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Blockchain Technology and Spontaneous Synthesis of High-Temperature Solution Prepared Magnesium Oxide Nanoparticles

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Abstract: The formulation of MgO's solution combustion in the study before this used lime juice and citric acid as fuel sources. In contrast to chemical methods, plants concentrating on the interaction of metal oxide nanoparticles are a viable option. This research aimed to synthesise magnesium oxide nanoparticles using an aqueous extract from the heartwood of Pterocarpus marsupium. Cyperus marsupium's cedar extract, abundant in polyphenols and quercetin, is used as a natural origin for the simple, cost-effective, and environmentally friendly manufacturing of magnesium oxide nanoparticles on a large scale. A similar analysis was conducted on the disqualified samples to better understand the benefits of using lemon juice and citrus extract as the igniting agent for the MgO microparticles. Germicidal research against Escherichia coli and Staphylococcus aureus has been done using a well-diffusion technique. A method known as microbroth dilution was used to determine the lowest inhibitory concentration feasible. In the case of MDA-MB-231 and HeLa cell lines, the anticancer behaviour of MgO NPs was investigated using a 3- (4,5-dimethylthiazolyl-2)-2,5-diphenyltetrazolium bromide test. The hemolysis experiment was done to determine how porous a nanoparticle behaves in MgO, which contains NPs.

Keywords: Blockchain Technology; Spontaneous Synthesis; High-Temperature Solution; Magnesium Oxide Nanoparticles; Cost-Effective and Environmentally Friendly; Innovative Features; Environmental Management.

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1. Introduction

Oxides derived from inert base metals, such as magnesium oxide, zinc oxide, copper oxide, and titanium dioxide, are gaining popularity in antimicrobial applications due to their unique combination of innovative features, a wide range of practical uses, safety, and stability at high temperatures [9]; [23]. Numerous studies have been conducted on these metal oxides due to their structural and chemical stability, compatibility with various environments, and relative safety in biological and ecological systems. Researchers are working hard to understand how they work, make them easier to produce, and discover more applications for them. Inorganic metallic oxides are recognised for being safe and effective compared to some of the chemical agents that were used for comparable objectives before [6]. This is because they possess several properties that make them suitable for a wide range of applications. Their numerous benefits place them at the intersection of materials science, nanotechnology, health, and environmental research. As a result, they are currently regarded as essential materials for addressing both technological and social challenges. Some of these applications include using them in lithium-ion batteries, superconductors, and the removal of hazardous contaminants.

They also play a crucial role in catalysis, where they facilitate the acceleration of chemical reactions in a manner that conserves energy. They also work as antibacterial agents in many areas of healthcare and environmental management [7]. These topics demonstrate the versatility of metal oxides, illustrating how they can be utilised in various applications and adapted to different functional domains [26]. For instance, zinc oxide nanoparticles are widely used in semiconductors and photocatalysts, while titanium dioxide has been heavily studied for its role in solar cells and in breaking down pollutants. Magnesium oxide, on the other hand, stands out as a potential medicinal application due to its powerful antibacterial and antiviral properties, even in situations where other antimicrobial agents may be ineffective. Magnesium oxide nanoparticles have garnered interest due to their superior efficacy as cetrimide agents, surpassing numerous conventional antibacterial agents in potency, safety, and environmental compatibility [12]. They have become a central focus of medical research because they can break down bacterial cell membranes, generate reactive oxygen species, and interfere with microbial metabolic pathways [5]. These traits make them especially effective at combating germs resistant to antibiotics and helping the world address antimicrobial resistance, which is becoming a growing public health concern. Magnesium oxide nanoparticles offer an alternative to traditional antibiotics, creating new possibilities for treating infections and developing antimicrobial coatings for medical devices, food packaging, and water purification systems.

Laboratory and clinical tests have consistently demonstrated their effectiveness, and their minimal toxicity to mammalian cells makes them even more promising for use in medicine [17]. Research into the antibacterial properties of these nanoparticles is also exploring potential applications in detoxification and bone regeneration [14]. Their capacity to absorb and neutralise toxic substances provides effective methods for water treatment and environmental cleanup during detoxification [33]. When used to help bones heal, magnesium oxide nanoparticles not only prevent germs from growing at implant sites but also stimulate osteogenic activity, promoting new bone growth and tissue repair. This dual functioning is very useful in orthopaedic and dental settings, where infections typically make healing more difficult. Their incorporation into composite scaffolds and coatings for implants offers a pathway to materials that are both biocompatible and antibacterial, improving patient outcomes and minimising medical problems. At the same time, the Spontaneous Combustion Synthesis or Self-Propagating Combustion Synthesis method has become a popular approach for producing these nanoparticles [1]; [3]. This synthesis technique, which utilises high-temperature solution-based reactions, is a straightforward yet effective method for producing metal oxide nanoparticles that exhibit consistent performance [7].

This method's unique strength lies in its use of organic molecules, such as urea, glycine, and citric acid, as fuel. The approach utilises readily available and inexpensive precursors, adhering to sustainable chemical principles by minimising waste and employing less hazardous reagents [8]. Sustainability is becoming a guiding principle in current material science. This means that magnesium oxide and other metal oxides are at the forefront of eco-friendly technology breakthroughs, as they can be produced using green synthesis methods like this one. The Self-Propagating Combustion Synthesis process is a smart and long-lasting method for producing nanoparticles that remain pure, have a consistent shape, and are stable. These features are essential to ensure the product performs effectively in a wide range of situations. This method enables the production of vast quantities of nanoparticles while maintaining control over their size, crystallinity, and surface properties. This is because it is both scalable and adaptable. Such control is essential because the physicochemical properties of nanoparticles frequently dictate their reactivity, bioavailability, and functional efficacy. By improving synthesis methods, researchers can create nanoparticles that are more suitable for specific applications, such as catalysis, biomedical use, or environmental protection. This makes them more effective and safer [18].

Researchers are increasingly investigating magnesium oxide, zinc oxide, copper oxide, and titanium dioxide, as they recognise that these compounds could impact several sectors. They are a promising solution to some of the world's most pressing problems, including hospital-acquired illnesses, food contamination, and the need for safer and more environmentally friendly disinfectants [32]. Metal oxides are less likely to cause microbes to become resistant than many other traditional agents, as they often work in multiple ways, such as inducing oxidative stress, disrupting membranes, and releasing ions. This multi-pronged strategy makes it less likely that germs will adapt fast, which keeps them effective over time. These metal oxides are crucial for developing sustainable technologies in the energy sector. For example, lithium-ion batteries use metal oxide parts for their cathodes. Lithium cobalt oxide and lithium manganese oxide are two examples of materials that provide them the energy density and stability they need. Magnesium oxide and titanium dioxide are not utilised directly in regular cathodes, but they do help make supporting materials and coatings that enhance battery performance and prolong their lifespan. Superconductors that include oxides, such as cuprates, are also crucial for developing high-performance energy transmission systems, medical imaging technologies, and quantum computing applications. These applications demonstrate the versatility of metal oxides and their significant contribution to advancing contemporary research. From an environmental perspective, metal oxides such as titanium dioxide are crucial for the photocatalytic degradation of contaminants.

They offer good ways to clean up water, improve air quality, and manage trash. They can utilise light energy to initiate chemical reactions, which is a sustainable method for breaking down hazardous organic compounds, heavy metals, and other contaminants. When mixed with magnesium oxide and zinc oxide, which add more antibacterial and adsorptive qualities, these materials work even better to keep the environment safe. Adding them to coatings, filters, and membranes makes the environment cleaner and reduces the need for toxic chemicals often used in cleaning and disinfecting. Biomedically, magnesium oxide nanoparticles are becoming acknowledged for their significance not only in antibacterial activities but also in enhancing drug delivery systems, tissue engineering, and cancer therapy. Because they are biocompatible and biodegradable, they are suitable candidates for carrying medicinal compounds, enabling targeted distribution and controlled release. Their capacity to produce reactive oxygen species has been examined in cancer therapy as a potential means to preferentially destroy cancer cells while minimising damage to adjacent healthy tissues.

Such applications exemplify the overarching transformation in medicine towards nanotechnology-driven interventions, emphasising precision, efficiency, and safety. At the same time, these materials must be carefully evaluated for their potential hazards and long-term effects to ensure safe and responsible use. Although they are typically considered safe, the potential for nanoparticles to accumulate in biological systems and ecosystems highlights the need for close monitoring and regulation. Studies have emphasised the importance of establishing standardised processes for testing toxicity, controlling dosage, and assessing environmental effects to ensure that the benefits of metal oxides are realised without causing harm. This balance between safety and innovation is what makes nanotechnology viable. Technological advancement must be in line with moral and environmental concerns. As more and more material scientists, medical researchers, environmental engineers, and industrial executives work together, the future of magnesium oxide and other metal oxides is expected to rise even more. These materials are poised to play a significant role in sustainable development by integrating innovative manufacturing techniques, such as green chemistry, with enhanced understanding of antimicrobial mechanisms and improved applications in energy, healthcare, and the environment.

Their unique features not only enhance the performance of current technologies, but they also pave the way for new ideas that can help solve the complex problems of the twenty-first century. In short, the growth of metal oxides, such as magnesium oxide, zinc oxide, copper oxide, and titanium dioxide, demonstrates how stable, safe, and useful materials can become important instruments in various scientific and industrial fields. Their antibacterial properties, along with their applications in biological processes, catalysis, energy storage, and pollution management, demonstrate their importance in various fields. The Self-Propagating Combustion Synthesis method demonstrates how environmentally friendly and cost-effective production methods can help scale these materials up to a usable level in the real world. As research progresses, these oxides represent the promise of nanotechnology to foster both creativity and sustainability, guaranteeing that their applications significantly enhance human health, environmental conservation, and technological advancement globally.

2. Review of Literature

The recent rise in organic chemicals, seen as a valuable source of fuel, has led to increased attention on using natural agents to produce nanoparticles [15]; [10]. People like these naturally produce substances because they can create more creative, cost-effective, and environmentally friendly solutions than traditional chemical methods [30]; [19]. People have long questioned the use of chemical synthesis due to environmental concerns about chemical byproducts and the costly steps needed to ensure its effectiveness and stability. In contrast, naturally removed substances, especially phytochemicals, work well as agents for both stabilisation and reduction during the synthesis of most nanoparticles [28]. These natural agents not only reduce environmental impact, but they also align with the growing global interest in green chemistry and sustainable development. The significance of phytochemicals in nanoparticle synthesis has garnered considerable interest, especially in the context of combining varying concentrations of metal or metal oxide nanoparticles. Phytochemicals are a major common asset that helps lower metal levels and keep nanoparticles stable during the production process [16]; [4]. For many years, phytochemicals were considered secondary metabolites that didn't significantly contribute to nutrition. However, their rising use as reducing and stabilising agents in nanoparticle synthesis has changed this view [34].

Their use has increased significantly over the last 10 years, highlighting their importance in creating nanoparticles that are effective, long-lasting, and cost-effective [29]; [21]. The growing recognition of phytochemicals as eco-friendly reagents prompts a significant research inquiry: do the benefits of utilising natural phytochemicals surpass those of chemically refined alternatives, aside from their cost-effectiveness and availability [27]; [25]. Numerous plants and natural sources have been examined to elucidate the role of phytochemicals in the sustainable production of nanoparticles. Previous research has demonstrated that fillers, including Abutilon indicum, Melia azedarach, and Indigofera tinctoria, are effective sources of plant-based fuel for nanoparticle manufacturing [35]. Plant leftovers, which would normally be considered waste, have thus been effectively reused in research settings, enabling both a cost-effective and environmentally safe route towards nanoparticle manufacturing. This new approach to utilising biological waste is part of a broader movement in nanotechnology towards a circular economy and resource-efficient methods. Alongside the significance of plants and phytochemicals, the interaction between nanoparticles, microorganisms, and bioparticles has been a focal point of growing scientific interest, although this domain remains largely unexamined [31]; [20]. Nanoparticles, especially metal and metal oxide nanoparticles, have special surface properties and are quite reactive. This means they can interact with microbial systems in ways that are both hopeful and difficult. For example, multiple studies have demonstrated that they exhibit antibacterial effects, although the mechanisms underlying these interactions are still being debated and require further research.

The biocompatibility of nanoparticles is equally important because it affects their potential utility in medicine and therapy. A recent area of research has focused on the environmentally friendly creation of magnesium oxide nanoparticles (MgO NPs) using two distinct fuels: lemon juice and citric acid [32]; [2]. This method demonstrates how green chemistry works by utilising organic, inexpensive, and readily available ingredients as fuel to produce nanoparticles. Lemon juice, which is high in citric acid and other phytochemicals, works as both a reducing and stabilising agent. Citric acid itself helps manage the synthesis process. Using these natural fuels makes the process safer and better for the environment because it minimises the need for dangerous chemicals. The generated MgO nanoparticles exhibited promising structural and functional attributes, underscoring the feasibility of green synthesis methods in contemporary nanotechnology. Researchers have also examined the effectiveness of MgO NPs produced using green approaches in combating germs. Researchers employed the well-dispersion method to assess the effectiveness of novel MgO NPs against gram-negative bacteria, a type of bacterium commonly resistant to antibiotics [22]; [11]. The dilution method was used to determine the minimum inhibitory concentration (MIC) necessary for successful microbial suppression, providing definitive evidence of the antibacterial activity of MgO NPs [13]; [24]. These findings support the idea that MgO nanoparticles, when made utilising eco-friendly and long-lasting technologies, can be very effective at killing germs.

3. Methodology

3.1. Experimental Details

Synthesis of MgO NPs: Magnesium nitrate and citrus extract can be used as an oxidant and fuel. While dissolving in 10.0 mL of double-refined water, 4.0 grams of Mg (NO3)2.6H2O and 1.8 grams of citrus extract were entirely dissolved. The mixture was then transferred onto a dish designed for solidification and placed in a heater with the mute that had been previously heated. The heater temperature was kept at 500 ± 10 °C. The arrangement formed a clear gel quickly, as observed by the rapid fuel consumption. The response delivered a substance that was white and exceptionally permeable. They marked the example as MgO-1. Presently, magnesium nitrate and lemon juice are mixed using the two oxidisers, and then the solidifying dish of the combination is placed in a heated suppressor heater (500 °C ± 10 °C). The arrangement formed a clear gel quickly, as observed through rapid fuel ignition. The example gathered had been calcined for two hours at 700 °C. The NPs orchestrated with MgO have been distinguished as MgO-2.

Characterisation Methods: The MgO NPs stage has been characterised through powder X-ray diffraction (PXRD) using a PANalytical X'Pert Pro diffractometer with Cu Kα radiation (λ = 1.5418 Å) as the source of a wide range of Bragg angles. Test surface morphology was investigated by using scanning electron microscopy (SEM) using a JEOL Model JSM-6390LV. Surface area estimations, using the Brunauer-Emmett-Teller (BET) method, were performed on a Micromeritics 3 Flex.

Antibacterial activity of MgO NPs: At 37°C, the trenchers were incubated for 24 hours. The plates were allowed to harden before being fanned out with sterile L-rods, and 100 µL of the pathogenic bacterial culture was transported to the plate, resulting in a complete culture lawn. Ultrasonic preparations were made for homogeneous dispersions of MgO NPs, with precise attention to achieving concentrations of 1000 to 250 µg/mL (achieved through two-fold dilution). Holes that have been cut remained filled with random MgO NPs (of different focuses). The antibacterial development was determined by working out the zone of inhibition (ZOI) surrounding the wells. MIC by microtechnique: Cell suspensions were used as inoculum after bacterial cultures were developed on soya stock trypticase (acclimated to 1-2 × 10^5 cells/mL). Fluid scatterings of 1000-1,953 µg/mL MgO NPs (two-crease weakenings) in MH stock have been compared with the test societies. Bacterial-treated societies have been incubated at 35 ° C. Following 24-48 hours, the test plates were examined, and the optical thickness in the Tecan plate peruser was determined at 600 nm. The percentage restraint assessment remained in place.

4. Results and Discussions

Crystal Structure: Precious stone designs of the blended MgO NPs utilizing various energizes are displayed in Figure 1. All diffraction designs agree with the card (45-0946) of the ordinary k is the consistent of the structure (~0.9), π is the X-beam frequency, β is the point of the Bragg, and β is the line of extension in radians at a large portion of the greatest force (FWHM). The typical crystallite sizes of fully produced MgO NPs are shown in Table 1. A section of the two samples revealed that MgO-2, which used lemon juice as fuel, had smaller crystallites than MgO-1, which had been arranged using citrus extract.

Morphology: The SEM focused on the MgO-1 and MgO-2 as-framed morphologies at the surface, respectively. SEM analyses revealed the presence of NP agglomerates. The large amounts of hot gases that discharge during combustion from the response mixture can be attributed to the morphology's abundance of voids and pores, as shown in the micrographs. The crystallites are connected through uneven forms and pore diameters to form substantial network architectures. The predominant MgO composition is revealed by an analysis of the specimens' EDS.

Surface Area Measurements: On a Micromeritics ASAP 2020, the surface area of MgO NPs was evaluated using standard BET analysis with N2 adsorption-desorption isotherms. The surface region BET estimates for MgO-1 and MgO-2 were observed to be 43.58 m²/g and 73.5 m²/g, respectively. It was found that the surface region, expressed in terms of unit volume or mass, extends as the crystallite size decreases. Equation (1) relates the computational power (hash rate) of a blockchain network to the reaction time required for the spontaneous synthesis of MgO nanoparticles. This could be a way to secure the timing of the synthesis process through blockchain verification.

$$\mathrm{T\_reaction} = \mathrm{C/H\_rate} \tag{1}$$

Where:

- $\mathrm{T_{reaction}}$ is the reaction time required for the synthesis of MgO nanoparticles.
- C is a constant that represents the complexity of the synthesis process.
- $\mathrm{H_{rate}}$ the hash rate of the blockchain network represents the computational power.

Equation (2) explores how the block time in blockchain (the time it takes to confirm a block of transactions and add it to the chain) could be analogically related to the distribution of nanoparticle sizes produced in the synthesis process.

$$\mathrm{S_{avg}} = \underline{\mathrm{K}}\mathrm{T_Q N} \tag{2}$$

Where:

- $\mathrm{S_{avg}}$ is the average size of the synthesised MgO nanoparticles.
- K is a proportionality constant that relates block time to nanoparticle size.
- $\mathrm{T_{block}}$ is the average block time in the blockchain.
- N is the total number of nanoparticles, indicating the synthesis scale.

Equation (3) links the efficiency of a blockchain consensus algorithm to the purity level of the MgO nanoparticles produced. This could be conceptualised as ensuring quality control in the synthesis process through blockchain oversight.

$$\mathrm{P_{MgO}} = 1 - \exp\left(-\eta \cdot \mathrm{E_{consensus}}\right) \tag{3}$$

Where:

- $\mathrm{P_{MgO}}$ is the purity of the magnesium oxide nanoparticles.
- η is a factor representing the efficiency of the synthesis process in response to the consensus algorithm.

4.1. Anticancer Activity by MTT Assay

The cytotoxic impact of MgO NPs is introduced in Figure 2 in MDA-MB-231 and HeLa cell lines. The qualities of IC50 are represented in Table 1. These discoveries showed that the cytotoxicity of test MgO-2 was more prominent than that of MgO-

1. According to the findings, using citrus extract as a fuel and lemon juice as a biofuel resulted in higher cytotoxicity than using MgO-1 coupled with MgO-2 on the two cell lines. According to the study's findings, nanoparticles (NPs) can induce cytotoxicity in a cell-specific manner and independently of cell proliferation.

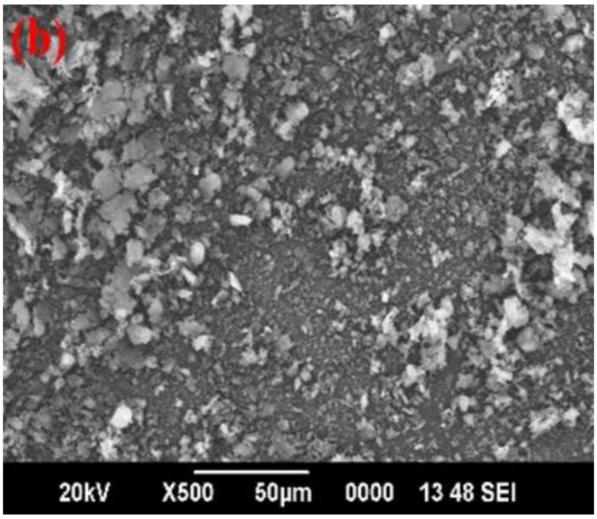

Figure 1: EDS, mgo-1, (b) mgo-2 NPS

This is done by quickly isolating disease cells, which are the most vulnerable cells, in contrast to the toughest and most resilient cells. The role of apoptosis in cancer cells can be inferred from MgO NPs; however, it is not part of MgO NPs' ability to combat cancer. The outcomes of hemolysis and antileukemic preparations are given in Table 1. Correspondence of MgO NPs through RBC at a 5 mg/mL MgO NPs' convergence revealed a significant hemolysis rate of more than 5. Since 5% hemolysis is considered a sensible limit for biomaterials, hemolysis action can occur at a concentration of up to 2.5 mg/mL of Mgo NPs.

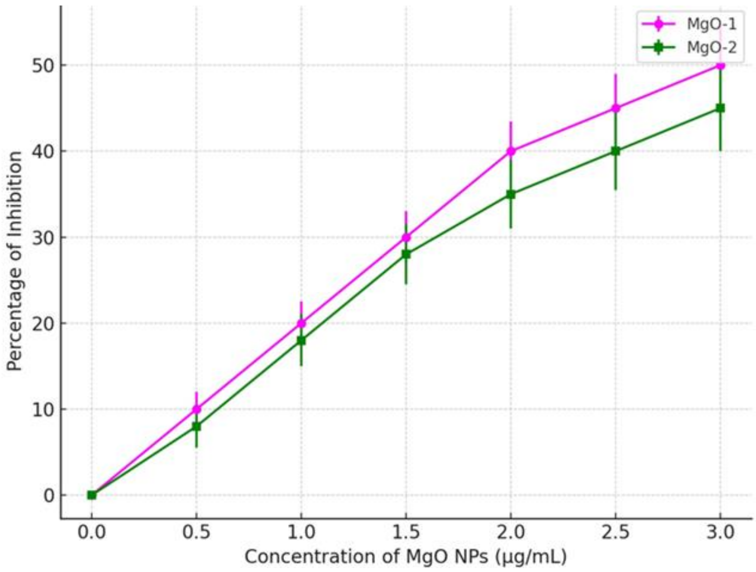

Figure 2: Percentage of inhibition as a function of MGO nanoparticle concentration, comparing two types of nanoparticles (mgo-1 and mgo-2), with error bars representing measurement variability

The relationship between the attention of magnesium oxide nanoparticles (MgO NPs) and the corresponding percentage of inhibition is illustrated in Figure 2, likely in a chemical or biological context. MgO-1 and MgO-2, one-of-a-kind types of MgO nanoparticles, are tested at concentrations from 0 to a few µg/mL. The magenta line for MgO-1 indicates a steeper increase in the percentage of inhibition with attention compared to the inexperienced line for MgO-2, suggesting that MgO-1 may be more reactive or effective. The variability of inhibitory measures is shown through blunder bars, which may represent organic variability or a positive amount of experimental uncertainty. The extent of cell passage remained unchanged, as determined by the MTT test.

Table 1: MGO NPS

Sample	Pathogen	Concentration µg/mL	ZOI Mean ± SD (mm)		ZOI (mm) Positive control
			MgO-1	MgO-2	
MgO NPs	E. coli	125	0.00 ± 0.00	0.00 ± 0.00	40.77 ± 1.05
		250	6.00 ± 0.00	0.00 ± 0.00	
		500	8.00 ± 0.00	9.50 ± 0.577	
		1000	12.50 ± 0.577	13.50 ± 0.577	
	S. aureus	125	0.00 ± 0.00	0.00 ± 0.00	38.0 ± 1.06
		250	10.00 ± 0.816	11.00 ± 0.00	
		500	12.50 ± 0.577	14.00 ± 0.00	
		1000	16.50 ± 0.577	19.50 ± 0.577	

This is because the phytochemicals in the crude extracts were destroyed during the reductive and normalisation methods used to create the nanoparticles. Figure 3 indicates the relation.

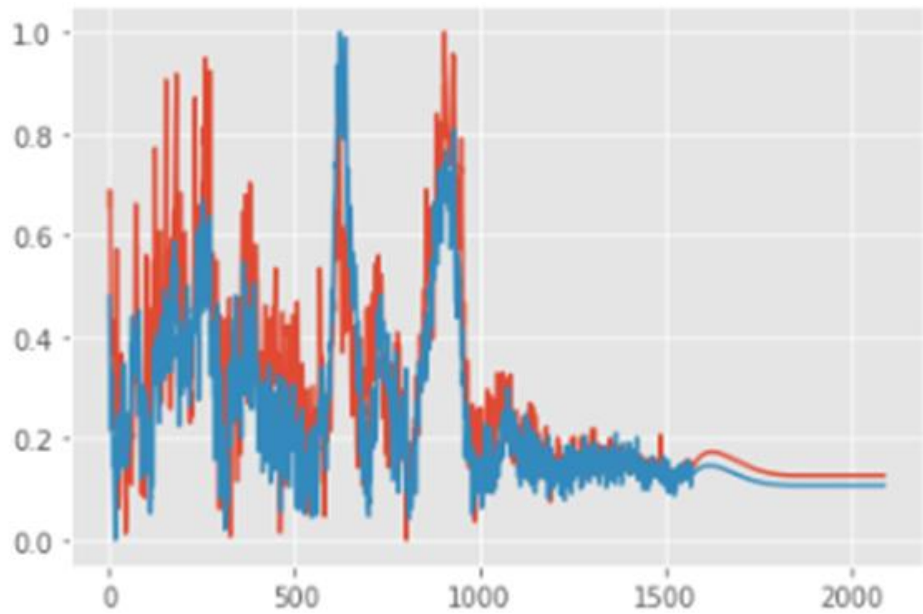

Figure 3: Relation between position and intensity

Table 2 indicates the synthesis of a natural nanocomposite. Additionally, Figure 4 illustrates the relationship between the optimal particle size and the number of particles.

Table 2: Nanocomposite saturation levels

	Regulation	Tincture of Immaculate condition	Natural Nanocomposite
E. coli MIC	5 ± 0.268	12 ± 0.380	32 ± 0.597
S. aureus MIC	7 ± 3.541	13 ± 0.239	33 ± 0.347

Researchers have created magnesium oxide nanoparticles (NPs) using the value-effective Solution Combustion Synthesis (SCS) process, a significant improvement in the field of nanomaterials, with the aid of citrus extract and lemon juice as innovative fillers. This creative method demonstrates the adaptability of SCS strategies in producing low-cost, potent antimicrobial compounds and highlights the promise of easily employing natural compounds in nanoparticle synthesis.

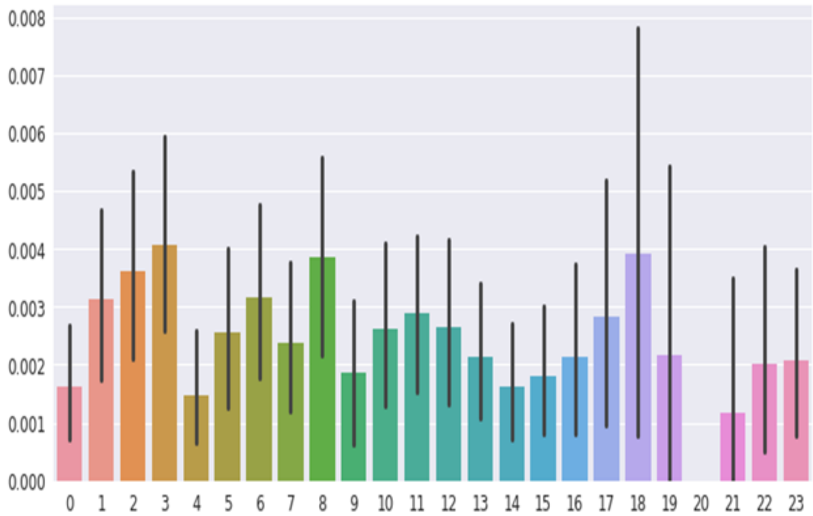

Figure 4: Particle size and number of particles

Using advanced techniques, including Powder X-ray Diffraction (PXRD), Brunauer-Emmett-Teller (BET) surface area evaluation, and Scanning Electron Microscopy (SEM) with Energy Dispersive Spectroscopy (EDS), the magnesium oxide nanoparticles are thoroughly analysed.

5. Conclusion

The surface qualities, crystal structure, and porosity of nanoparticles are all crucial factors that influence their effectiveness in various applications. Research on magnesium oxide nanoparticles (MgO NPs) has provided valuable insights into their properties, demonstrating how changes at the nanoscale can directly impact performance. Antibacterial investigations using MgO NPs yielded good outcomes against harmful bacteria, including Staphylococcus aureus and Escherichia coli, with substantial inhibition of microbial activity. These results indicate that the distinctive physicochemical characteristics of MgO NPs augment their interaction with microbial membranes, resulting in effective suppression of bacterial proliferation. In addition to their ability to kill bacteria, MgO NPs have also been demonstrated to exhibit strong anticancer effects. Especially interesting results were from using vinegar instead of citrus extract as the fuel source during synthesis.

This resulted in nanoparticles with enhanced antileukemic activity. These nanoparticles exhibited cytotoxicity towards MDA-MB-231 breast cancer cells and HeLa cervical cancer cell lines, indicating their potential for targeted cancer therapy. The fact that MgO NPs can both kill cancer cells and inhibit microbial growth makes them useful in both biological and therapeutic settings. Additionally, using citrus-based fillers in the making of nanoparticles adds to the environmentally favourable and long-lasting aspects of green nanotechnology. These natural extracts not only possess antibacterial capabilities but also help us use fewer hazardous chemicals, aligning with the principles of green chemistry. Therefore, MgO NPs derived from fuels based on citrus and vinegar represent a novel and eco-friendly approach to producing multifunctional nanomaterials that can be applied in various biomedical fields.

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