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Review article

Application of Pharmaceutical Coating to Avoid SARS-COVID-2

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ABSTRACT

To prevent the spread of COVID-19 infection, there is an urgent global demand for the protection of daily handling surfaces from viral contamination. To combat the present pandemic, nanotechnologists and material scientists offer sustainable options for developing antiviral surface coatings for various substrates such as fabrics, plastics, metal, wood, and food. They develop or propose antiviral surfaces by coating them with nanomaterials that interact with the SARS-CoV-2 spike protein to prevent the virus from infecting the host cell. It was discovered that polymer nanocomposites made from nanoparticles can be used to create useful coating materials. The numerous elements of antiviral nanocoatings are discussed in this article, including the method of interaction with the Corona Virus, the various types of nanocoatings developed for diverse substrates.

Keywords: *Antiviral coating; Nanomaterials; Covid-19; SARS-CoV-2*

Introduction

Pandemics pose a grave threat to human life. Since its outbreak in Wuhan, China in December 2019, the coronavirus disease 2019 (COVID-19) caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has become a global pandemic. SARS-CoV-2, despite its various mutations, continues to have a persistent presence. COVID-19 has claimed the lives of 3,742,653 people worldwide as of June 9, 2021, with 173,609,772 verified cases. The coronavirus SARS-CoV-2 is the sixth coronavirus to infect humans [1-3].

Nanomaterials may be able to provide technology for the development of universal antiviral coatings. A greater understanding of the virus's structure would aid in the development of antiviral nanomaterials. Coronavirus is a single-stranded RNA virus with an enclosed positive sense strand. The coronavirus has a diameter of 65–125 nm and is characterised by glycoprotein spikes on the outer surface. Coronaviruses have crown-like spikes that are responsible for the virus's attachment and penetration into host cells. This morphological trait underlines the prospect of coronavirus-nanomaterial interaction, which will be the target of nanotechnologists seeking to combat coronavirus. The nanoparticles may prevent SARS-CoV-2 entrance into the host cell, according to recent review papers [4-6]. Employing nanoparticles as antiviral coatings for PPEs such as masks and daily handling surfaces in residential and public areas to protect humans from COVID-19 has significance.

Nano approach for COVID-19

In the healthcare environment and in everyday life, antiviral surface coatings provide pathogen-free surfaces. Textile materials, personal protective equipment (PPE), portable electronics, medical gadgets, domestic home furnishings, automotive, food packaging, and many more applications require similar coatings today. Metal nanostructures and metal oxide nanostructures have become popular antiviral agents. Nanostructured silver (Ag), titanium dioxide (TiO_2), copper oxide (CuO), zinc oxide (ZnO), and other oxides have been shown to have antiviral properties. TiO_2 is suitable for fabricating antiviral films because of its intrinsic sterilising effect caused by photocatalytic destruction of microbiological debris [7-9]. The silver nanoparticles and nanowires, according to the authors, work against coronavirus by blocking TGEV-induced apoptotic signaling cascades. It has been found that the liberated copper ions form reactive oxygen species (ROS), which entirely destroy the virus in the case of copper nanoparticles [10].

In addition to nanomaterials' natural antiviral properties, hierarchical nano-surfaces have superhydrophobicity, which prevents virus adherence. When compared to bare surfaces, superhydrophobic materials show a considerable reduction in SARS-CoV-2 adhesion of up to 99.99995 percent [11]. Because the cytotoxicity of metal nanoparticles is a serious concern, researchers are focusing more on nanomaterials other than metals and metal oxides. Traditional natural medicines have been studied in this setting for their ability to combat a variety of viral illnesses, including SARS-CoV1 infections. Turmeric, an important part of India's traditional medical system, has antiviral properties. Curcumin is a polyphenol molecule found in turmeric roots that has antiviral properties [12,13]. Curcumin carbon dots (CDs) are an excellent approach to increase the bioavailability of curcumin [14,15]. Du et al. used a simple hydrothermal process to synthesise carbon dots from curcumin (CCM-CDs) and established their inhibitory impact against the pig epidemic diarrhoea virus (PEDV) as a coronavirus model. Curcumin was used to make less harmful cationic carbon dots with an ultra-small size (diameter ca. 1.5 nm), abundant hydrophilic groups, and a positive potential (+15.6 mV). The survival rate of Vero cells subjected to various concentrations of CCM-CDs is shown in Fig.1, with cell viability above 90% after 24 and 48 hours, demonstrating that CCM-CDs have low cytotoxicity. Curcumin-derived cationic carbon dots were discovered to block all stages of viral infection, including viral entrance, virus synthesis of negative-strand RNA, virus budding, and the buildup of reactive oxygen species (ROS) by PEDV. The positively charged CCM-CD has strong electrostatic interactions with PEDV, making it difficult for the virus to connect to cells. PEDV titer values when exposed to CCM-CDs and EDA-CDs suggested that CCM-CDs had superior antiviral efficacy than conventional CDs (ethylene diamine (EDA)-CDs) [16].

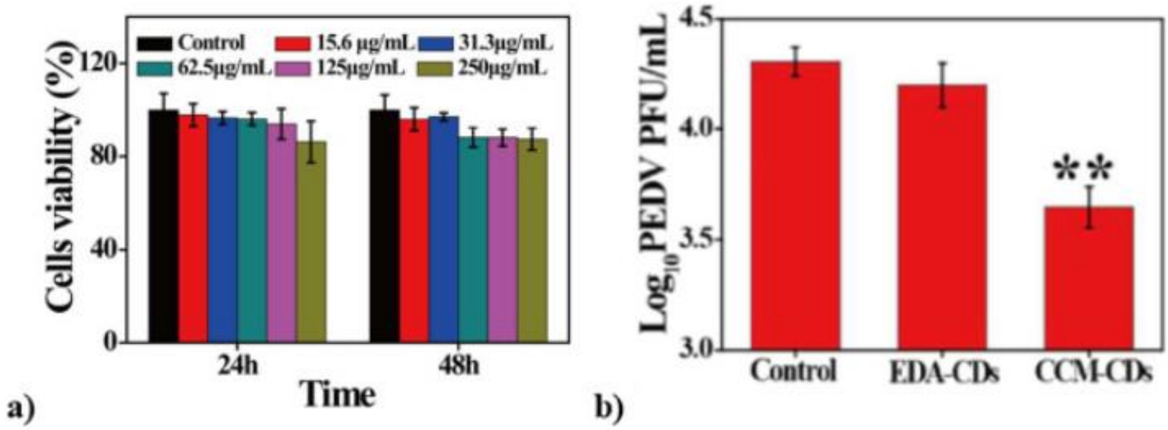

Figure 1: (a) CCK-8 assay was used to assess the effects of different concentrations of CCM-CDs on Vero cell viability; (b) the titer of PEDV when exposed or unexposed to 125 g/mL EDA-CDs or CCM-CDs.

Chitosan nanoparticles are another promising non-toxic nanoparticle that could have antiviral properties against the Corona virus. Chitosan is a polysaccharide that is cationic. The inhibitory activity of N-(2-hydroxypropyl)-3-trimethylammonium chitosan chloride (HTCC) against coronavirus entrance has been reported. HTCC's effect against SARS-CoV-2 and MERS-CoV has been reported in preliminary studies. Coronavirus entry into the host cell is inhibited by the electrostatic contact between the cationic polymer and the spike protein of the virus [17].

Nanocoating is future hope for COVID-19

The use of disinfectants on a daily basis is not a long-term option for preventing the spread of the corona virus. Disinfectants are both environmentally unfriendly and short-lived. In this case, developing self-sanitizing surfaces is a more sensible answer to the problem. In this case, nanotechnology might provide a permanent coating over everyday handling materials (fabrics, glass, metals, plastics, and so on), resulting in a virus-free environment. Since early 2020, scientists have been working to develop an antiviral coating solution that takes advantage of natural antiviral properties, as well as the size and shape effects of nanomaterials and nanostructures. The commercial medical masks are comprised of three layers of polypropylene (PP) non-woven fabric. The outer layer filters big particles, the middle layer is a fine particle filter media, and the third layer is a direct skin contact layer. Commercially available medical masks and respirators provide very little protection in some situations. Li et al. investigated the effectiveness of commercial medical masks and N95 respirators in 2006. They discovered that viruses smaller than 100 nm could get through both medical masks and respirators. Balazy et al. studied the filtering efficacy of N95 respirators and surgical masks against airborne viruses in the same year. They used bacteriophage MS2 virus (a non-harmful simulant of numerous infections) in the particle size range of 10 to 80 nm to examine the masks' collection effectiveness. According to the findings, N95-respirators may not always stop penetrating particles smaller than 300 nm. As a result, N95 respirators occasionally failed to provide 95 percent protection against airborne viral agents, and some surgical masks allowed a considerable fraction of airborne viruses to get through. The ineffectiveness of medical masks prompted international researchers to consider high-performance, reusable medical masks for the protection of both the general public and medical personnel. Even though a triple-layered medical mask is effective at blocking respiratory droplets, it may not be able to filter fine droplet nuclei in some cases [18,19]. (Fig. 2)

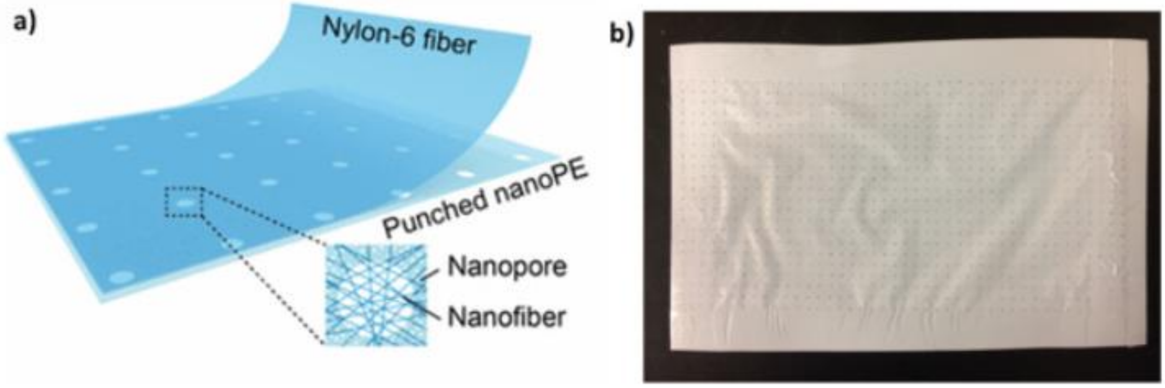

Figure 2: (a) A diagram of the suggested face masks with electrospun nylon-6 nanofibers on a needle-punched nano PE substrate, and (b) a photo of the face mask.

Because of the documented shortcomings of commercially available medical masks in filtering, killing infections, and the risk connected with their disposal, researchers have been working to develop effective medical masks that are both inexpensive and simple to use. To attain this purpose, two basic tactics were used. The first is to develop an alternative material for commercial face mask textiles, such as electrospun polymer nanofibers. For proper heat control, Yang et al. developed a user-friendly mask consisting of nanofiber on nanoporous polyethylene (fiber/nanoPE). This form of nanofiber mask would substantially remove breathing difficulties, especially for the elderly and those suffering from lung illnesses. The Ag coating on the fiber/nanoPE also has a warming effect [20-22]. The second strategy is to either modify the fabric's surface or coat the fabrics used in commercial face masks with a protective coating. Among these efforts, the use of antimicrobial protective coatings for fabric layers has emerged as a promising method of infection control. Some antimicrobial coatings have been applied to commercial medical masks and N95 respirators without compromising their basic performance. Antimicrobial properties are found in some metals and metal oxides. Copper oxide was incorporated into disposable N95 respiratory mask layers by Borkow et al. Copper oxide mask layers have antiviral efficacy against the human influenza A virus (H1N1) and the avian influenza virus, according to the researchers. The mask could lower the danger of virus contamination in the environment by incorporating antiviral action [23].

Copper nanoparticles (CuNPs) are also employed to generate photo sterile coatings for commercial masks, in addition to graphene nanosheets. Kumar et al. created a nonwoven surgical mask with a nanocomposite coating of natural bioadhesive polymer (shellac) and CuNPs. Shellacs act as a binder for CuNPs in the mask fabric in this coating. The mask was created utilising a scalable approach that involved spraying nanocomposite particles onto the surface of nonwoven fibres. CuNPs' combination photocatalytic and photothermal effects are responsible for the mask's self-sterility in this situation [24].

It is crucial in the current pandemic crisis to incorporate self-disinfection capacity into fabrics used in apparel, surgical dressings, beddings, wipes, and other items. Hamouda et al. created a silver nanoparticle-treated cellulose-based wipe. AgNPs' antiviral activity gave the wipe disinfecting properties, and it was successfully tested against MERS-CoV, with 48.3% viral suppression at 0.0625 L. They recommend using these wipes in hospitals and healthcare facilities in the future to combat human dangerous viruses, including coronavirus. They've also created a low-cost antibacterial and antiviral winter jumper with AgNP-treated cotton yarns [25-29].

Aside from masks and textiles, there are a number of other materials used in hospitals and other public places that must be virus-proof. Consumer electronics and smartphone display glass are among them. Hospitals, public offices, schools, and public transportation, for example, have touchable glass and metal surfaces. A universal transparent coating technique has been created for face shields, mobile phone screen guards, doorknobs, lift buttons, medical instruments, and other surfaces without compromising their appearance or function.

Fig.3 depicts nanomaterials-based surface coatings, their benefits, and their ability to protect against various viruses.

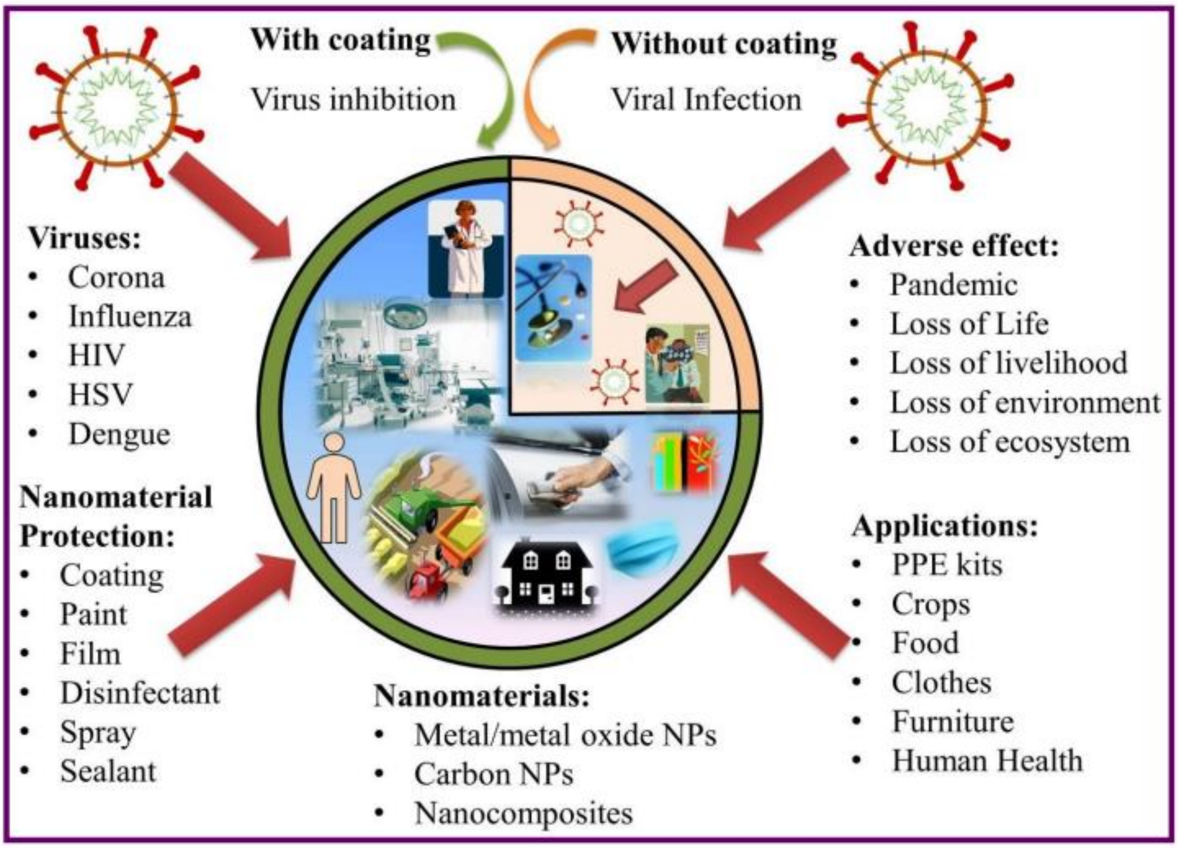

Figure 3: The usage of various nano-coatings on medical, domestic, and other items.

Nanostructure properties in antiviral coatings

The ability to use nanostructures for a certain application is mostly determined by the intrinsic qualities of nanoparticles that are suitable for the task. These properties can be tweaked or modified after synthesis, or they can be regulated during synthesis. Reaction conditions (temperature, pressure, time, rate of reaction, and so on), chemical conditions (precursor ratio, concentration, mixing rate, and so on), and physical conditions (use of precise equipment, contamination-free synthesis, purification, and so on) all play a role in determining the conditions under which desired products are synthesised. As a result, methodology is valued, as it is required to attain specific features such as size, form, electrical conductivity, mechanical, optical, surface, chemical, and biocompatibility, among others, depending on their practical application. The peculiar sheet-like structure of two-dimensional nanostructures has significance in biomedical applications.

Since the viral infection outbreak has grown uncontrollable and there is no effective treatment, the viral inhibitory potential of nanostructured materials is being explored extensively. The application of nano-systems is through their employment in various types of coatings for various applications such as virus prevention, contamination avoidance, and transmission inhibition. A lot of work has gone into developing nanostructures, composites, and hybrids that have proven to be better alternatives and ideal prospects for antiviral applications [30-37].

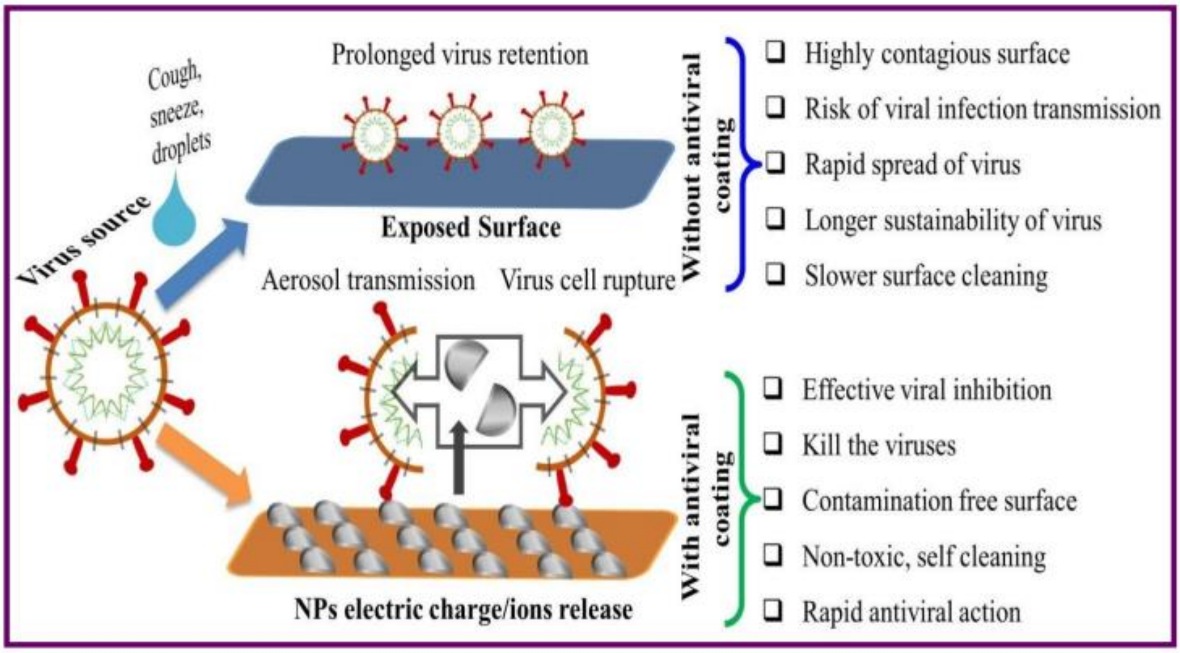

Figure 4: A mechanistic analysis of the effects of antiviral nano-coating on surfaces with and without antiviral nano-coating.

Conclusion

In summary, nanomaterials, in the form of nanocoatings on sensitive surfaces, could provide a long-term solution for limiting the spread of COVID-19. The potential of various nanomaterials, in producing antiviral coatings for various substrates is highlighted in this review. A combination of two or three of the above nanomaterials could have a synergistic antiviral effect against the lethal spike virus.

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Conflict of Interest

The author declares no conflict of interest.

References

1. Shahab MS, Imam SS, Jahangir MA. A review on the contemporary status of mutating coronavirus and comparative literature study of current COVID-19 vaccines. Journal of Pharmaceutical Research Science & Technology [ISSN: 2583-3332]. 2021 Jun 10;5(1):1-9.
2. Jahangir MA, Muheem A, Rizvi MF. Coronavirus (COVID-19): history, current knowledge and pipeline medications. Journal of Pharmaceutical Research Science & Technology [ISSN: 2583-3332]. 2020;4(1):1-9.
3. Andersen, K. G., Rambaut, A., Lipkin, W. I., Holmes, E. C., & Garry, R. F. (2020). The proximal origin of SARS-CoV-2. In Nature Medicine. https://doi.org/10.1038/s41591-020-0820-9
4. Basak, S., & Packirisamy, G. (2020). Nano-based antiviral coatings to combat viral infections. In Nano-Structures and Nano-Objects. https://doi.org/10.1016/j.nanoso.2020.100620
5. Medhi, R., Srinoi, P., Ngo, N., Tran, H. V., & Lee, T. R. (2020). Nanoparticle-Based Strategies to Combat COVID-19. In ACS Applied Nano Materials. https://doi.org/10.1021/acsanm.0c01978
6. V'kovski, P., Kratzel, A., Steiner, S., Stalder, H., & Thiel, V. (2021). Coronavirus biology and replication: implications for SARS-CoV-2. In Nature Reviews Microbiology. https://doi.org/10.1038/s41579-020-00468-6
7. Yugandhar, P., Vasavi, T., Jayavardhana Rao, Y., Uma Maheswari Devi, P., Narasimha, G., & Savithramma, N. (2018). Cost Effective, Green Synthesis of Copper Oxide Nanoparticles Using Fruit Extract of Syzygium alternifolium (Wt.)

Walp., Characterization and Evaluation of Antiviral Activity. Journal of Cluster Science. https://doi.org/10.1007/s10876-018-1395-1

8. Mishra, Y. K., Adelung, R., Röhl, C., Shukla, D., Spors, F., & Tiwari, V. (2011). Virostatic potential of micro-nano filopodia-like ZnO structures against herpes simplex virus-1. Antiviral Research. https://doi.org/10.1016/j.antiviral.2011.08.017
9. Hajkova, P., Spatenka, P., Horsky, J., Horska, I., & Kolouch, A. (2007). Photocatalytic effect of TiO2 films on viruses and bacteria. Plasma Processes and Polymers. https://doi.org/10.1002/ppap.200731007
10. Kumar, A., Sharma, A., Chen, Y., Jones, M. M., Vanyo, S. T., Li, C., Visser, M. B., Mahajan, S. D., Sharma, R. K., & Swihart, M. T. (2021). Copper@ZIF-8 Core-Shell Nanowires for Reusable Antimicrobial Face Masks. Advanced Functional Materials. https://doi.org/10.1002/adfm.202008054
11. Zhu, P., Wang, Y., Chu, H., & Wang, L. (2021). Superhydrophobicity preventing surface contamination as a novel strategy against COVID-19. Journal of Colloid and Interface Science. https://doi.org/10.1016/j.jcis.2021.05.031
12. Barnard, D. L., & Kumaki, Y. (2011). Recent developments in anti-severe acute respiratory syndrome coronavirus chemotherapy. Future Virology, 6(5), 615–631. https://doi.org/10.2217/FVL.11.33
13. Subramani, P. A., Panati, K., Lebaka, V. R., Reddy, D. D., & Narala, V. R. (2017). Nanostructures for Curcumin Delivery: Possibilities and Challenges. In Nano- and Microscale Drug Delivery Systems: Design and Fabrication. https://doi.org/10.1016/B978-0-323-52727-9.00021-2
14. Jahangir MA, Gilani SJ, Muheem A, Jafar M, Aslam M, Ansari MT, Barkat MA. Quantum dots: next generation of smart nano-systems. Pharmaceutical nanotechnology. 2019 Jun 1;7(3):234-45.
15. Gilani SJ, Imam SS, Jafar M, Alshehri S, Taleuzzaman M, Jahangir MA. Curcumin Nanomedicine and Their Application in the Management of Disease. InBiomarkers as Targeted Herbal Drug Discovery 2021 Jul 4 (pp. 43-63). Apple Academic Press.
16. Ting, D., Dong, N., Fang, L., Lu, J., Bi, J., Xiao, S., & Han, H. (2018). Multisite inhibitors for enteric coronavirus: antiviral cationic carbon dots based on curcumin. ACS Applied Nano Materials. https://doi.org/10.1021/acsanm.8b00779
17. Sharma, N., Modak, C., Singh, P. K., Kumar, R., Khatri, D., & Singh, S. B. (2021). Underscoring the immense potential of chitosan in fighting a wide spectrum of viruses: A plausible molecule against SARS-CoV-2? In International Journal of Biological Macromolecules. https://doi.org/10.1016/j.ijbiomac.2021.02.090
18. Li, Y., Wong, T., Chung, J., Guo, Y. P., Hy, J. Y., Guan, Y. T., Yao, L., Song, Q. W., & Newton, E. (2006). In vivo protective performance of N95 respirator and surgical facemask. American Journal of Industrial Medicine. https://doi.org/10.1002/ajim.20395
19. Bałazy, A., Toivola, M., Adhikari, A., Sivasubramani, S. K., Reponen, T., & Grinshpun, S. A. (2006). Do N95 respirators provide 95% protection level against airborne viruses, and how adequate are surgical masks? American Journal of Infection Control. https://doi.org/10.1016/j.ajic.2005.08.018
20. Akduman, C. (2021). Cellulose acetate and polyvinylidene fluoride nanofiber mats for N95 respirators. Journal of Industrial Textiles. https://doi.org/10.1177/1528083719858760
21. Conlon, M. (2016). A facemask having one or more nanofiber layers. In United States Patent.
22. Yang, A., Cai, L., Zhang, R., Wang, J., Hsu, P. C., Wang, H., Zhou, G., Xu, J., & Cui, Y. (2017). Thermal Management in Nanofiber-Based Face Mask. Nano Letters. https://doi.org/10.1021/acs.nanolett.7b00579
23. Borkow, G., Zhou, S. S., Page, T., & Gabbay, J. (2010). A novel anti-influenza copper oxide containing respiratory face mask. PLoS ONE. https://doi.org/10.1371/journal.pone.0011295
24. Kumar, S., Karmacharya, M., Joshi, S. R., Gulenko, O., Park, J., Kim, G. H., & Cho, Y. K. (2021). Photoactive Antiviral Face Mask with Self-Sterilization and Reusability. Nano Letters. https://doi.org/10.1021/acs.nanolett.0c03725
25. Hamouda, T., Ibrahim, H. M., Kafafy, H. H., Mashaly, H. M., Mohamed, N. H., & Aly, N. M. (2021). Preparation of cellulose-based wipes treated with antimicrobial and antiviral silver nanoparticles as novel effective high-performance coronavirus fighter. International Journal of Biological Macromolecules. https://doi.org/10.1016/j.ijbiomac.2021.04.071
26. Jahangir MA, Imam SS, Muheem M, Yamini K. Silver Nanoparticles: The Good, The Bad and The Future. J. Pharm. Nanotechnol. 2016;4.
27. Mohanty D, Gilani SJ, Zafar A, Imam SS, Kumar LA, Ahmed MM, Jahangir MA, Bakshi V, Ahmad W, Eltayib EM. Formulation and Optimization of Alogliptin-Loaded Polymeric Nanoparticles: In Vitro to In Vivo Assessment. Molecules. 2022 Jul 13;27(14):4470.

28. Muheem A, Jahangir MA, Jaiswal CP, Jafar M, Ahmad MZ, Ahmad J, Warsi MH. Recent patents, regulatory issues, and toxicity of nanoparticles in neuronal disorders. Current Drug Metabolism. 2021 Apr 1;22(4):263-79.
29. Bin-Jumah M, Gilani SJ, Jahangir MA, Zafar A, Alshehri S, Yasir M, Kala C, Taleuzzaman M, Imam SS. Clarithromycin-loaded ocular chitosan nanoparticle: formulation, optimization, characterization, ocular irritation, and antimicrobial activity. International Journal of Nanomedicine. 2020;15:7861.
30. Khan, R., & Barua, S. (2019). Two-dimensional nanostructures for biomedical technology: A bridge between material science and bioengineering. In Two-Dimensional Nanostructures for Biomedical Technology: A Bridge between Material Science and Bioengineering. https://doi.org/10.1016/C2018-0-00949-4
31. Cartwright, A., Jackson, K., Morgan, C., Anderson, A., & Britt, D. W. (2020). A review of metal and metal-oxide nanoparticle coating technologies to inhibit agglomeration and increase bioactivity for agricultural applications. In Agronomy. https://doi.org/10.3390/agronomy10071018
32. Mohanty D, Zafar A, Jafar M, Upadhyay AK, Haque MA, Gupta JK, Bakshi V, Ghoneim MM, Alshehri S, Jahangir MA, Ansari MJ. Development, In-Vitro Characterization and Preclinical Evaluation of Esomeprazole-Encapsulated Proniosomal Formulation for the Enhancement of Anti-Ulcer Activity. Molecules. 2022 Apr 25;27(9):2748.
33. Ahmad J, Nollet LM, editors. Nanoemulsions in Food Technology: Development, Characterization, and Applications. CRC Press; 2021 Oct 17.
34. Imam SS, Jahangir MA, Gilani SJ, Zafar A, Alshehri S. Nanoemulsions as Delivery Vehicle for Nutraceuticals and Improving Food Nutrition Properties. InNanoemulsions in Food Technology 2021 Oct 17 (pp. 187-204). CRC Press.
35. Rahman M, Beg S, Zamzami MA, Choudhry H, Ahmad A, Alharbi KS, editors. Biomarkers as Targeted Herbal Drug Discovery: A Pharmacological Approach to Nanomedicines. CRC Press; 2021 Jul 4.
36. Gilani SJ, Bin-Jumah MN, Imam SS, Alshehri S, Jahangir MA, Zafar A. Formulation and optimization of nano lipid based oral delivery systems for arthritis. Coatings. 2021 May 6;11(5):548.
37. Taleuzzaman M, Jahangir MA, Chauhan S, Kala C, Beg S. Good laboratory practice and current good manufacturing practice requirements in the development of cancer nanomedicines. InNanoformulation Strategies for Cancer Treatment 2021 Jan 1 (pp. 341-352). Elsevier.