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Can Nano-Materials Provide Solution to Pandemic? Opportunities and Challenge

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Abstract

A pandemic is considered to be any infectious disease that spreads to more than one continent. It is caused by pathogens, like bacteria and viruses, which may be transmitted from human to human. The size of such viruses varies from 50 to 200 nm in diameter, and they can replicate themselves inside the living cells of an organism [1]. A virus can be considered a nanoparticle outside the living cell. Hence, the characterization techniques that are used for characterizing nanoparticles, including polymeric nanospheres, may be applicable to viruses. Furthermore, the pandemic can be contained by preventing its spread, improving detection and diagnosis, curing diseases with targeted therapy, and developing antibodies through vaccination. Nanomaterials and nanotechnology play essential roles in all these processes. The aim of the present commentary is to evaluate the role of nanomaterials and nanotechnology in combating pandemics at present and in the near future.

Keywords: Pandemic; Corona-Virus; SARS-CoV-2; Covid-19; Antimicrobial Materials

Content

The size of viruses ranges from 50-200 nm in diameter, whereas the size of coronavirus ranges from 65-125 nm in diameter [2]. In the absence of a host cell, it can be treated as a nanoparticle, similar to a nano-polymer. Thus, the characterization techniques that are used for nano-polymers may be used to characterize this virus as a particle. But it may not be possible to isolate and characterize the virus in the absence of a host living cell. Also, the growth kinetics of viruses may depend on the characteristics of the living cells. This makes the isolation and detection of the virus a challenge. The virus may remain on surfaces as a particle in respiratory droplets from an infected person with virus-containing cells. It may also remain as an aerosol in the air. The isolation of the virus outside the host cell comes with various issues. The isolation of viruses is done using cell culture technology. It is reported that nano-emulsion technology is efficient for cell culture due to higher bioavailability [3]. Thus, employing nano-emulsion technology for the isolation of viruses from aerosol can be attempted. On the other hand, it is possible to detect the virus in aerosol using nanotechnology tools. Nano-biosensors are being developed based on optical and electrical properties for the detection of the virus. The various nano-materials that are used for detection of the virus are listed below:

Magnetic nanoparticles like iron oxide can be used for the detection of viruses. It is reported that silica-coated iron oxide nanoparticles have strong affinity for SARS-CoV-2 RNA4. Magnets can be used to separate the coated particle from the solution.

Au-NP can be used for target-specific detection of viruses [5]. This is due to their unique photonic, electric, and catalytic properties, coupled with the molecular interactions6 .

A nano-crystalline semiconductor, or quantum dot, is used for the detection of viruses, considering its optical and electrical properties. It is used as a biosensor and helps in fluorescence imaging [7]. Various quantum dots, such as CdSe, CdS, and ZnS, are used for rapid detection of the influenza A virus [8]. Zr quantum dot is also used. Quantum dot has excellent optical properties, such as high quantum yield, high fluorescence efficiency, broad excitation range, wide range of excitation wavelengths, narrow and symmetric emission spectra, and excellent stability against photobleaching properties, which make it a potential biosensor for the detection of viruses 8. Graphene oxide-Au NP nanocomposite can be used for foot-and-mouth disease virus detection [9].

Carbon-based nanomaterials provide a better signal and are used as promising biosensors for the detection of viruses [10].

Silica nanoparticles, Ag-NP and Al-NP, and polymeric nanomaterials have potential applications for virus detection.

Further, nanomaterials are used for tracking and diagnosis purposes also. Ag-NP, Au-NP, C-Au–NP, colloidal Au-NP, carbon-based nanoparticles, Quantum dot such as zirconium quantum dot as well as zirconium nano particles are used for diagnosis of viruses. Nano-biosensor is used for tracking of viruses. Fluorescent based quantum dot is used for single virus tracking [11]. Metal nanomaterial like Au-NP is also used for single virus tracking. Similarly, fluorescent inorganic non-metallic materials are also used for single virus tracking.

Nanotechnology has also influenced treatment against viruses. Reports suggest the use of nanomedicine as well as the application of nanomaterials to medicine by using them in vectors, biosensors, drugs, and gene delivery [12]. Nanomaterials are considered effective antiviral agents due to their small size, large surface area, targetability, and stimulus-responsive characteristics. Iron-oxide, zinc-oxide, Ag, carbon-based, and Au nanoparticles help to fight against viral infection. Nanomaterials have an antiviral therapeutic effect. It can be used for target cell therapy. Nanoparticles prevent the replication of viruses as well as block virus entry into host cells. It has been studied that both inorganic as well as polymeric nanoparticles can be used as nanocarriers for drug delivery in the respirable form [13].

A nano-based vaccine is considered a candidate material for the treatment of viruses. Au-NP and ferritin-based NP are used for the preparation of a viromimetic nanoparticle vaccine [14].

Nanomaterials and nanotechnology play important roles in the transmission of viruses through various mediums and surfaces. Ag-NP, Cu-NP, and TiO2-NP can be used for disinfectant purposes and may be applied to a potential surface to prevent the transmission of viruses from the surface to a human being. This is due to intrinsic anti-viral properties such as reactive oxygen species (ROS) generation and photo-dynamic and photo-thermal capabilities [15]. Cu-graphene nanocomposite coating also has potential disinfecting properties [16]. Pandemics can be controlled through Prevention, Detection, and Treatment (PDT) routes, where nanomaterials and nanotechnology have crucial roles to play. The research and development on nanomaterials and nanotechnology have been increasing over the years. The same is reflected in accelerated patent filing trends [17]. There are several scopes for the application of nanomaterials and technology in every step and sub step of PDT, which include virus characterization and vaccine development. Nanosized particles and or organisms can be prevented and treated through the application of nanomaterials, but the challenge lies with isolation, proper structural characterization, and the prevention of mutation. A nano framework for the prevention and control of COVID-19 using nanomaterials and nanotechnology have been shown below.

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