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Review Article

An Overview of Biomedical Nanotechnology

Shadma Nafis, Ruby Farheen, Neerja Masih*

Department of Biotechnology, Isabella Thoburn College, Lucknow University, Lucknow, Uttar Pradesh, India

ABSTRACT

Nanomedicine has demonstrated its worth in the treatment of different diseases through the use of drug delivery and nanosensors. With the invention of nanoparticles (NPs), nanomedicines, nanomaterial-based biosensors, and antibody diagnostic kits, nanotechnology has opened new horizons for the prevention and treatment of various diseases. To diagnose and treat HIV, Zika virus, influenza, and Herpes Simplex virus various nanomaterials such as carbon dots, gold, and silver NPs are used. Nanomedicine and its components have the potential to play a significant role in disease prevention, diagnosis, treatment, vaccine, and research at various phases. Antimicrobial nanotechnology can be implemented into personal equipment to improve the safety of health-care personnel and the general public. Various NPs formulations for diagnostic and therapeutic purposes have been developed as result of recent breakthroughs in nanotechnology. Diagnostic NPs are designed to aid in the visualization of pathologies and the better understanding of important physiological principles underlying a variety of diseases and treatment.

Key words: Nanotechnology, Nanomedicine, Nanoparticles, Nanomaterials.

1. INTRODUCTION

Nanotechnology is all about discovering new ways to make things. Nanotechnology is a technology that is used to bridge the gap between classical and quantum mechanisms. A nanosystem is consequently something that is so small that it cannot be seen with the naked eye or even a conventional microscope. The development of nanotechnology began in 1981 with the invention of the scanning tunneling microscope by Bennig and Rohrer. Nanotechnology will have an impact on every industry. When creating a vaccine, the antigen, adjuvant, manufacturing technique, and distribution strategy are all important considerations. Furthermore, for enhancing the stability and delivery of mRNA-based vaccines, it uses nanotechnology platforms such as cationic nanoemulsions, dendrimers, or polysaccharide particles [1]. Subunit vaccines use protein nanoparticles (NPs) or virus-like particles for drug delivery [2]. Some NPs which were used earlier for vaccine development are virus such as protein, gold, inorganic NPs, ferritin, chiypsan, ISCOM, DLPC liposome, and poly (lactic-co-glycolic acid) (PLGA) [3]. Through ongoing research and study, medical nanotechnology aspires to create less expensive yet high-quality health services, and diagnostic options. Because of its multiple benefits and practical applications, a number of pharmaceutical companies throughout the world incorporated medical nanotechnology.

2. NANOTECHNOLOGY

Nanotechnology in medicine includes imaging, diagnosis, or the delivery of drugs that will help medical professionals treat various diseases. Improving the ability of nanotechnologies to target specific cells or tissue is of great interest to companies producing nanomedicine. This area of research involves attaching NPs onto drugs or liposomes to increase specific localization.

Nanotechnology is important for the earliest uses of nanotechnology to be thoughtful and attractive. The public is looking for control of their lives. At present, nanotechnology is mostly used in medicine/drugs, fabric, defense, energy, and water purification. Research is developing customized NPs in the field of medical application to deliver drugs to specific cells. The maximum drug consumption and their side effects are effectively minimized by the deposition of the active agent in the selected region of morbid. This selective treatment can reduce the cost and also reduce the human agonize.

Nanomaterials can be utilized in the administration of broad-spectrum antiviral drugs/vaccines, infection detection, the manufacture of face masks, surface coatings to prevent viral adherence and inactivation, and the creation of contact tracking systems. Nanomaterials have distinct physicochemical properties due to their small size, shape, increased surface area to volume ratio, charge, functional groups, and composition, distinguishing them from bulk materials and providing specificity, functionality, sensitivity, and efficiency for biomedical applications.

3. SOME ESSENCE OF NPS

NPs are tiny particles that range from 1 to 100 nm in size and are not visible by the human eye [4]. NPs are represented as NPs. These polymeric particles can occur naturally or be manufactured by humans. In comparison to bulky compounds, NPs have a great surface area to volume ratio.

***Corresponding author:**
E-mail: neerjamasih@yahoo.com

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3.1. Some Examples of NPs

Lipid-based NPs (LBNPs) are the most widely studied NPs and are used in drug delivery and cancer therapy. The LBNPs can be categorized into liposomes, nanoemulsions, solid lipid NPs (SLNs), and nanosuspension. The LBNPs are a great drug loading capacity which is the amount of drug per unit weight of NPs and escalate drug delivery. The important components of liposome NPs are phospholipids which have amphipathic properties, are arranged in the bilayer form [5].

SLNs have been utilized to administer antiviral medications such as ritonavir, maraviroc, darunavir, efavirenz, zidovudine, and lopinavir. This application results in reduced first-pass metabolism and improved tissue dispersion [6]. Lipid NPs can also be investigated for gene silencing by RNA interference (RNAi) for antiviral therapy [7]. To target the Ebola virus, a kind of siRNA is encapsulated in LBNPs. The lipid NP consolidates the delivery of siRNA efficiently into the hepatocytes and also protects the siRNA from nuclease degradation. It suggests that RNAi is effective and can be tested in other viruses [8,9].

Micelles are amphiphilic structures with a hydrophobic core and a hydrophilic shell that are spherical. The hydrophilic covering makes the micelle water-soluble, allowing it to be delivered intravenously, while the hydrophobic center delivers the therapeutic payload. The hydrophilic shell of polymeric micelles protects them from being eliminated by the reticuloendothelial system, allowing them to circulate longer and deliver drugs to their intended targets [10,11].

Dendrimers are complex synthetic structures that are highly branched and well-defined. They are used widely in gene therapy [12], drug delivery [13], targeting cancer cells [14], and nanocomposites, mostly used in the treatment of HIV and HSV2. Dendrimers are one of the most adaptable and adjustable nanotechnologies due to their ability to carefully alter their dimensions, structure, and surface activity. Glycodendropeptide has recently been suggested as a viable viral treatment [13].

Metals (Au and Ag) and metal oxides (SiO_2, TiO_2, and CeO_2) are commonly used NPs for antiviral drug treatment. These NPs are used to diagnose and treat the virus-like HIV, Herpes Simplex virus, Hepatitis virus (A, B, and C), and influenza virus [15]. Gold NPs (AuNPs) are used in biological imaging, electronics, and materials research [16]. AuNPs are available in different sizes ranging from 5 nm to 400 nm in diameter. AuNP can penetrate cells where HIV replication is occurring, such as lymphocytes and macrophages. It also prevents the reproduction of HIV in peripheral blood mononuclear cells. HSV, human papillomavirus, dengue, respiratory syncytial virus, and lentivirus all can be treated with AuNPs [17].

Quantum dots (QDs) are semiconductor nanocrystals with favorable optical and electrical characteristics. QDs are employed in viral illness sensing, imaging, and treatment [18]. QDs are also used for the diagnosis of various ovarian cancers. The conjugated quantum dot is effective with anti-AIDS medicines and to transport saquinavir through the blood-brain barrier [19]. Figure 1 represents various types of nanocarriers that are used for antiviral drug therapy.

4. NANOMATERIALS INVOLVED IN THE TREATMENT AND PREVENTION OF DISEASES

Nanomaterial aid in blocking the human influenza virus, HIV by preventing the binding to its receptor, for example, chloroquine, is extensively adopted for preventing endocytic entry of the virus. The polylactic acid NP is commonly utilized to enclose chloroquine, improving its transport and cellular absorption efficiency [20].

5. FUTURE PERSPECTIVE OF NANOMATERIALS

Recently nanomaterials such as Chitosan nanospheres, carbon quantum dots nanocrystals, gold nanorods, titanium oxide, and PLGA NPs with anti-coronavirus activity were discovered as prospective candidates against human coronaviruses detected before SARS-CoV-2 [21,22]. Some present NPs which are used for COVID-19 management are

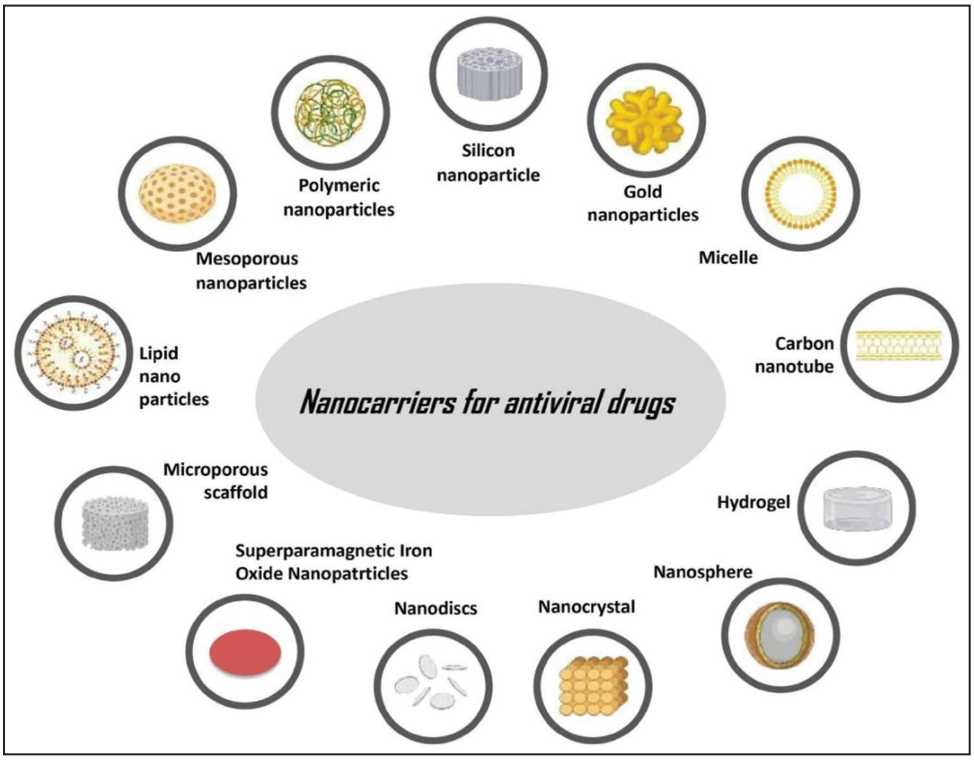

Figure 1: Different types of Nanocarriers for antiviral drug system.

gold, silver, silica, and iron oxide NPs [23,24]. A nano-disinfectant EWNS is developed which is effective for the H1N1 influenza virus and can be used as a surface disinfectant [25].

A field-effect transistor-based biosensor is a rapid method for the diagnosis of coronavirus, an alternative to reverse transcription–polymerase chain reaction, as it takes less time. This biosensor uses a graphene nanosheet to detect SARS-COV2 antigen protein from nasopharyngeal swabs and clinical samples. It is developed by layering graphene sheets with silica oxide, SARS spike(S) protein binds with the SARS-CoV-2 antigen. This sensor was able to differentiate the antigen protein of SARS-CoV-2 from that of MERS-CoV [26].

6. CONCLUSION

The global desire to provide efficient technology to tackle has prompted researchers and companies to shift away from traditional approaches and move toward new and intelligent technology known as nanotechnology. Nano-based methods are effective in boosting medication delivery to a specific target location, increasing residence duration, and increasing drug use efficiency. Liposome NPs and AuNPs were discovered to have an antiviral property. Nanotechnology also has a large potential in prevention, diagnosis, treatment, immunization, and research of various viral diseases in near future. Despite various benefits, the toxicity and adverse effects of NPs in human health have yet to be completely investigated and require more research in this direction.

REFERENCES

1. N. Pardi, M. J. Hogan, F. W. Porter, D. Weissman, (2018) mRNA vaccines-a new era in vaccinology, ***Nature Reviews Drug Discovery***, **17(4)**: 261-279.
2. R. Kathleen, S. Senapati, J. Alley, R. Darling, J. Goodman, M. Jefferson, M. Uz, B. Guo, K. J. Yoon, D. Verhoeven, M. Kohut, S. Mallapragada, M. Wannemuehler, B. Narasimhan, (2019) Single dose combination nanovaccine provides protection against influenza a virus in young and aged mice, ***Biomaterials Science***, **7**(3): 809-821.
3. V. S. Sivasankarapillai, A. M. Pillai, A. Rahdar, A. P. Sobha, S. S. Das, A. C. Mitropoulos, M. H. Mokarrar, G. Z. Kyzas, (2020) On facing the SARS-CoV-2 (COVID-19) with combination of nanomaterials and medicine: Possible strategies and first challenges, ***Nanomaterials (Basel)***, **10(5)**: 852.
4. P. J. Kumar, G. Das, L. F. Fraceto, E. V. R. Campos, M. del Pilar Rodriguez-Torres, L. S. Acosta-Torres, L. A. Diaz-Torres, L. A. Diaz-Torres, R. Grillo, M. K. Swamy, S. Sharma, S. Habtemariam, H. S. Shin, (2018) Nano based drug delivery systems: Recent developments and future prospects, ***Journal of Nanobiotechnology***, **16(1)**: 1-33.
5. H. A. Khalil, R. Dungani, M. S. Hossain, N. L. M. Suraya, S. Aprilia, A. A. Astimar, Y. Davoudpour, (2015) Mechanical properties of oil palm biocomposites enhanced with micro to nano bio fillers. In: ***Biocomposites***. United Kingdom: Woodhead Publishing, p401-435.
6. S. Mukherjee, S. Ray, R. S. Thakur, (2009) Solid lipid nanoparticles: A modern formulation approach in drug delivery system, ***Indian Journal of Pharmaceutical Sciences***, **71(4)**: 349.
7. V. Makwana, R. Jain, K. Patel, M. Nivsarkar, A. Joshi, (2015) Solid lipid nanoparticles (SLN) of Efavirenz as lymph targeting drug delivery system: Elucidation of mechanism of uptake using chylomicron flow blocking approach, ***International Journal of Pharmaceutics***, **495(1)**: 439-446.
8. E. P. O'Keefe, (2013) siRNAs and shRNAs: Tools for protein knockdown by gene silencing, ***Mater Methods***, **3:** 197.
9. E. P. Thi, A. C. H. Lee, J. B. Geisbert, R. Ursic-Bedoya, K. N. Agans, M. Robbins, D. J. Deer, K. A. Fenton, A. S. Kondratowicz, I. MacLachlan, T. W. Geisbert, C. E. Mire, (2016) Rescue of non-human primates from advanced Sudan ebolavirus infection with lipid encapsulated siRNA, ***Nature Microbiology***, **1(10)**: 1-10.
10. K. T. Oh, T. K. Bronich, A. V. Kabanov, (2004) Micellar formulations for drug delivery based on mixtures of hydrophobic and hydrophilic Pluronic® block copolymers, ***Journal of Controlled Release***, **94(2-3)**: 411-422.
11. M. L. Adams, A. Lavasanifar, G. S. Kwon, (2003) Amphiphilic block copolymers for drug delivery, ***Journal of Pharmaceutical Sciences***, **92(7)**: 1343-1355.
12. C. Dufès, I. F. Uchegbu, A. G. Schätzlein, (2005) Dendrimers in gene delivery, ***Advanced Drug Delivery Reviews***, **57(15)**: 2177-2202.
13. D. A. Tomalia, L. A. Reyna, S. Svenson, (2007) Dendrimers as multi-purpose nanodevices for oncology drug delivery and diagnostic imaging, ***Biochemical Society Transactions***, **35(1)**: 61-67.
14. R. M. Kannan, E. Nance, S. Kannan, D. A. Tomalia, (2014) Emerging concepts in dendrimer-based nanomedicine: From design principles to clinical applications, ***Journal of Internal Medicine***, **276(6)**: 579-617.
15. T. Yadavalli, D. Shukla, (2017) Role of metal and metal oxide nanoparticles as diagnostic and therapeutic tools for highly prevalent viral infections, ***Nanomedicine: Nanotechnology, Biology and Medicine***, **13(1)**: 219-230.
16. X. Huang, M. A. El-Sayed, (2010) Gold nanoparticles: Optical properties and implementations in cancer diagnosis and photothermal therapy, ***Journal of Advanced Research***, **1(1)**: 13-28.
17. C. Valeria, P. Andreozzi, M. D'Alicarnasso, P. J. Silva, M. Mueller, M. Galloux, R. Le Goffic, S. T. Jones, M. Vallino, J. Hodek, J. Weber, S. Sen, E. R. Janecek, A. Bekdemir, B. Sanavio, C. Martinelli, M. Donalisio, M. A. R. Welti, J. F. Eleouet, Y. Han, (2018) Broad-spectrum non-toxic antiviral nanoparticles with a virucidal inhibition mechanism, ***Nature Materials***, **17(2)**: 195-203.
18. C. T. Matea, T. Mocan, F. Tabaran, T. Pop, O. Mosteanu, C. Puia, C. Iancu, L. Mocan, (2017) Quantum dots in imaging, drug delivery and sensor applications, ***International Journal of Nanomedicine***, **12:** 5421.
19. S. Mahajan, I. Roy, G. X. Xu, K. T. Yong, H. Ding, R. Aalinkeel, J. L. Reynolds, D. Sykes, B. B. Nair, E. Y. Lin, P. N. Prasad, S. A. Schwartz, (2010) Enhancing the delivery of anti retroviral drug "Saquinavir" across the blood brain barrier using nanoparticles, ***Current HIV Research***, **8(5)**: 396-404.
20. K. Uzunova, E. Filipova, V. Pavlova, T. Vekov, (2020) Insights into antiviral mechanisms of remdesivir, lopinavir/ritonavir and chloroquine/hydroxychloroquine affecting the new SARS-CoV-2, ***Biomedicine and Pharmacotherapy***, **131:** 110668.
21. A. Sánchez, S. P. Mejía, J. Orozco, (2020) Recent advances in polymeric nanoparticle-encapsulated drugs against intracellular infections, ***Molecules***, **25(16)**: 3760.
22. J. Ciejka, K. Wolski, M. Nowakowska, K. Pyrc, K. Szczubiałka, (2017) Biopolymeric nano/microspheres for selective and reversible adsorption of coronaviruses, ***Materials Science and Engineering: C***, **76:** 735-742.

23. A. Łoczechin, K. Séron, A. Barras, E. Giovanelli, S. Belouzard, Y. T. Chen, N. Metzler-Nolte, R. Boukherroub, J. Dubuisson, S. Szunerits, (2019) Functional carbon quantum dots as medical countermeasures to human coronavirus ***ACS Applied Materials and Interfaces***, **11:** 42964.
24. S. Khaiboullina, T. Uppal, N. Dhabarde, V. R. Subramanian, S. C. Verma, (2021) Inactivation of human coronavirus by titania nanoparticle coatings and UVC radiation: Throwing light on SARS-CoV-2, ***Viruses***, **13(1)**: 19.
25. N. Vaze, G. Pyrgiotakis, J. McDevitt, L. Mena, A. Melo, A. Bedugnis, L. Kobzik, M. Eleftheriadou, P. Demokritou, (2019) Inactivation of common hospital acquired pathogens on surfaces and in air utilizing engineered water nanostructures (EWNS) based nano-sanitizers, ***Nanomedicine: Nanotechnology, Biology and Medicine***, **18:** 234-242.
26. G. Seo, G. Lee, M. J. Kim, S. H. Baek, M. Choi, K. B. Ku, C. S. Lee, S. Jun, D. Park, H. G. Kim, S. J. Kim, J. O. Lee, B. T. Kim, E. C. Park, S. I. Kim, (2020) Rapid detection of COVID-19 causative virus (SARS-CoV-2) in human nasopharyngeal swab specimens using field-effect transistor-based biosensor, ***ACS Nano***, **14(4)**: 5135-5142.

***Bibliographical Sketch**

Shadma Nafis is a Master of Science student in the Department of Biotechnology, Isabella Thoburn College, Lucknow. She holds a bachelor's degree in engineering from A.K.T.U, Lucknow. She has also worked as a Junior Research Fellow at Council Of Scientific And Industrial Research–Institute Of Genomics And Integrative Biology (CSIR–IGIB), Delhi and has worked on Machine Learning, Analytics and Visualization in the field of Computational Biology.

Ruby Farheen is a Master of Science student in the Department of Biotechnology, Isabella Thoburn College, Lucknow.

Dr (Maj) Neerja Masih, MSc, PhD (Biochemistry) is an Asst Prof of Biochemistry at Isabella Thoburn College and She is Incharge, PG Department of Biotechnology. She has 10 years of experience as Defense Food Analyst in Army Service Corps in Indian Army and took release as a Major. She is passionate about Environment and has presented many papers at International and National levels.She has taught 'Women and Environment' at the Post Graduate Department of Women's Studies at Isabella Thoburn College for past 7 years. Under the Biotech Society of Isabella Thoburn College, she is involved in training and sensitizing the students regarding Management of green waste on campus by Vermicomposting and has organized sessions of Guest Speakers with the students to ignite the scientific temper in them. She has organised, attended and participated in many workshops related to Environment and gender issues.She has been teaching post graduate students of Biotechnology & Nutrition for last 15 years and guided more than 60 students for project dissertation. She has many publications in national & international journals, she has contributed chapters in books. She is reviewer for many journals.