method. The experimental results were indicating that the MnO_2 NPs are good antibacterial agents against different bacterial species.

Keywords: Antibacterial activities, Characterizations, Green synthesis, Manganese oxide nanoparticles

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Introduction

The nano-based materials have been used for efficiency, durability, and effectiveness. Such materials are commonly used in biological, physical, chemical, pharmaceutical, engineering, and environmental sciences due to improved surface area to volume ratio.[1] The nano-based materials or nanoparticles (NPs) can be synthesized using different physical and chemical methods. In general, such methods are not safe to environment, less efficient, and high cost. Green or biological methods are good alternatives over these conventional methods. The plant extract-based synthesis of inorganic NPs is highly efficient, low cost, and non-toxic. The biomolecules present in plant materials act as reducing and capping agents. The metal and metal oxide NPs have been used in chemical, electronics, ceramics, pharmaceuticals, and others.[2] The common metal oxide NPs are copper oxide, calcium oxide, magnesium oxide, zinc oxide, titanium dioxide, manganese oxide (MnO_2), and iron oxides.[1,3] The MnO_2 NPs also have many applications in different fields of science and technology. In general, MnO_2 NPs are used in sensors, energy storage, catalysis, environmental remediation, and antimicrobial activities.[4-9] In this study, we have synthesized MnO_2 NPs using the extract of *Aloe vera* plant. The plant *A. vera* is used for beauty, good health, skin problems, and other health problems. The real botanical name of this plant is *Aloe barbadensis* miller and belonging to a family Asphodelaceae or Liliaceae. It is green in color, stem less, perennial, shrubby, and xerophytic plant.[10]

Materials and Methods

The collected aerial parts of *A. vera* were washed with distilled water and then crushed in a mortar. The paste of the plant was boiled with distilled water for 30 min and then filtered. The filtrate has been used as plant extract and preserved at below 4°C for the synthesis of MnO_2 NPs. The extract (10 ml with pH 6) was treated with 100 ml of 0.1 M $KMnO_4$ solution and color of the solution changed. This solution was stirred over a magnetic stirrer for 3 h at room temperature and then sonicated for 30 min. The suspension was then subjected to centrifugation at 10,000 rpm. The MnO_2 NPs have been settled down and collected particles washed with ethanol and double-distilled water. The washed MnO_2 NPs were completely dried at 90°C and then calcined at 300°C for 1 h. Finally, MnO_2 NPs were preserved in airtight bottles for characterizations and antimicrobial activities. The characterization of MnO_2 NPs was done by means of Fourier transform infrared (FTIR), X-ray diffraction (XRD), and field emission scanning electron microscope (FESEM) methods. The antibacterial activity of MnO_2 NPs has been checked for *Escherichia coli*, *Streptococcus mutans,* and *Staphylococcus aureus* using well diffusion method. The MnO_2 NPs were loaded in the wells over the Petri plates containing solid media. After incubation period, the zones of inhibition have been measured around the MnO_2 NPs.

Results and Discussion

FTIR spectroscopy is basically used to determine the presence of chemical bonds on the biologically synthesized NPs. This spectroscopy is interference based and highly sensitive.[1,2] The FTIR spectra are represented in Figure 1a for biologically synthesized

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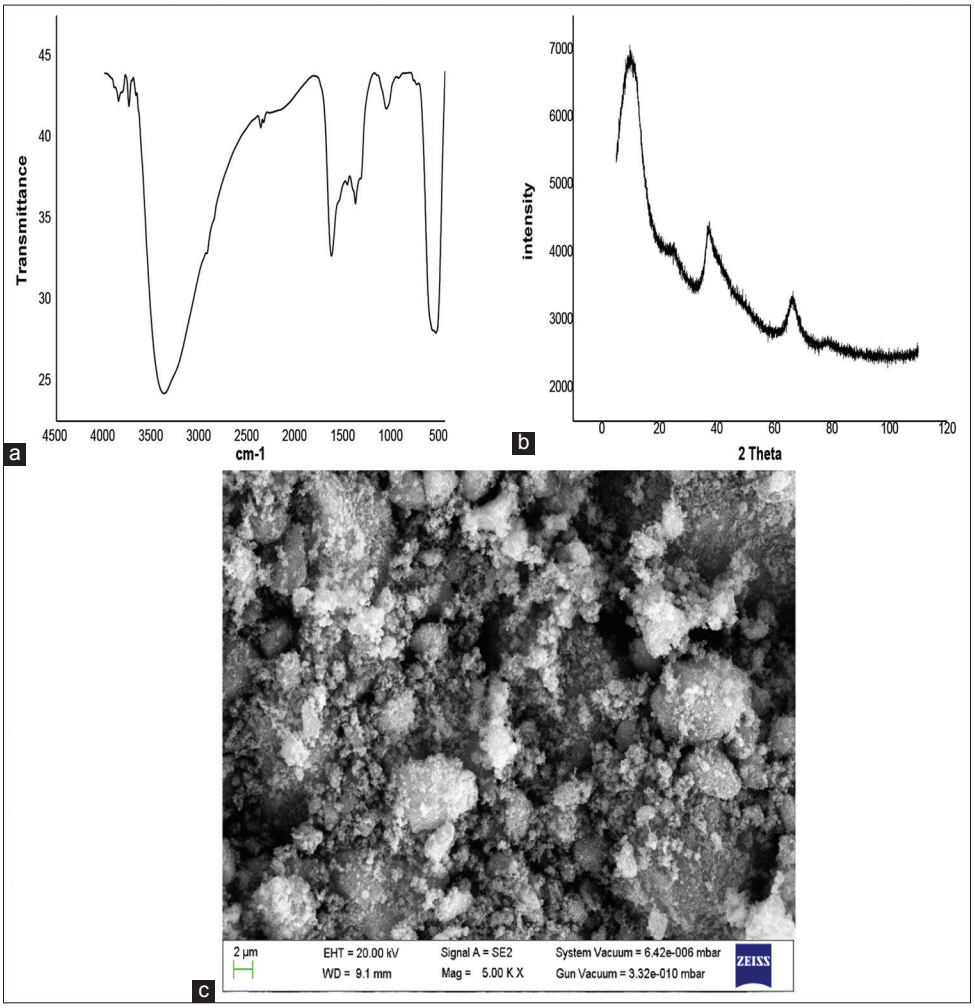

Figure 1: (a) Fourier transform infrared, (b) X-ray diffraction, and (c) field emission scanning electron microscope image of manganese oxide nanoparticles

MnO_2 NPs using the extract of *A. vera* plant. The characteristic peaks are obtained at 3378 cm^{-1}, 1633 cm^{-1}, 1383 cm^{-1}, 1060 cm^{-1}, and 545 cm^{-1}. These peaks indicate the presence of O-H, C=O, C=C, C-C, C-Mn, and Mn-O bonds on the surface of MnO_2 NPs. The powder XRD technique is also a common analytical technique. This technique is used to observe the crystalline, semi-crystalline, and amorphous nature of powdered NPs. The XRD pattern of MnO_2 NPs is shown in Figure 1b and indicating its semi-crystalline nature. The characteristic peaks are obtained at 12 θ, 40 θ, and 64 θ. The peaks indicate the formation of MnO_2 NPs using the extract of *A. vera*.[11]

FESEM technique is used to observe the morphological characters of NPS.[3] The FESEM image of MnO_2 NPs is represented in Figure 1c and indicating the agglomerated sphere-shaped MnO_2 NPs. MnO_2 NPs have been utilized as an antibacterial agents for *E. coli*, *S. mutans,* and *S. aureus* using well diffusion method. The experimental results show that the MnO_2 NPs are good antibacterial agents. Antibacterial activity of MnO_2 NPs is due to the smallest size; they can easily enter into the bacterial cells and destroy the cell membranes. Finally, it results death of bacterial cell due to a distortion mechanisms in the bacterial cell.[1-4] After incubation period, the zones of inhibition have been found as 22 mm, 18 mm, and 16 mm for *E. coli*, *S. mutans,* and *S. aureus*.

Conclusions

The green synthetic method using the extract of *A. vera* for the synthesis of MnO_2 NPS was found very low cost, efficient, and non-toxic. The freshly synthesized MnO_2 NPs have been characterized using FTIR, XRD, and FESEM methods. The antibacterial activity of MnO_2 NPs for *E. coli* was found more than *S. mutans* and *S. aureus*.

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