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Nano-sized Metal Oxides and Their use as a Surface Disinfectant Against COVID-19: (Review and Perspective)

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ABSTRACT

Contamination of surfaces has long been identified as a significant factor in viral transmission. Therefore, sustained efforts are required to address this issue. This work aims to build a scientific database on nano-sized metal oxides as intelligent materials for surface disinfection against corona viruses, synthesize and characterize nano-sized MgO, and discuss the possibility of using it in virus eradication. The MgO nanoparticle was prepared through the heating method. Meanwhile, XRD diffractometer, Scan electron microscope, and nitrogen adsorption were used to characterize the MgO nanoparticle. The synthesized MgO nanoparticle showed an average crystallite size of 18.55nm, lattice strain 0.0053, surface area 27.56 m^2/g and d-spacing 2.1092. The outcomes of this review highlight the advantage and challenges of AgO, CuO, ZnO, TiO_2 and MgO nanoparticles and their utilization for surface disinfection against coronaviruses.

Keywords: Nanoparticles, Metal oxides MgO, AgO, CuO, ZnO, TiO_2, SARS-CoV-2, Surface disinfectants.

INTRODUCTION

A novel coronavirus (SARS-CoV-2) was reported in Wuhan, the People's Republic of China, in December 2019.[1] Coronaviruses are a vast group of viral pathogens responsible for many diseases, including respiratory illness.[2] This disease can produce a variety of signs involving temperature, respiratory problems, sneezing and aggressive lung diseases.[3] When viruses enter the lungs, they cause harm, which results in fluid seeping from tiny blood vessels in the lung tissue. The fluid gathers in the lungs' alveolar or air sacs. Because of this, the lungs have a tough time transferring oxygen from the air to the blood. It has the potential to extend to the lower respiratory tract, resulting in viral meningitis. Patients with severe breathlessness and breathing stress syndrome suffer from the condition.[4] COVID-19 could be spread from person to person via the air, and in extreme cases, the incubation time might be up to

14 days or more.[5] There are no clinical indications or symptoms to help identify those at risk, and the virus can be spread even during the incubation or recessive infection phase.[6] Infection rates and fatalities have already overtaken SARS cases significantly in the same timeframe. Coronavirus is a sphere-shaped, encapsulated particle with a diameter of around 120nm produced by the virus. Several features of the viral life cycle are influenced by envelope proteins, including virus assembly, envelope development and pathogenesis.[7] The coronavirus structure and essential components were depicted in Fig. 1, which comprised the spike protein, nucleocapsid protein, hemagglutinin esterase glycoprotein, viral genome RNA and envelope and the membrane protein.[8-10] According to current studies, the virus is more likely to spread amongst people near by.[11,12] Tiny liquid particles can spread the virus when an infected person coughs, sneezes, talks, sings, or breathes.[13,14] Viruses can also spread within busy or poorly ventilated spaces, where people are more prone to linger for long periods.[15-25] A person may get COVID-19 if they come into contact with a surface or object that has been infected with the virus because aerosol particles have the potential to float in the air or travel beyond a conversational distance.[26-30] In the past few decades, nanotechnology and nanostructured materials significantly assisted the progress of scientific and technological fields. The study of nanomaterials, including graphene, nanotubes, metal and polymer nanoparticles, has received much attention. Due to their smaller size (less than 100nm), these nanostructured materials display exceptional physical and chemical characteristics like higher molar extinction coefficients, superior reactivity, higher sorption and surface area, tunable plasmonic properties, photo and magnetic properties, and quantum effects. As a result, numerous nanomaterials have been examined extensively in various sectors. Significant focus has been placed in particular on the biomedical small molecule treatments have substantial drawbacks in human health applications, including poor photostability, non-biocompatibility, adverse effects on other organs, rapid renal clearance, a shorter blood fluid retention period, poor targeting, and insufficient cellular uptake. Nanomaterials were later created and studied. However, although they are superior to tiny molecules in some ways, their unregulated medicinal applications limit their use. In recent times, stimuli-responsive materials have been developed to address the current issues. Substantial attention results from their controlled responses to particular stimuli and these materials are frequently referred to as intelligent mates.[31-33] Nanotechnology is one of the most important technologies developed recently for preventing virus infection in the air and contact with infected surfaces.[34-35] They might be very effective in sterilizing protective equipment and the hospital environment.[36-38] Nanoparticles and nanocomposites are also physical and chemical characteristics that have been extensively investigated in the development of biomedical purposes.[39-40] The purpose of the present review is to establish a scientific baseline data of metallic nanocoating as intelligent materials for surface disinfection against bacteria and coronaviruses and introduce MgO nanoparticles as promising and prospects material for viral surface disinfectant.

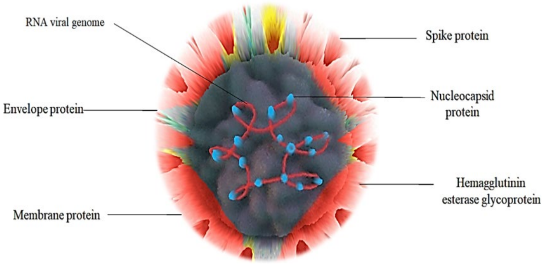

Fig. 1. Diagram showing the structure of coronavirus.[41]

MATERIALS AND METHODS

Synthesis of nanoparticles MgO

An adequate amount of magnesium carbonate ($MgCO_3$) was loaded into a hollow cylindrical furnace and heated to 700°C for one hour. The obtained white powder was characterized by employing various techniques to prove the MnO at the nanoscale level.

Nanoparticles characterization

The Rigaku Mini Flex 600 X-ray diffractometer was utilized to acquire the XRD data. N_2 adsorption-desorption technique was employed to measure the surface area and pore size. The textural characteristics of the produced materials were examined using scanning electron microscopy (Phenom) Energy Dispersive X-ray (EDX) microanalysis combined with scanning electron was utilized to determine the elemental compositions of the samples.

RESULT AND DISCUSSION

COVID-19 and surfaces contamination

The National Institutes of Health (NIH) has proposed that healthy people might become infected with COVID-19 by contacting virus-infested surfaces.[42] The virus may survive on surfaces for many hours to several days.[43-46] However, studies demonstrate that the virus is less likely to spread three days after a person with COVID-19 contacts a common surface. Breath droplets or droplets can linger in the air for minutes or hours.[47-50] Droplets condense enough in tight, poorly ventilated locations to transmit the virus to individuals nearby long after the patient has left the room.[51-52] The potential of Coronavirus spread can be reduced by cleaning and disinfecting frequently touched surfaces, such as tables, doorknobs, furniture, light switches, desks, toilets, taps and sinks.[53-54] There are already some protective tools available today. In this sense, nanotechnology opens up new avenues for developing COVID-19 preventive strategies that provide high disinfection with minimal dosages, no adverse effects, are environmentally acceptable, and have a long life.[55-57]

Nanotechnology and surfaces control against COVID-19

The interest in nanotechnology has increased because of its exceptional properties to enter many fields and applications.[58-60] Nanomaterials are particles with sizes varying between 1 and 100 nanometers, allowing them to have many properties.[61] It has been used in the chemical, mechanical and technological industries, and it has entered the medical field and the pharmaceutical industry.[61-62] The field of nanotechnology is one of the most popular areas of research and development in all disciplines.[63-65] This is due to its high strength, lightweight, excellent chemical reactivity, minimal size, high surface area, and increased stability.[66] Recently, nanotechnology has emerged as one of the most advanced techniques for preventing surface contamination with microbes such as bacteria, viruses, and other pathogens.[67-68]

Metallic nanoparticles

Titanium dioxide nanoparticles TiO_2

TiO_2 is semiconducting substances having distinct physicochemical characteristics, which might affect their bioactivity.[69-70] These features can be used in a variety of applications.[71] Titanium oxide nanocrystals (TiO_2) are frequently employed in contemporary medicine because they exhibit significant antimicrobial and antiviral capabilities and the capacity to be used as drug delivery carriers[72-73]. These NPs are valuable in livestock farming as an antibacterial agent for treating bacteria resistant to medications and as development boosters; however, their usage and usage are being limited in several countries.[74-75] Metal nanoparticles are also used to improve nutritional supply, enhance meat productivity, improve milk and egg quality, and improve sperm function.[76] Despite, TiO_2 nanoparticles being believed to be non-toxic in minimal quantities, cytotoxicity has been shown at large dosages.[77] Because of their vast surface area, TiO_2-NPs have a significant propensity to capture various toxic compounds. Exposure to TiO_2-NPs inhibits development in certain animals and induces oxidative stress, damage, and disability.[78] TiO_2-NPs exhibit a substantial antiviral effect against coronavirus and can generate numerous free radicals, which could cause oxidative stress to coronavirus, which is a good potential in the fight against coronavirus.[79-85]

ZnO nanoparticle

Zinc oxide is one of the most widely used semiconducting materials in various fields such as flat displays, electroacoustic devices, and photocatalysts.[86] Zinc oxide is a remarkable material with multiple properties suitable for high technology, such as light-emitting diodes, photodetectors, chemical and biological sensors and energy collectors; including solar cells.[87] The use of nano-zinc oxide was not limited to these areas only.[88] Still, it was an essential element in the medical field, especially in the last few years, where it witnessed a remarkable development in nanotechnology in medicine.[89] Among the many semiconductors, metal oxides, especially zinc oxide, are biologically safe, cost-effective, and non-toxic medicine.[90] Zinc oxide is beneficial against pathogenic bacteria, and viral has received increasing attention in recent years due to its stability under harsh environmental conditions.[91-92] ZnO-NPs display substantial inhibitory activity on some types of bacteria, and SARS-CoV-2 is one of the most challenging viruses to tackle in terms of human health.[93-96]

Copper oxide nanoparticle CuO

CuO is a remarkable nanoscale material with various applications, including catalytic reactions, heating processes, superconductors, photovoltaic cells, chemical technology, gaseous sensors, and batteries. CuO nanoparticles are primarily used as antibacterial agents in medical applications.[97-98] CuO employed in healthcare centers because of their antimicrobial properties, which allow them to eradicate over 99.9 percent of bacteria after 2 h of exposure if a sufficient dose is administered.[99] Copper ions are antiviral substances and can be used to treat viruses such as herpesvirus, pneumonia, and hepatitis A. 100. Further, compared to AgNPs and AuNPs, CuO NPs display numerous benefits, such as being less costly and stable. According to an investigation carried out by The National Institutes of Health (NIH) in the United States, the viral lifetime on Cu surfaces was less than on cardboard, stainless steel, and plastics surfaces.[101] CuO nanoparticles inter-reaction with the virus including coronavirus appears to be time and dosage based, leading to irreparable virus destruction and cell wall breakdown.[102-104]

Silver oxide nanoparticles AgO

AgNPs have specific optical, electrical, and thermal characteristics and are employed in various products, including environmental, photovoltaics, sensors and industry.[105-106] Furthermore, silver nanoparticles are increasingly used in antimicrobial coatings, different textiles, wound dressings, and biomedical equipment.[107] Silver nanoparticles absorb and scatter light with incredible efficiency and their color changes with particle size and shape, unlike many dyes and pigments.[108] The antimicrobial, antiviral, and immunological properties of AgNPs are well-established.[109] AgNPs are a possible antiviral medication that is efficacious versus COVID-19 and other viral such as respiratory syncytial, HBV, and HIV[110-111] AgNPs can produce free radicals and reactive oxygen species (ROS), which cause apoptosis-mediated cellular damage and hence prevent virus replication.[112] AgNPs bind to the viral genome, controlling the function and interaction of numerous viral and cellular replication components, leading to viral replication suppression and the release of progeny virions.[113] Furthermore, numerous physicochemical features, including size, morphology, surface characteristics, disparity, can be used to improve AgNPs-virus interactions.[114] The use of silver nanoparticles is limited due to the high cost.[115]

MgO nanoparticle

Magnesium oxide (MgO) nanoparticles attract many researchers owing to their special features, including odorless, non-toxic, and positive antimicrobial attributes.[116] Hence, MgO NPs was synthesized and characterize to present it as a material with suitable properties that might act as a surface disinfectant against bacteria and viruses.[117-120]

XRD diffraction patterns analysis of MgO

In accordance with the spectra, the samples have an excellent crystalline structure, with the highest peak position around 42.5 (2 theta) as shown in Fig. (2). The diffraction peaks might be associated to face-centered cubic structure of MgO (JCPDS card No: 78-0430). The XRD pattern revealed no impurities existence in the sample. The presence of nanostructures in the specimens was suggested by greatly expanded lines in the XRD pattern. The X-ray diffraction parameters of MnO nanoparticles including average crystallite size, lattice strain and d spacing were computed employing Debye-Scherer's equation. The average crystallite size was (18.55nm), lattice strain (0.0053) and d spacing (2.1092).[121]

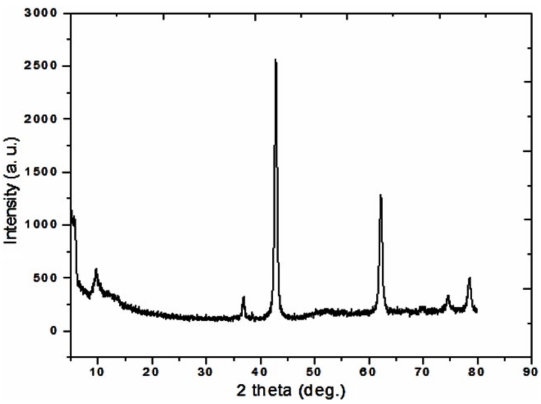

Fig. 2. XRD diffraction patterns Of MgO nanoparticles annealed at 700 for 1 hour

Morphological features of MgO

Figure 3 illustrates the morphological characteristics of MgO nanoparticles at various micrographs. The SEM analysis showed that the MgO nanoparticles seem to have an irregular shape; however, some of them look like coffee beans. The SEM images show that the obtained materials were in nanoscale form. The energy dispersive X-ray analysis shows the chemical composition of the MgO nanoparticle.

Nitrogen Adsorption Study of MgO

An investigation of nitrogen isotherms

and the pore size distribution of MgO nanoparticles are described in the Figure (4 and 5). The absorption isotherm of MgO nanoparticles showed nanostructures feature according to the IUPAC categorization of mesoporous oxide.[122] The value of surface area, pore volume, and pore size of MgO nanoparticle are summarized in Table 1.

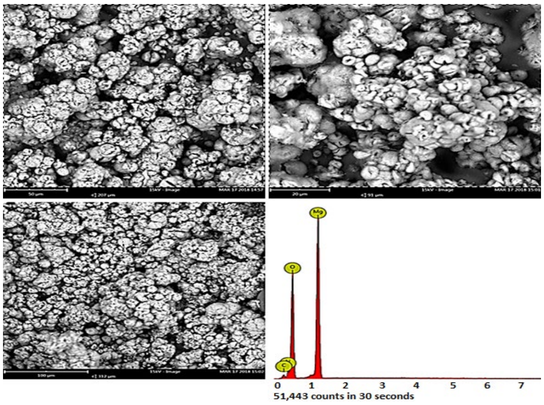

Fig. 3. SEM image of MgO NPs at various micrographs

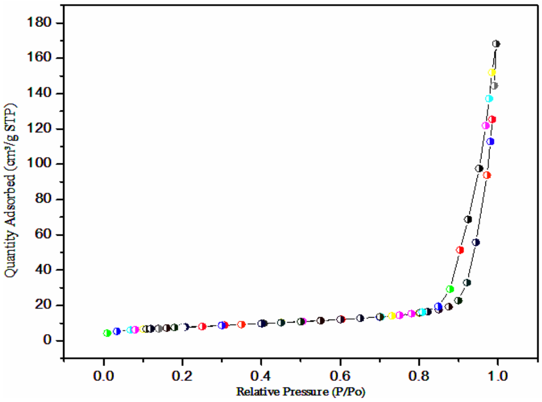

Fig. 4. Nitrogen adsorption-desorption isotherms of MgO NPs

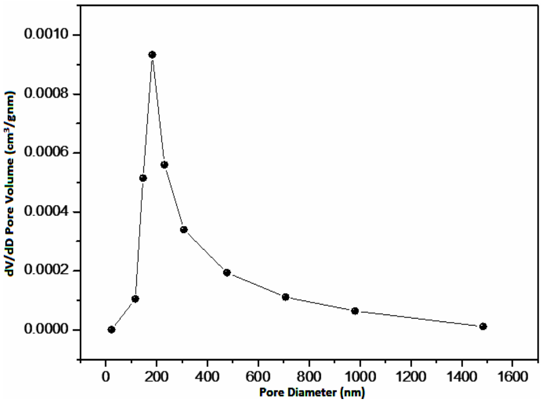

Fig. 5. Pore size distribution of MgO NPs

Table 1: Summary of surface area, pore volume, and pore size values of MgO NPs

Surface Area	
Single point surface area at P/Po=0.200365063	26.6493 m²/g
BET Surface Area	27.5683 m²/g
Langmuir Surface Area	38.6759 m²/g
t-Plot Micropore Area:	1.6599 m²/g
t-Plot External Surface Area:	25.9084 m²/g
between 17.000 Å and 3000.000 Å diameter	28.261 m²/g
between 17.000 Å and 3000.000 Å diameter	33.2095 m²/g
Pore Volume	
less than 1301.586 Å diameter at P/Po = 0.984901476	0.193801 cm³/g
less than 862.205 Å diameter at P/Po = 0.977020323	0.212019 cm³/g
between 17.000 Å and 3000.000 Å diameter	0.260676 cm³/g
between 17.000 Å and 3000.000 Å diameter	0.260250 cm³/g
Pore Size	
Adsorption average pore width (4V/A by BET)	281.1938 Å
Desorption average pore width (4V/A by BET)	307.6281 Å
BJH Adsorption average pore diameter (4V/A)	368.960 Å
BJH Desorption average pore diameter (4V/A)	313.465 Å

Virus elimination by metallic oxides nanoparticles

Metal nanoparticles have several uses, including disinfectants, due to their antiviral and antibacterial capabilities.[123] Metallic particles such as as AgO, CuO, ZnO, TiO_2 and MgO, in contrast to alcohol-based sanitizers, which is ecologically beneficial, fireproof, and nonvolatile, are considered as clean technology[124]. In addition, metal nanoparticles primarily operate on the virus's surface, preventing physical connection with viruses and host cells.[125-128] This is extremely useful because the virus infects the host cell by introducing the virus's nucleic acid into the host cell following physical touch.[129] Therefore, sanitizer's metal-oxide nanoparticles offer enhanced safety and health features that might be effective towards COVID-19.[130] The primary idea behind our study is to coat any material including, leather surface with AgO, CuO, ZnO, TiO_2 and MgO nanoparticles in order to eliminate Coronavirus.[131] To adhere the AgO, CuO, ZnO, TiO_2 and MgO nanoparticles to the leather surface, a binder material was utilized. Metallic oxide NPs were then dispersed in an ethanol solution and distributed across the leather surface to produce a coating as shown Fig. (6). Various studies have been investigated the lifetime of SARS-CoV-2 on porous and non-porous surfaces.[132] The results have shown that viable viruses cannot be found on porous surfaces for minutes to hours; however, viruses may be detected on non-porous surfaces for days to weeks, according to the findings.[133-134] Because of capillary action inside pores and quicker aerosol droplet evaporation, it is possible that SARS-CoV-2 inactivation occurs more quickly on porous surfaces than on non-porous surfaces when compared with non-porous surfaces.[135-137] Various studies have obtained varied results when examining negative-stained SARS-CoV-2 viral samples under electron microscopy; it has been determined that the virus's diameter ranges between 50 nanometers to 140 nanometers.[138-139] Therefore, coating nanomaterials such as AgO, CuO, ZnO, TiO_2, and MgO with a particle size of fewer than 50 nanometers can stop the virus from penetrating surfaces. The average crystal size of MgO NPs nanoparticles in our investigation was 18.55 nm, indicating that MgO NPs have the potential to inhibit coronavirus.[140] Some microscopic imaging investigations of bacterial cells and virus proteomics data revealed that MgO nanoparticles caused membrane damage.[141] Fig. (7) presents the proposed mechanism of AgO, CuO, ZnO, TiO_2 and MgO nanoparticles in the virus elimination by means of three processes.[142] The metallic oxide nanoparticles break the viral membrane and envelope, interfering with the virus's critical proteins, which lead to the destruction of the RNA of the virus.[142-143] Moreover, as proved by the SARS-CoV, metallic oxide nanoparticles induce reactive oxygen species that ultimately eradicate the virus.[144-145]

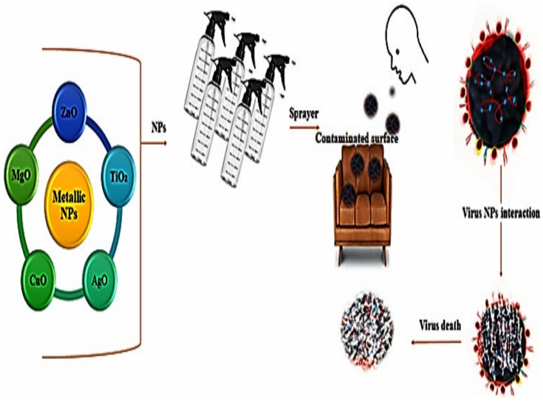

Fig. 6. Proposed Scenario for surface disinfection against SARS-CoV-2 by AgO, CuO, ZnO, TiO_2 and MgO nanoparticles

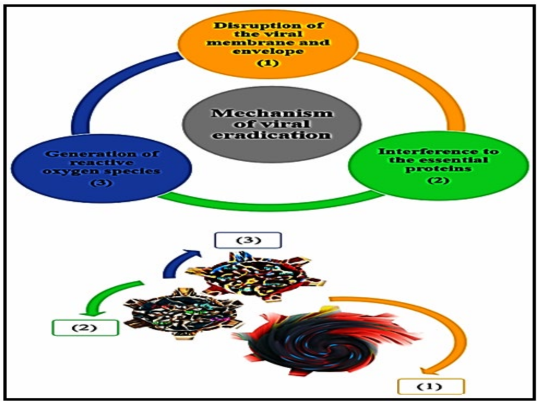

Fig. 7. Proposed mechanism of AgO, CuO, ZnO, TiO_2 and MgO nanoparticles in virus elimination

CONCLUSION

To sum up, metallic oxides nanoparticles including AgO, CuO, ZnO, TiO_2 and MgO and their uses as a surface disinfectant against Coronavirus were considered in this work. MgO nanoparticle samples were prepared through the heating method. The synthesized MgO nanoparticle showed that the average crystallite size was (18.55nm), lattice strain (0.0053), surface area (27.56m^2/g) and d-spacing (2.1092). Magnesium oxide nanoparticle has properties that enable it to act, as a surface coating material against coronaviruses due to its unique properties beside it is eco-sustainable, cheap. Obviously, AgO, CuO, ZnO, TiO_2 and MgO nanoparticles will play a crucial part in the fight against COVID-19 by producing nanocoating materials that will inhibit the virus's infection and might be utilized to clean public spaces and medical devices.

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