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Silver Nanoparticles as Antiviral-A Mini Review

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ABSTRACT

Objective: *There are many different species that nanoparticles can suppress, such as bacteria, algae, fungus, archaea, and a vast class of viruses.* ***Method:*** *The method of action involves preventing the creation of the cell membrane or its function, interfering with energy transmission, generating harmful reactive oxygen species (ROS), and preventing or lowering the synthesis of RNA and DNA.* ***Results:*** *Numerous nanomaterials, including those based on silicon, carbon, and metals, as well as nanoarchitectures, have been effectively employed to combat various viruses. The solid-state activity of these nanoarchitecture-based virucidal materials (also known as nano-antivirals) has been firmly supported by recent research. The development of many items, including high-touch surfaces and fabric, benefits greatly from their use.* ***Novelty:*** *The development of scalable and sustainable nano-antiviral products with contact-killing capabilities is recommended in this study, which carefully and critically evaluates current developments in the use of nanomaterials to block the effectiveness of Rotavirus, one of the enteroviruses that kill children.*

INTRODUCTION

With over 125,000 fatalities each year globally, rotavirus is the primary cause of infectious diarrhoea in children under the age of five [1]. All around the planet, rotavirus is present. Rotavirus-caused severe diarrhoea among children under five years old was comparable in wealthy and underdeveloped nations in the prevaccine era (about 35–40%), indicating that better sanitation is not enough to stop infection. Certain rotavirus genotypes may have different regional and temporal distributions [2].

The 11 double-stranded RNA (dsRNA) segments that make up the rotavirus genome, which belongs to the Reoviridae family, and the coding of the six structural proteins (VP1 VP7) and six nonstructural proteins (NSP1 NSP6) aid in the classification of various RV groups. An A. Rotaviruses have a high degree of genetic diversity [3]. Children frequently get gastroenteritis from group A rotavirus, whereas adults in China get severe diarrhoea from group B rotavirus. Acute gastroenteritis in children and adults has also been linked to rotavirus B (RVB) in Asian countries including Bangladesh, Myanmar, India, Nepal, and China. Human diarrhoea is occasionally caused by the Group C rotavirus in several regions of the world [4], [5].

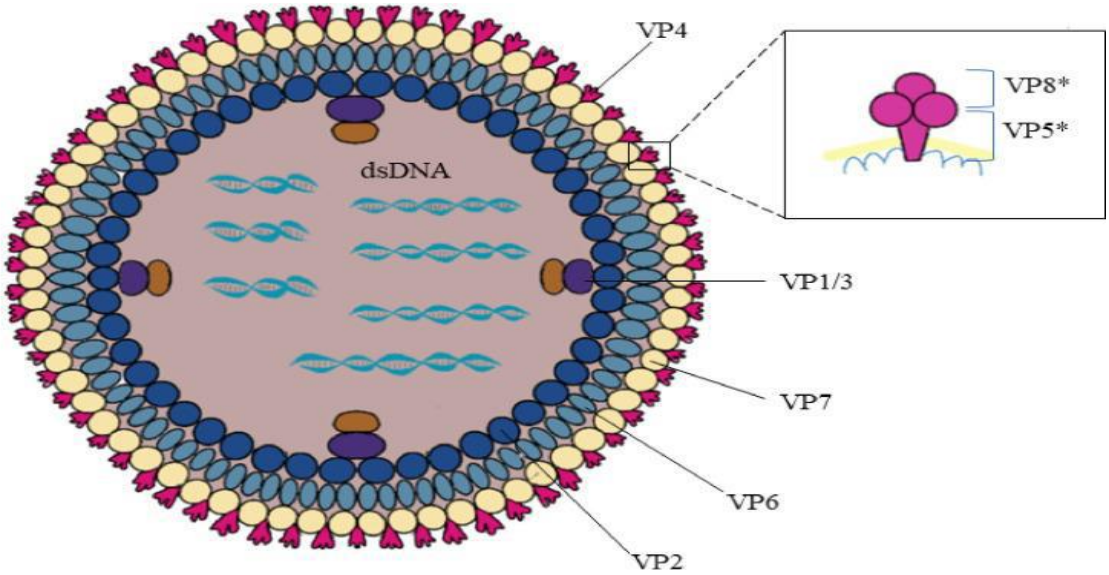

Figure 1. Rotavirus structure.

Around the rotavirus are eleven segmented double-stranded RNA pieces and three concentric coat layers. Its genome is 18,500 bp long and encodes six structural proteins (VP1 4, VP6 7) and five non-structural proteins (NSP1 5/6). The three layers of the capsid structure include the outer layer (capsid glycoprotein VP7 and hemagglutinin spike protein VP4), the middle layer (VP6), and the inner layer (VP2). Trypsin cleaves VP4 into VP5* and VP8*, increasing the rotavirus's ability to infect. Within the VP6 protein, the bottom of the VP5* protein is partially hidden [6].

RESEARCH METHOD

This mini review employed a narrative literature review approach to synthesize current evidence on silver nanoparticles (AgNPs) as antiviral agents. Relevant studies were retrieved from PubMed, Scopus, Web of Science, and Google Scholar (2000–2025) using keywords such as “silver nanoparticles,” “antiviral,” and “virus inhibition,” with additional snowball searches from reference lists. Inclusion criteria comprised peer-reviewed experimental and review articles reporting AgNP synthesis methods, physicochemical properties (size, shape, functionalization), antiviral activity (IC_{50}, inhibition rates, selectivity index), and mechanisms of action, while non-English, inaccessible full texts, and non-AgNP studies were excluded. Data were extracted on nanoparticle characteristics, biological protocols, antiviral outcomes, and cytotoxicity, then synthesized thematically according to virus type, nanoparticle features, and targeted replication stage. Given the heterogeneity of synthesis methods and assay conditions, findings were integrated narratively rather than meta-analyzed, with emphasis on consistent trends, mechanistic insights, and research gaps.

RESULTS AND DISCUSSION

Epidemiology of Rotavirus

When it comes to children under five, rotavirus is the main cause of severe gastroenteritis. In 1973, rotavirus was identified using faecal samples and duodenal

biopsies from people who had severe diarrhoea. Even with the availability of a vaccination, rotavirus still causes over 200,000 fatalities annually around the world. In wealthy nations with regular immunisation programmes, rotavirus infections are less common than in developing nations, where they remain a leading cause of potentially fatal diarrhoea in babies and children under five [7].

By the third year of life, most people are infected with group A rotaviruses, which are common. With between 30 and 50 percent of cases needing hospitalisation or treatmentThey are the world's most common cause of severe diarrhoea in infants and young children. Incidence rises in the winter in temperate settings, but the illness is year-round in tropical regions [8]. About 1,537,000 hospitalisations among children under five and 258 million diarrheal episodes that did not require hospitalisation were caused by rotavirus in 2016 [9]. An estimated 14% of the world's paediatric rotavirus gastroenteritis fatalities in 2013 were in Nigeria, causing a significant economic and health burden on the populace and the nation [10]. Different Rota virus infection rates were noted by researchers throughout Iraqi governorates. For example, [11] found that the greatest infection incidence was among children under five in Baqubah Diyala province, and the total rotavirus infection rate among 500 patients was 20.3%. In Baqubah City, Using the Cer Test One Step, 20% (30 out of 160) of children with gastroenteritis hospitalised to the Al Batool Teaching Hospital for Maternity and Children were found to have the illness [12]. [13] discovered that, using a fast test, [14] identified 32.6% of rotavirus group A in 150 children with diarrhoea who were hospitalised to the Maternity and Children Hospital in Ramadi city, Al Anbar governorate. Another study, which employed the latex agglutination test, found that among 384 infants with gastroenteritis admitted to the Maternity and Child Teaching Hospital in three governorates (Addiwaiya, Najaf, and Babylon), 42.45% of 214 infants from the attendants of outpatient departments of hospitals, some primary health care centres, and some private clinics tested positive for rotavirus by June 2010 to April 2012. [15] who discovered that 45.76 percent (112 out of 236) of faecal samples from hospitalised and outpatient children with acute gastroenteritis in the Babylon Governorate were employing ELISA and the latex agglutination test to identify rotavirus antigen, and [16] who reported 48% in Babylon City.

Pathogenesis of Rotavirus

Viral infection enters the body through the oral cavity. The small intestine's villous epithelium is where viral replication takes place. Serum rotavirus antigen (antigenemia) can be found in up to two-thirds of children with severe rotavirus gastroenteritis, and rotavirus RNA can also be found in these children. An infection may cause isotonic diarrhoea, lower intestinal lactase, alkaline phosphatase, and sucrase activity, and reduced intestinal absorption of water, salt, and glucose. We do not completely understand the immunological correlates of rotavirus protection. Mucosal and serum antibodies against VP7 and VP4 are most likely crucial for disease prevention. It is likely that cell-mediated immunity contributes to both infection prevention and recovery [17].

Replication

The cytoplasm of infected cells is where rotavirus replication occurs in viroplasms, The areas near the nucleus and ER are electron-dense. Viral particles that were newly formed and linked to the ER transmembrane viral glycoprotein NSP4 budded into the ER from viroplasms. Rotavirus replication does not include the Golgi apparatus, despite the fact that the process involves the production and transport of glycoproteins. Rather, intracellular calcium levels control the replication, morphogenesis, and pathogenicity of rotavirus [18]. Rotavirus replication has been extensively studied in vitro using the rhesus rotavirus strain (RRV) and the MA104 cell line. A high multiplicity of infection (MOI) of at least 10 infectious viral particles per cell is required for in vitro rotavirus replication in nonpolarized MA104 cells to reach peak replication, which occurs after 10 to 12 hours at 37 °C. Rotavirus replication varies by cell type, though, and in polarised human intestinal cells (Caco-2), it was slower. Between 20 and 24 hours after infection, the viral production peaked at the apical side. Beginning four hours after infection, the rotavirus toxin NSP4 is first produced as a cleavage product that includes the poisonous area released from infected cells. Later on in the infection, it is completely glycosylated as NSP427 [19]. The following are the general processes of rotavirus replication, as determined by cell culture experiments [20], [21].

Rotaviruses have a complicated entrance step:

1). The initial stage of infection involves the identification of host surface molecules such as histo-blood group antigens (HBGAs), sialic acid, and α2β1. Rotavirus enters cells using a direct penetration method and two distinct endocytosis mechanisms (dynamin-dependent or clathrin-dependent, depending on the strain).

2). The Rab5/7 metamorphosis causes triple-layered particles (TLPs) to enter the same endosome from the cytoplasm and change from early endosomes (EEs) to mature endosomes (MEs) and late endosomes (LEs). The virus begins to translate and replicate when its outer capsid breaks down, releasing double-layered particles (DLPs) into the cytoplasm.

3). The primary location for rotavirus genome packaging and replication is the viroplasm. In order for viral plasmids to develop, NSP2/NSP5 must first interact with lipid droplets (LDs).

4). The outer capsid construction is finished in the endoplasmic reticulum (ER) by the viral precursor DLPs.

5). The polarised cells, like the kidney cells of monkey embryos MA-104, undergo cell lysis, which releases mature virus particles. In contrast, non-polarized cells like the human intestinal cells Caco-2, which do not split host cells, release mature virus particles by budding [22].

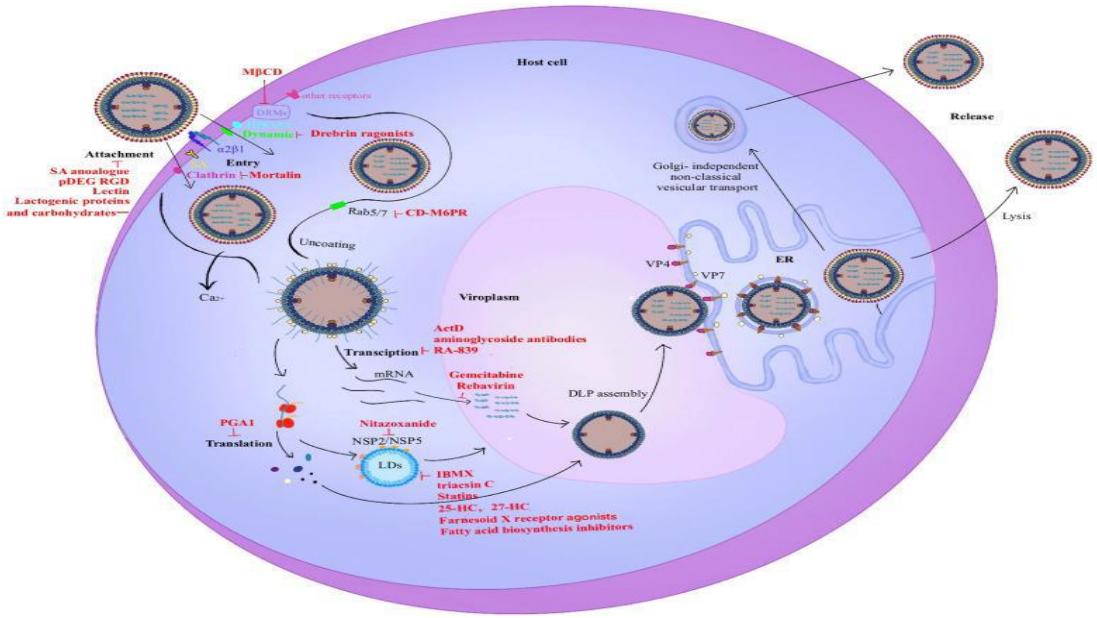

Figure 2. Rotavirus life cycle.

Nanotechnology

Nanotechnology is made up of two parts: "Nano" and "technology." The prefix "Nano" comes from the Greek word "Nanos," which means dwarf, and the suffix "technology" has the specific meaning "one billionth" (10-9) [23] when used in the names of units of measurement. In material science and technology, nanotechnology is a promising new field that makes it possible to manipulate particles at the nanoscale (NS) to create totally new goods. According to the Nanoscience Society, a nanoscale is between 1 and 100 nm [24]. In the domains of biology and materials research, nanoparticles are extremely desirable due to their unique properties [25].

This fundamental science is called nanoscience. Materials have different properties at the nanoscale than they do at the larger scale. The qualities of the material first stay the same as its dimensions are reduced from a big size, and subsequently minor modifications take place. Finally, notable property changes may take place when the particle gets closer to 100 nanometers in size [23]. The special physical and chemical properties of nanomaterials can be applied to both commercial and innovative public-benefitting applications. By the end of the 20th century, there were more chances to create innovative nanostructures and nanomaterials because of the discovery of new nanostructured materials, events, and activities as well as the creation of new theoretical and experimental research methods. Future potential in science and technology are being laid by this field [26].

Nanoparticles have long been produced using a variety of conventional techniques. Chemical procedures like thermolysis, photo reduction, microemulsion, and sol-gel are examples, as are physical vapour deposition, sputtering, melt mixing, laser ablation, and others. These methods, however, frequently result in the instability of nanoparticles, the attachment of harmful materials to their surface, and the production of dangerous byproducts [27]. Consequently, there is an increasing emphasis on creating novel

methods for producing nanoscale items, such biological synthesis. Green approaches use biological resources, such as microbes and plants, to produce metallic nanoparticles through biogenic synthesis. Usually, microorganisms use a process known as bio-reduction, in which metallic ions build up to lessen their toxicity. Additionally, producing consistent, high-quality nanoparticles is another essential step in producing top-notch goods [26]. Numerous techniques exist for characterising nanomaterials, such as FT-IR spectroscopy, which is widely employed in the study of pharmaceutical raw materials. Mid- and near-IR spectroscopy are also typical practices for evaluating active compounds and active medicinal ingredients. For analysing incoming raw materials, near infrared spectroscopy is without a doubt the most widely used spectroscopic method. Mid-IR spectroscopy usually provides the most information about the chemical makeup of a sample, making it very useful for detecting and analysing active substances in pharmaceutical samples [27].

Silver nanoparticles

A notable natural noble metal with a range of physical, chemical, and biological properties, such as electrical conductivity, high thermal behaviour, optical qualities, nonlinear catalytic activity, and biochemical traits, AgNPs are a significant advancement in nanotechnology [28]. To optimise AgNPs' potential uses across a range of industries and reduce their hazards to people and the environment, these characteristics are required. The larvicidal and anticancer potential of AgNPs makes them a good choice for a variety of applications, including textiles, electronics, optical receptors, antiseptic agents, pharmaceuticals, food packaging, food preservation, water disinfectants, surgical instruments, biolabeling, and drug delivery applications [29]. Antimicrobial dressings or bandages, breathing tubes, catheters, and a variety of care products have all employed AgNPs. AgNPs offer high promise for treating human lung cancer cells as anticancer agents. AgNPs are also good at optical features like Surface Plasmon Resonance (SPR), which makes nano-silver an ideal choice for biosensors, imaging, drug delivery, and diagnostics. AgNPs are employed extensively as a component in many consumer goods, such as pastes, soaps, and cosmetics [30]. AgNPs are also utilised in electronics products, such as transistors, photonic and antireflective materials, high conductive pathways, and optical fibres, due to their increased stability and extremely low electrical resistance. AgNPs are used in biomedicine as anti-inflammatory, antiviral, and anti-diabetic agents [31].

Antiviral Mechanisms of Action of AgNPs

Typically, antiviral drugs work by either directly targeting the virus or preventing important stages of viral replication, which prevents the development of new viruses [32]. For the purpose of developing novel antiviral techniques that effectively use nanoparticles, it is crucial to comprehend the antiviral mode of action of AgNPs. However, their antiviral processes remain unexplored and appear to rely on AgNP production, with a variety of parameters impacting the antiviral efficacy, including size, shape, and surface functionalization. AgNPs primarily interact with the free or cell-bound viral particles through physical interactions, as several studies have shown [33].

Thus, AgNPs can either perform virucidal activity, which involves inactivating the infectious viral particle or changing the virion's morphology, or they can prevent the first stages of viral replication, which include the virus's attachment to the host cell or its penetration mechanisms. While suppression of the latter stages of viral replication has also been suggested, these actions at the intracellular level are less well understood, despite the fact that these are the most well-represented antiviral mechanisms. Accordingly, AgNPs' broad-spectrum antiviral activity and capacity to stop cell infection have garnered significant interest across a wide range of industries, including the cleaning of water and air, the manufacturing of personal protective equipment, food packaging, the textile sector, and the biomedical sector—which is arguably one of the fastest-growing sectorsFrom a medical perspective, it is true that methods such as disrupting viral particles or blocking viral attachment and entrance mechanisms are extremely appealing. Preventing cell infection would first reduce human toxicity and the potential for viral resistance, which would be excellent for providing a quick and effective strategy against novel, developing viral strains [34].

When available, the mechanisms of action of the AgNPs under study are included in Table 1's fifth column. A further description of these processes will be provided in the upcoming subchapters. The primary modes of action of AgNPs in relation to the impacted viruses are listed in Table 2. It should be highlighted, however, that the varied studies used to elucidate the mechanisms of action of AgNPs might occasionally make it challenging to identify a suppressed phase of viral propagation. Despite the fact that several studies have clearly shown the antiviral activity of AgNPs and occasionally their physical engagement with a virus, they have merely proposed a potential mechanism of action and said that more research is necessary to fully understand their findings [35].

CONCLUSION

Fundamental Finding : The treatment and elimination of infectious illnesses are anticipated to benefit greatly from the application of cutting-edge nanomedicine. Nanoparticles may increase antiviral medications' effectiveness and lessen their negative side effects. These nanoparticle properties are important for antiviral therapy, when a large dosage of a medication is required, and these medications are sometimes quite costly. **Implication :** The use of nanoparticulate carriers can boost the efficacy of existing antiviral therapies and get around their drawbacks, including limited bioavailability. This suggests that nanomedicine can provide more accessible and efficient therapeutic strategies for combating infectious illnesses, particularly in situations where conventional approaches are insufficient. **Limitation :** At the same time, the reliance on high dosages and the costly nature of antiviral medications highlight the limitations that still exist in their widespread use. The fact that nanoparticle intervention becomes critical under these circumstances indicates that without such advancements, patients may continue to face issues related to affordability and effectiveness. **Future Research :** The continued exploration of how nanoparticulate carriers reduce the frequency of medication intake and treatment duration opens avenues for future research. Further

studies are necessary to validate these benefits across diverse viral infections and to ensure long-term safety, scalability, and cost-effectiveness in clinical settings.

REFERENCES

[1] M. Hassanpour, A. Tazarghi, A. Teimoori, A. Tabaraei, V. Erfani-Moghadam, A. Yamchi, S. Akhondi, and H. Razavi Nikoo, "Curcumin Inhibits the Replication of Rotavirus in Vitro," *Acta Virologica*, vol. 66, no. 2, 2022.

[2] Centers for Disease Control and Prevention, "Rotavirus," *CDC*, 2021.

[3] M. J. Tohmé and L. R. Delgui, "Advances in the Development of Antiviral Compounds for Rotavirus Infections," *mBio*, vol. 12, no. 3, p. e01028-21, 2021.

[4] S. Modrow, D. Falke, U. Truyen, and H. Schätzl, *Molecular Virology*, Springer, Berlin Heidelberg, Germany, 2013.

[5] M. M. Alam, S. B. Pun, P. Gauchan, M. Yokoo, Y. H. Doan, H. T. Tran, T. Nakagomi, O. Nakagomi, and B. D. Pandey, "The First Identification of Rotavirus B from Children and Adults with Acute Diarrhoea in Kathmandu, Nepal," *Trop. Med. Health*, vol. 41, no. 3, pp. 129–134, 2013.

[6] L. Jiang, A. Tang, L. Song, Y. Tong, and H. Fan, "Advances in the Development of Antivirals for Rotavirus Infection," *Front. Immunol.*, vol. 14, 1041149, 2023.

[7] S. E. Crawford, S. Ramani, J. E. Tate, U. D. Parashar, L. Svensson, M. Hagbom, M. A. Franco, H. B. Greenberg, M. O'Ryan, and G. Kang, "Rotavirus Infection," *Nat. Rev. Dis. Primers*, vol. 3, no. 1, pp. 1–16, 2017.

[8] A. Z. Kapikian and R. E. Shope, "Rotaviruses, Reoviruses, Coltiviruses, and Orbiviruses," in *Medical Microbiology*, 4th ed., 1996.

[9] C. Troeger, I. A. Khalil, P. C. Rao, S. Cao, B. F. Blacker, T. Ahmed, G. Armah, J. E. Bines, T. G. Brewer, and D. V. Colombara, "Rotavirus Vaccination and the Global Burden of Rotavirus Diarrhea among Children Younger than 5 Years," *JAMA Pediatr.*, vol. 172, no. 10, pp. 958–965, 2018.

[10] J. E. Tate, A. H. Burton, C. Boschi-Pinto, U. D. Parashar, WHO Global Rotavirus Surveillance Network, M. Agocs, F. Serhan, L. de Oliveira, J. M. Mwenda, and R. Mihigo, "Global, Regional, and National Estimates of Rotavirus Mortality in Children < 5 Years of Age," *Clin. Infect. Dis.*, vol. 62, suppl. 2, pp. S96–S105, 2016.

[11] M. S. H. Al-Zuheiry, A. A. Al-Duliami, A.-R. S. H. Hasan, and A.-K. Y. Al-Azawi, "The Prevalence of Rotavirus Infection in Baquba-Diyala Province," *Acad. Sci. J.*, vol. 6, no. 3, pp. 16–27, 2010.

[12] A. A. Hussein, R. A. Hussein, and M. J. Shaker, "Enteric Viruses Co-Infection with Giardiasis among Diarrheal Children in Diyala Province-Iraq," *J. Pure Appl. Microbiol.*, vol. 12, no. 2, pp. 793–799, 2018.

[13] M. Ayyed, M. F. Al-Dulaim, R. K. Al-Ani, and S. O. G. Al-Mawla, "Incidence of Rota Virus Gastroenteritis among Vaccinated and Non-Vaccinated Children Less than Two Years Old in Ramadi City, Iraq," *Al-Anbar Med. J.*, vol. 16, no. 1, pp. 8–11, 2020.

[14] S. A. Abd-Al Fattah, M. A. Hamad, and M. Q. Al-Ani, "Prevalence and Molecular Detection of Rotavirus in Children in Ramadi City-Iraq," *Medico Legal Update*, vol. 20, no. 4, pp. 2096–2102, 2020.

[15] Y. A. Al-Khafaji and H. J. Al-Jiboury, "Detection of Rotavirus in Diarrhea Stool Samples of Children with Acute Gastroenteritis in Babylon Governorate, Iraq," *Int. Res. J. Microbiol.*, vol. 4, no. 3, pp. 84–88, 2013.

[16] Q. M. Mutlak, M. K. Abdulridha, and L. M. A. Al-Huseini, "Updates in the Prevalence of Rotavirus Gastroenteritis in Babylon City," *Al Mustansiriyah J. Pharm. Sci.*, vol. 18, no. 2, pp. 1–12, 2018.

[17] Centers for Disease Control and Prevention, "Transmission of Rotavirus," *CDC*, 2021.

[18] A. Bugarcic and J. A. Taylor, "Rotavirus Nonstructural Glycoprotein NSP4 Is Secreted from the Apical Surfaces of Polarized Epithelial Cells," *J. Virol.*, vol. 80, no. 24, pp. 12343–12349, 2006.

[19] M. Zhang, C. Q.-Y. Zeng, A. P. Morris, and M. K. Estes, "A Functional NSP4 Enterotoxin Peptide Secreted from Rotavirus-Infected Cells," *J. Virol.*, vol. 74, no. 24, pp. 11663–11670, 2000.

[20] D. Knipe, P. Howley, D. Griffin, R. Lamb, M. Martin, B. Roizman, and S. Straus, *Fields Virology*, vol. 1–2, Lippincott Williams & Wilkins, Philadelphia, USA, 2013.

[21] S. D. Trask, S. M. McDonald, and J. T. Patton, "Structural Insights into the Coupling of Virion Assembly and Rotavirus Replication," *Nat. Rev. Microbiol.*, vol. 10, no. 3, pp. 165–177, 2012.

[22] L. Jiang, A. Tang, L. Song, Y. Tong, and H. Fan, "Advances in the Development of Antivirals for Rotavirus Infection," *Front. Immunol.*, vol. 14, 1041149, 2023.

[23] B. T. Nair, K. G. Bhat, and M. Shantaram, "In Vitro Biofilm Production and Virulence Factors of Uropathogenic Escherichia coli," *Int. J. Pharm. Bio Sci.*, vol. 4, no. 1, pp. 951–956, 2013.

[24] M. Mehta, "NCMS Study of Nanotechnology in the US Manufacturing Industry," *Natl. Center Manuf. Sci.*, Ann Arbor, MI, 2014.

[25] T. Deka, M. K. Das, S. Das, L. R. Singha, and P. Das, "Nanobiotechnology and Its Application in Nanomedicine: An Overview," in *Nanomedicine and Nanosafety: Recent Trends and Clinical Evidences*, pp. 3–25, 2020.

[26] I. Singh, H. K. Gautam, and G. Dhawan, "Nanobiotechnology: Current and Future Perspectives in Combating Microbial Pathogenesis," in *Pathogenicity and Drug Resistance of Human Pathogens: Mechanisms and Novel Approaches*, pp. 337–350, 2019.

[27] J. J. Schwartz, D. S. Jakob, and A. Centrone, "A Guide to Nanoscale IR Spectroscopy: Resonance Enhanced Transduction in Contact and Tapping Mode AFM-IR," *Chem. Soc. Rev.*, vol. 51, no. 13, pp. 5248–5267, 2022.

[28] B. Javed, M. Ikram, F. Farooq, T. Sultana, Z.-R. Mashwani, and N. I. Raja, "Biogenesis of Silver Nanoparticles to Treat Cancer, Diabetes, and Microbial Infections: A Mechanistic Overview," *Appl. Microbiol. Biotechnol.*, vol. 105, no. 6, pp. 2261–2275, 2021.

[29] M. A. Islam, M. V. Jacob, and E. Antunes, "A Critical Review on Silver Nanoparticles: From Synthesis and Applications to Its Mitigation through Low-Cost Adsorption by Biochar," *J. Environ. Manage.*, vol. 281, 111918, 2021.

[30] G. Zhou and W. Wang, "Synthesis of Silver Nanoparticles and Their Antiproliferation against Human Lung Cancer Cells in Vitro," *Orient. J. Chem.*, vol. 28, no. 2, p. 651, 2012.

[31] N. S. Al-Radadi and A. M. Abu-Dief, "Silver Nanoparticles (AgNPs) as a Metal Nano-Therapy: Possible Mechanisms of Antiviral Action against COVID-19," 2020.

[32] B. C. Gonçalves, M. G. L. Barbosa, A. P. S. Olak, T. N. Belebecha, L. Nishi, M. A. Watanabe, P. Marinello, D. Z. Rechenchoski, S. D. Rocha, and L. C. Faccin-Galhardi, "Antiviral Therapies: Advances and Perspectives," *Fundam. Clin. Pharmacol.*, vol. 35, pp. 305–320, 2021.

[33] H. H. Mao and S. Chao, "Advances in Vaccines," *Curr. Appl. Pharm. Biotechnol.*, vol. 171, pp. 155–188, 2019.

[34] T. A. J. de Souza, L. R. R. Souza, and L. P. Franchi, "Silver Nanoparticles: An Integrated View of Green Synthesis Methods, Transformation in the Environment, and Toxicity," *Ecotoxicol. Environ. Saf.*, vol. 171, pp. 691–700, 2019.

[35] A. A. Yaqoob, K. Umar, and M. N. M. Ibrahim, "Silver Nanoparticles: Various Methods of Synthesis, Size Affecting Factors and Their Potential Applications—A Review," *Appl. Nanosci.*, vol. 10, pp. 1369–1378, 2020.

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