RESEARCH PAPER

Synthesis, Characterization and Antibacterial Activity of Al_2O_3 Nanoparticles Against Gram Negative

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ABSTRACT

The current work examined the antibacterial efficacy of produced alumina (Al_2O_3) nanoparticles against gram negative organisms. Aluminum sulfates as well as NaOH were used as precursors in the precipitation technique of synthesis. Scanning electron microscopy (SEM) and X-ray diffraction (XRD) together with energy dispersive x-ray analysis (EDX) methods have been used to analyze the produced aluminum oxide NPs. Additionally, the antibacterial activity as well as minimum inhibitory concentration (MIC) regarding Al_2O_3 NPs against gram-negative (E. coli) bacteria are determined in the presented work.

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INTRODUCTION

Because of its use in technology and science to engineer novel materials at the nanoscale level, nanotechnology is quickly emerging field [1]. In the case when put to comparison with the bulk forms with comparable chemical compositions, NPs have distinct chemical characteristics [2]. In the case when put to comparison with organic compounds, metal oxide NPs have demonstrated superior selectivity, stability, durability, and reduced toxicity [3]. Furthermore, the variations in these particles' fundamental chemical and physical characteristics are caused by their size. Diagnostics, catalysis, water treatment, medication delivery, semiconductors, cosmetics, solid oxide fuels, and sensing are just a few of the impressive uses for such particles [4,5].

Aluminum oxide NPs could be utilized as absorbent in heterogeneous catalysis, as abrasive material, as reinforcements of metal-matrix composites, and as a biomaterial [7, 8]. They also have significant uses in the ceramic industry [6]. The number of microbes resistant to commonly utilized antibiotics has rapidly increased recently [9]. The contact surface area will rise by 109 nm when the size of particles is reduced from about

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10µm to 10nm. Because of their high surface area to volume ratio as well as distinct physical and chemical properties, Nano-scale materials emerged as possible antimicrobial agents in the context [10]. It is anticipated that such a wide contact surface will increase the degree of bacterial eradication [11]. The biological activity of particle is possibly to be altered by reactive groups on its surface. Thus, with regard to microbial toxicity problems, modifications to metal oxide NPs type as well as surface chemistry are crucial [12]. Over a broad temperature range, alumina NPs exhibit thermodynamic stability. With alumina ions occupying 2/3 regarding octahedral positions in lattice and oxygen atoms that adopt hexagonal close packing, they resemble corundum [13]. To the best of our knowledge, little substantial study has been done on alumina NPs antibacterial qualities. Therefore, an effort was made to look into the minimal inhibitory concentration as well as antibacterial activity regarding Al_2O_3 NPs generated using co-precipitation approach.

MATERIAL AND METHODS

Synthesis of alumina nanoparticles

The alumina nanoparticles were prepared by co-precipitation method using Aluminium sulfate and sodium hydroxide precursors. Aluminium

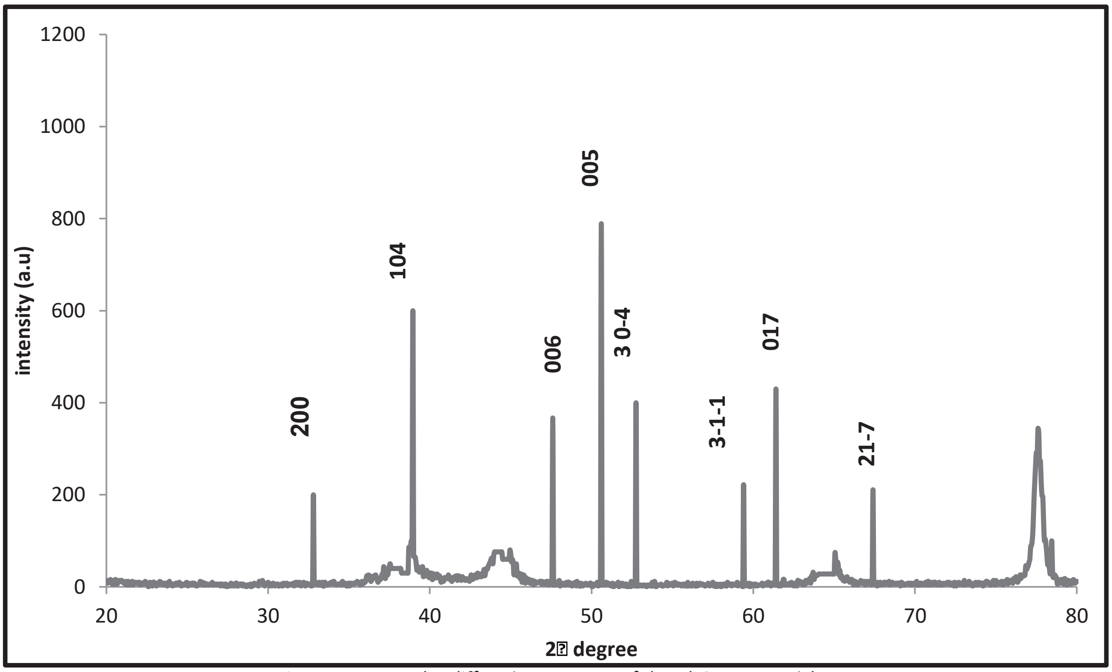

Fig. 1. X-ray powder diffraction patterns of the Al_2O_3nanoparticle.

Table 1. X-ray diffraction patterns of Alumina Nano powder.

Observed 2θ	Standard 2θ	h k l
32.08	32.80	2 0 0
38.57	38.95	1 0 4
47.98	47.66	0 0 6
50.74	50.66	0 1 5
52.49	52.79	3 0-4
58.28	58.77	3-1-1
59.94	59.47	3 1-3
61.25	61.48	3 0-6
65.25	65.44	0 1 7
67.46	67.47	2 1-7

sulfate, 0.1M, was dissolved in distilled water and the solution was kept under constant stirring using a magnetic stirrer for one hour. After complete dissolution of Aluminium sulfate, 0.2M of sodium hydroxide solution was added. The obtained white creamy solution was allowed to settle for an overnight and the supernatant was then discarded carefully. The precipitate was washed several times using distilled water, then dried at 80°C for overnight. During drying, complete conversion of Aluminium hydroxide into alumina takes place.

Minimum inhibitory concentration

Aluminum sulfate as well as sodium hydroxide precursors have been used in co-precipitation process to create alumina NPs. After dissolving 0.1M aluminum sulfate in distilled water, the solution has been continuously stirred for an hour with the use of magnetic stirrer. 0.20M of the solution of sodium hydroxide has been added once aluminum sulfate had completely dissolved. After letting the white, creamy solution settle for full night, the supernatant has been properly disposed of. After being repeatedly cleaned with distilled water, the precipitate was left to dry overnight at a temperature of 80 °C. Aluminum hydroxide is completely transformed into alumina throughout the drying process. [15].

RESULTS AND DISCUSSION

X-ray diffraction studies

The aluminum oxide NPs' peaks of diffraction are displayed in Fig. 1. The produced Al_2O_3 Nano-powder's XRD pattern shows monoclinic structure and 2(θ) phases. The stated values (JCPDS # 35-0121) are in good agreement with the measured diffraction peaks as well as the relative intensities regarding each diffraction peak. The 2θ- Al_2O_3 Nano-powder's powder XRD pattern showed peaks of diffraction at 2θ = 18.96°, 32.08o, 38.57°, 47.98°, 50.74o, 52.49°, 59.94°, 61.25°, 65.25°, and 67.46°. These peaks are assigned in Table 1 and correspond to the (102), (200), (104), (006), (015), (304), (313), (306), (017), and (217) planes, respectively. Debye-Scherrer formula, which is represented by the following equation, has been

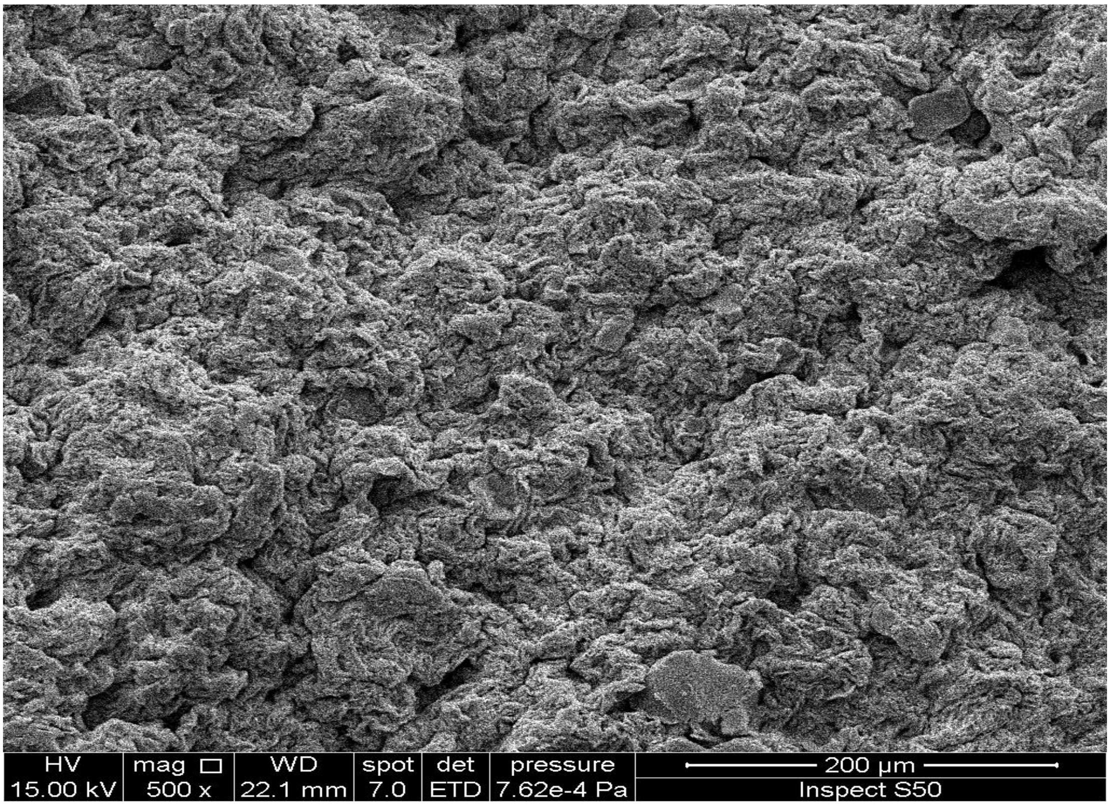

Fig. 2. SEM images of Aluminium oxide nanomaterial.

used to determine Al_2O_3 NPs' size:

$D = 0.90\lambda/\beta\cos\theta$

D stands for crystal size, λ for X-ray wavelength, β for full width half maximum height, and diffraction angle [16]. It has been determined that the average crystallite size was 35 nm. The results closely match the analyzed cell parameters, a = 0.5681, b = 0.2890, and c = 1.1776 nm.

Scanning electron microscope and energy dispersive X-ray spectroscopy analysis

Surface morphology regarding aluminum oxide has been irregularly spherical, as seen in Fig. 2 [17]. Because of segregation among crystal nuclei, the grain sizes calculated through XRD and those seen through SEM differ. EDX, was used to analyze the chemical composition related to aluminum oxide nanomaterial in (Fig. 3). The purity of aluminum oxide is shown in quantitative measurement findings from EDX analysis. Using precursor salts in the synthesis of NPs is responsible for the other, lower K signal. It shows how pure the sample is. Al and O peaks are present, according to EDX measurements.

The AFM image (Fig. 4) support this conclusion and reveal spherical (rounded) Al NPs with average crystallographic size about 10nm. The generated the nanoparticles have good distribution and the crystalline size are homogenous and oriented vertically.

Antibacterial activity of the Al Nano powder

The anti-bacterial activity related to aluminum oxide NPs has been examined using bacterial strain E. coli (MCC 2412). Fig. 5 illustrates the antibacterial efficacy related to Al_2O_3 NPs against various microorganisms with the use of well

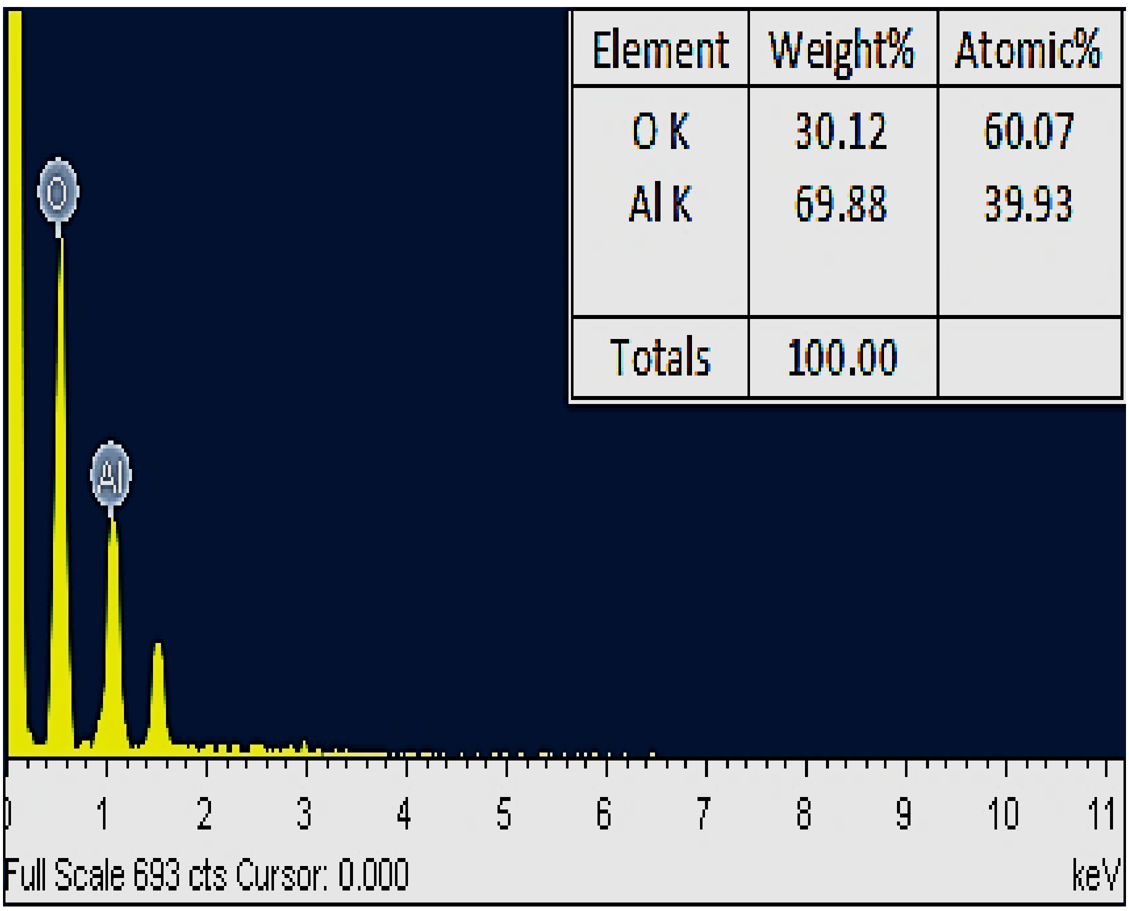

Fig. 3. EXD of Aluminium oxide nanomaterial.

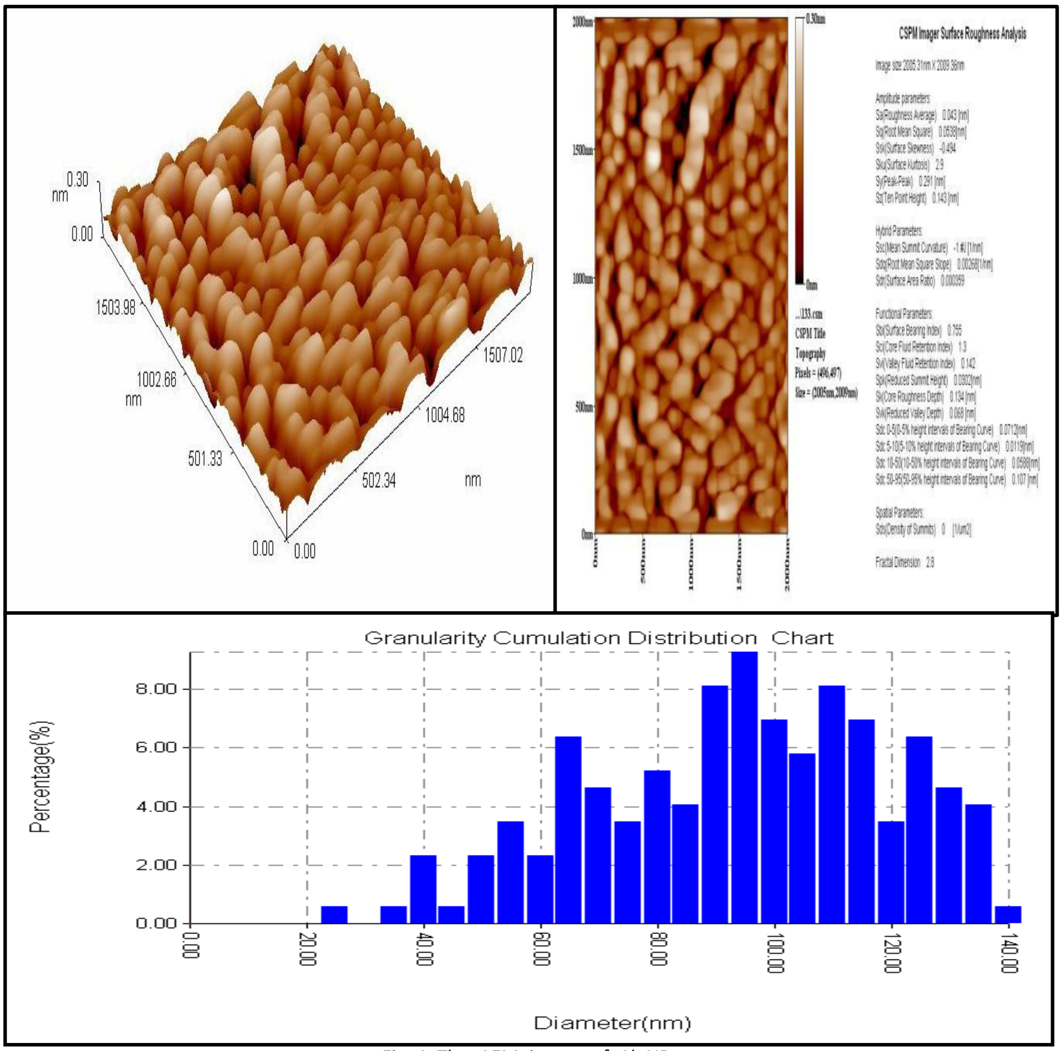

Fig. 4. The AFM image of Al NPs.

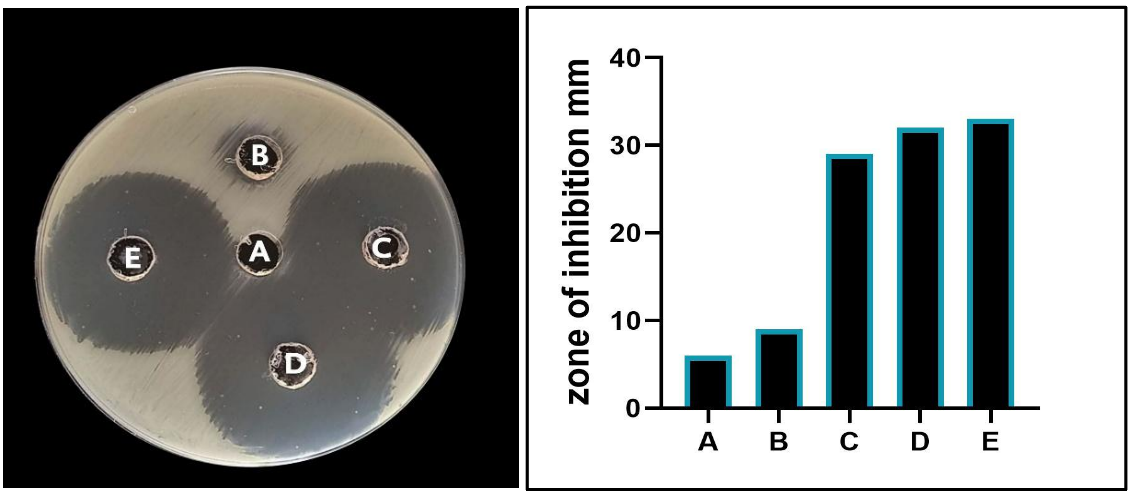

Fig. 5. Antibacterial activities *E .c o l i* of Aluminium oxide nanoparticles against bacteria using agar well diffusion method.

Table 2. Inhibition zones at different concentrations.

S. No.	Name of the organism	Mean zones of inhibition [mm]±SD [n=2]				
		10 mg/ml	20 mg/ml	30 mg/ml	40 mg/ml	50 mg/ml
1	*E. coli*	9±0.20	18±0.25	27±0.25	31±0.10	39±0.35

Table 3. MIC values of Aluminium oxide by broth dilution method.

S. No.	Name of the organism	MIC (mg/ml)
1	*E. coli*	4

diffusion technique. According to the findings, Al_2O_3 NPs produced via co-precipitation method have shown substantial anti-bacterial activity against dangerous microorganisms. Results have shown that inhibitory effect regarding Al_2O_3 NPs increased with their concentration. The diameter related to inhibitory zone shows how susceptible the bacteria are. A larger zone of inhibition was shown by the strain that responded to Al_2O_3 NPs (E. coli) [18].

Determination of minimum inhibitory concentration

Findings have shown significant MIC values between 2 and 8mg/ml. MIC for aluminum oxide Nano-powder at 4 mg/ml for E. Coli is shown in Table 3. Since it helps verify microbe's resistance to antimicrobial agent as well as tracks the effectiveness regarding new antimicrobial agents, MIC determination is important in diagnostic labs.

CONCLUSION

With the use of co-precipitation approach, aluminum oxide NPs with monoclinic structure as well as 2(θ) phases were created. According to XRD results, the crystallite size regarding aluminum oxide is 20 nm. It was shown that the aluminum oxide NPs had antibacterial properties. We may conclude that aluminum oxide is one of the potent antibacterial agents because of inhibition zone formation.

CONFLICT OF INTEREST

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

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