SUSHANT UNIVERSITY ORGANIZED INTERNATIONAL CONFERENCE ON
"ADVANCES IN MULTIDISCIPLINARY RESEARCH AND INNVOATION" ICAMRI-2023
ON 28-29TH OCTOBER 2023
INTERNATIONAL ADVANCE JOURNAL OF ENGINEERING, SCIENCE AND MANAGEMENT (IAJESM)
July-December 2023, Submitted in October 2023, iajesm2014@gmail.com, ISSN -2393-8048
Multidisciplinary Indexed/Peer Reviewed Journal. SJIF Impact Factor 2023 =6.753

Unlocking Nanotechnology's Potential: Small Wonders with Big Impact

Anjali Sudha, Assistant Professor, SHS, Department of Pharmacy, Sushant University
Email-anjalisudha@sushantuniversity.edu.in
Dr. Jyoti Sinha, Principal, SHS, Department of Pharmacy, Sushant University
Email- jyotisinha@sushantuniversity.edu.in

Abstract

The use of nanotechnology in medicine, known as nanomedicine, has changed the field significantly in recent years. Although some of the features of nanoparticles have been found to have biological applications, their occasional demonstration of cell toxicity has raised concerns about their therapeutic use. Here we have explained the many applications of nanoparticles in different diseases and how nanoparticle showing its impact on all this. The unique properties of nanomaterials enable precise targeting, enhanced drug delivery and improved imaging, making them invaluable in the fight against a range of diseases. Antioxidant-containing nanoparticles may thereby alleviate vascular dysfunction brought on by high blood pressure, or diabetes. we explore the applications of nanotechnology in addressing various health challenges.

Keywords: Nanotechnology, History, Recent approaches

Introduction:

In the past, a variety of illnesses have been treated by drug delivery systems (DDSs). To treat illnesses, all medications rely on pharmacologic active metabolites, or pharmaceuticals [1]. Certain medications are intended to be inactive precursors that the body must change into active forms [2]. The administration method affects their efficacy. Traditionally, oral, nasal, inhalation, mucosal, and injectable administration modalities were used in conventional drug delivery systems (CDDSs) [3]. Commonly administered drugs took longer to heal the sickness, were excreted early, damaged unaffected areas, and had a slower rate of absorption [4]. Many barriers, such as their fast release that enhanced blood toxicity, multiple mucosal barriers, their enzymatic breakdown or pH difference, and off-target effects, rendered them less effective. [5]. The development of the sustained drug delivery system was motivated by all of these factors. Drug efficacy is improved by this DDS development in a number of ways [6]. Recently, DDSs have been designed to regulate the release of drugs [7]. In order to extend life expectancy by reinventing medication delivery technologies, drug discovery and delivery have shifted from the micro to the nano level in recent decades [8].

The theory of nanotechnology was first presented by physicist Feynman in his 1959 lecture "There's Plenty of room at the Bottom." This idea sparked amazing rise in the field of nanotechnology [9]. The study of incredibly small objects is known as nanotechnology, and it serves as the central focus for several scientific fields, including material science, physics, chemistry, biology, engineering, and information technology [10]. At the nanoscale level, the structures observed by nanotechnology span from 1 to 100 nm [11]. Nanoparticles have special material qualities due to their sub-microscopic size, which makes them useful in many different disciplines like engineering, drug transport, nanomedicine, environmental protection, catalysis, and many more. Additionally, they have the potential to treat a number of specific illnesses, including skin problems, liver ailments, melanoma, cardiovascular diseases (CVD), and many others [12]. Published studies on protein-based nanomedicine show that various protein subunits work together to deliver medication directly to a targeted tumor [13].

History:

Petros and a colleague presented a study on nanotechnology research conducted in the middle of the 19th century. The first controlled-release polymer device was introduced in 1964. The first micelle was created and approved in 1983; albumin-based NPs were published in 1972;

liposome-based medications were developed in 1973; The first micelle was found by Bangham in 1965, and the first drug-polymer conjugation happened in 1955. The FDA approved the first controlled formulation in 1989, and the first protein-conjugated polyethylene glycol (PEG) was commercially accessible in 1990. [14,15].

Recent methods for treating a variety of diseases with drug carriers:

Fig-1 Various applications of nanotechnology | Download Scientific Diagram

Brain Drug Delivery Systems:

The majority of pathological illnesses disrupt the blood-brain barrier (BBB), including diabetes, gliomas, AIDS, multiple sclerosis, Alzheimer's disease, Parkinson's disease, and others [16]. One of the main causes of the blood–brain barrier's disintegration is the pathologic alteration of the protein complex at intra-endothelial junctions. [17]. In order to maintain blood-brain equilibrium, the blood-brain barrier normally prevents blood macromolecules and micro-molecules from entering [18]. Drugs that penetrate the blood-brain barrier cannot be used to treat brain illnesses because they are less bioavailable and do not build up as much in the intracerebral area of the brain [19]. The transport of medicines intranasally, aided by nanocarriers, is a commonly used technique in the treatment of brain disorders [20,21].

The role of nanocarriers in major cancers:

Brain Cancer

Brain cancer is the most serious sickness in terms of therapy [22]. Brain malignancies are the hardest to cure because of the blood–brain barrier, which limits available therapy options [23]. Because the blood brain barrier prevents many therapeutic medicines from entering the brain, brain cancer—including gliomas—presents a special set of difficulties. Since they can penetrate the blood-brain barrier and reach the target cell in the brain due to their small size, nanoparticles present a viable solution to this issue. Nanoparticles offer a great deal of promise as a treatment for brain cancer because of their small size (nm), capacity to target certain areas, and simplicity of BBB crossing. [24].

Breast Cancer

Because of its aggressiveness, breast cancer is more likely to be lethal than lung cancer and is the most common type of melanoma seen in women alone [25]. Surgery, chemotherapy, radiation therapy, hormone therapy, and targeted therapy are all effective therapies for breast cancer [26]. On the other hand, interest in using nanotechnology to treat breast cancer has grown recently. To transport medications precisely where they are needed, a variety of organic and inorganic nanocarriers are employed [27]. Nanocarriers offer customized drug delivery and increase the hydrophobicity of anticancer medications. [28].

Lung Cancer

The main organ used for inhaling is the lungs [29]. The alveoli, or gas exchange zones, and airways that carry air into and out of the lungs make up the lung [30]. When exposed to external

INTERNATIONAL ADVANCE JOURNAL OF ENGINEERING, SCIENCE AND MANAGEMENT (IAJESM)
July-December 2023, Submitted in October 2023, iajesm2014@gmail.com, ISSN -2393-8048
Multidisciplinary Indexed/Peer Reviewed Journal. SJIF Impact Factor 2023 =6.753

stressors, the alveoli's large surface area and deep air blood exchange make them less healthy. Lung cancer is one of the conditions that may have been brought on by such events [31]. In an effort to address the shortcomings of conventional treatments, a multitude of nanoparticles are presently being created for respiratory applications [32]. Numerous lung conditions, including cancer, tuberculosis, emphysema, cystic fibrosis, and asthma, can be treated with nanoparticles. [33].

Drug delivery strategy for heart disease

Abnormalities in the human heart's structure and function, together with periodic contractions and relaxations of the cardiac muscles, are linked to cardiac diseases [34, 35]. In order to reduce the risk of heart failure following myocardial infarction, contemporary treatment techniques have been established [36]. Among the drug delivery methods are liposomes, silica NPs, dendrimers, micelles, cerium oxide NPs, TiO_2 NPs, nano-coated stents, microbubbles, and polymer–drug conjugates. When liposomes and magnetic nanoparticles combine, magnetic nanoparticles like magneto liposomes (MLs) are produced. They are employed in the magnetic targeted delivery of drugs. [37].

Approach to medicine delivery in skin condition

Dermatological and follicular illnesses are examples of skin diseases. Nanotechnology is now being used to treat a number of dermatological conditions. The administration of nanoparticles is advised for the treatment of skin illnesses due to their minimal adverse effects. Commonly used lotions, gels, and ointments do not penetrate skin tissues well enough to be effective in delivering medications. This is overcome by the employment of polymeric, lipid, and surfactant nanocarriers. Polymeric micelles help drugs penetrate the skin more easily, which is beneficial for treating skin cancer. By increasing the drug's penetration into the dermal and epidermal layers, this study shows that liposomes, gold nanoparticles, and chitosan polymeric NPs can all be used to treat atopic dermatitis. [38].

Method of drug administration for disorders of bone

Bone diseases are abnormalities in the bone caused by a variety of pathological illnesses, including osteoporosis, arthritis, fractures, infections, trauma, and many more. The intricate process of bone regeneration as a disease treatment integrates biological components and nanomaterials to effectively restore bone structure. Bone implantation has decreased as a result of the development of bone bio-scaffolds, which combine biomaterial and nanomaterial. [39]. It has recently been found that a variety of nanoparticles can deliver medications by regulating immune cells like macrophages in inflammatory joints. [40,41]. By using this technique, the medication becomes more accessible and soluble, avoids overdosing, and patient adherence is enhanced.[42]. A successful drug delivery plan guarantees that a medication is bioavailable at the intended site.[43],44] .Even if advances in drug delivery studies and strategies have been made, many medications still have unfavourable side effects because they interact with human organs that are not the drugs' intended targets. [45]. A few ground-breaking discoveries have made modern times possible. To comprehend the cellular pathways and molecular targets for targeted therapy, a wide range of cellular receptors and targets have been investigated. One such therapeutic approach is the use of small interfering RNA (siRNA) to downregulate certain signaling-specific genes. [46,47, 48] Recent advancements have shown the enormous potential of nanoparticles in medical applications; An exciting area of multidisciplinary research that blends the knowledge of scientists and engineers is applied nanotechnology. [49]. Nanomedicines overcomes the drawbacks of traditional therapy, as evidenced by preclinical and clinical studies that provide superior treatment outcomes, decreased side effects, and targeted drug administration. Improvements in carrier capacity. Changes in size and shape, the ability to combine hydrophilic and hydrophobic materials, and the formation of long-lasting interactions with ligands make this an attractive topic for cell-specific and regulated transport of micro- and macromolecules in treatment. Nano-systems decrease drug consumption and the possibility of unintended side effects while enabling site-specific and targeted pharmaceutical administration. [50]

Conclusion

Treatment of diseases using nanomedicine is a broad field based on nanotechnology. These days, nanotechnology is showing promise as the most effective treatment for all diseases. Researchers at California University are working on ways to get cardiac stem cells into the heart. To enhance the quantity of stem cells in wounded tissue, they affixed nanovesicles that specifically target that area. Therefore, the application of stem cells to nanotechnology will lead to the development of several answers for medical problems pertaining to diseases. Nanomedicine and nano-pharmaceuticals, however, address a lot of uncertainties. Development will focus on irregularities, toxicity, and safety assessments in the future. Demand for nanotechnology will be quite strong. Pharmaceutical researchers worldwide are now paying attention to drug-targeted delivery via nanoparticles.

All of the negative consequences of conventional treatment will be eliminated by nanomedicine. The National Cancer Institute states that the medical system will use this nanoscale technology to diagnose patients, deliver therapeutic medications, and identify the spread of cancer. Nanomedicine is being used by researchers to treat SARS-CoV-2 because particles as small as 10–200 nm have the ability to recognize and eradicate the virus for site-specific transmission. Since nanotechnology inhibits viral contamination, it might be useful in the fight against COVID-19. Future research will produce very precise nano-based sensors that can swiftly identify the virus and, by spraying them, protect both the general public and front-line medical personnel. Furthermore, nanobiotechnology is being used to develop a wide range of antiviral disinfectants to inhibit the spread of viruses.

Refrences:

1.Li S., Zhang H., Chen K., Jin M., Vu S.H., Jung S., He N., Zheng Z., Lee M.S. Applicatio of chitosan/alginate nanoparticle in oral drug delivery systems: Prospects and challenges. *Drug Deliv.* 2022;29:1142–1149. doi: 10.1080/10717544.2022.2058646.

2.Vlachopoulos A., Karlioti G., Balla E., Daniilidis V., Kalamas T., Stefanidou M., Bikiaris N.D., Christodoulou E., Koumentakou I., Karavas E., et al. Poly (Lactic Acid)-Based Microparticles for Drug Delivery Applications: An Overview of Recent Advances. *Pharmaceutics.* 2022;14:359. doi: 10.3390/pharmaceutics14020359.

3.Tibbitt M.W., Dahlman J.E., Langer R. Emerging frontiers in drug delivery. *J. Am. Chem. Soc.* 2016;138:704–717. doi: 10.1021/jacs.5b09974.

4.Builders P.F., Arhewoh M.I. Pharmaceutical applications of native starch in conventional drug delivery. *Starch-Stärke.* 2016;9–10:864–873. doi: 10.1002/star.201500337

5.Alshammari M.K., Alshehri M.M., Alshehri A.M., Alshlali O.M., Mahzari A.M., Almalki H.H., Kulaybi O.Y., Alghazwni M.K., Kamal M., Imran M. Camptothecin loaded nano-delivery systems in the cancer therapeutic domains: A critical examination of the literature. *J. Drug Deliv. Sci. Technol.* 2022;79:104034. doi: 10.1016/j.jddst.2022.104034.

6.Lai H., Liu S., Yan J., Xing F., Xiao P. Facile Fabrication of Biobased Hydrogel from Natural Resources: L-Cysteine, Itaconic Anhydride, and Chitosan. *ACS Sustain. Chem. Eng.* 2020;8:4941–4947. doi: 10.1021/acssuschemeng.0c00774.

7. Marco-Dufort B., Willi J., Vielba-Gomez F., Gatti F., Tibbitt M.W. Environment Controls Biomolecule Release from Dynamic Covalent Hydrogels. *Biomacromolecules.* 2021;22:146–157. doi: 10.1021/acs.biomac.0c00895.

8. Su Y., Xie Z., Kim G.B., Dong C., Yang J. Design strategies and applications of circulating cell-mediated drug delivery systems. *ACS Biomater. Sci. Eng.* 2005;4:201–217. doi: 10.1021/ab500179h.

9. Baig N., Kammakakam I., Falath W. Nanomaterials: A review of synthesis methods, properties, recent progress, and challenges. *Mater. Adv.* 2021;2:1821–1871. doi: 10.1039/D0MA00807A. [CrossRef] [Google Scholar]
10. Prasad R.D., Charmode N., Shrivastav O.P., Prasad S.R., Moghe A., Sarvalkar P.D., Prasad N.R. A review on concept of nanotechnology in veterinary medicine. *ES Food Agrofor.* 2021;4:28–60. doi: 10.30919/esfaf481. [CrossRef] [Google Scholar]
11. Lateef A., Darwesh O.M., Matter I.A. *Microbial Nanobiotechnology.* Springer; Singapore: 2021. Microbial nanobiotechnology: The melting pot of microbiology, microbial technology and nanotechnology; pp. 1–19. [Google Scholar]
12. Mansor N.I., Nordin N., Mohamed F., Ling K.H., Rosli R., Hassan Z. Crossing the blood-brain barrier: A review on drug delivery strategies for treatment of the central nervous system diseases. *Curr. Drug Deliv.* 2019;16:698–711. doi: 10.2174/1567201816666190828153017. [PubMed] [CrossRef] [Google Scholar]
13. Dilnawaz F., Acharya S., Sahoo S.K. Recent trends of nano-medicinal approaches in clinics. *Int. J. Pharm.* 2018;538:263–278. doi: 10.1016/j.ijpharm.2018.01.016.
14. MaHam A., Tang Z., Wu H., Wang J., Lin Y. Protein-based nanomedicine platforms for drug delivery. *Small.* 2009;5:1706–1721. doi: 10.1002/smll.200801602. [PubMed] [CrossRef] [Google Scholar]
15. Harrington K.J. Phase II study of pegylated liposomal doxorubicin (Caelyx[TM]) as induction chemotherapy for patients with squamous cell cancer of the head and neck. *Eur. J. Cancer.* 2001;37:2015–2022. doi: 10.1016/S0959-8049(01)00216-7. [PubMed] [CrossRef] [Google Scholar].
16. Thi T.T., Suys E.J., Lee J.S., Nguyen D.H., Park K.D., Truong N.P. Lipid-based nanoparticles in the clinic and clinical trials: From cancer nanomedicine to COVID-19 vaccines. *Vaccines.* 2021;9:359. doi: 10.3390/vaccines9040359.
17. Mallakpour S., Azadi E., Hussain C.M. The latest strategies in the fight against the COVID-19 pandemic: The role of metal and metal oxide nanoparticles. *New J. Chem.* 2021;45:6167–6179. doi: 10.1039/D1NJ00047K.
18. Kelleni M.T. Resveratrol-zinc nanoparticles or pterostilbene-zinc: Potential COVID-19 mono and adjuvant therapy. *Biomed. Pharmacother.* 2021;139:111626. doi: 10.1016/j.biopha.2021.111626. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
19. Zhang H., Zhang L., Zhong H., Niu S., Ding S., Lv S. Iridium oxide nanoparticles-based theranostic probe for in vivo tumor imaging and synergistic chem/photothermal treatments of cancer cells. *Chem. Eng. J.* 2022;430:132–675. doi: 10.1016/j.cej.2021.132675. [CrossRef] [Google Scholar]
20. Fricke I.B., Schelhaas S., Zinnhardt B., Viel T., Hermann S., Couillard-Després S., Jacobs A.H. In vivo bioluminescence imaging of neurogenesis—The role of the blood brain barrier in an experimental model of Parkinson's disease. *Eur. J. Neurosci.* 2017;45:975–986. doi: 10.1111/ejn.13540.
21. Sahni J.K., Doggui S., Ali J., Baboota S., Dao L., Ramassamy C. Neurotherapeutic applications of nanoparticles in Alzheimer's disease. *J. Control. Release.* 2012;152:208–231. doi: 10.1016/j.jconrel.2010.11.033.
22. Chaiyana W., Rades T., Okonogi S. Characterization and in vitro permeation study of microemulsions and liquid crystalline systems containing the anticholinesterase alkaloidal extract from Tabernaemontana divaricata. *Int. J. Pharm.* 2013;452:201–210. doi: 10.1016/j.ijpharm.2013.05.005. [PubMed] [CrossRef] [Google Scholar]
23. Hayes M.T. Parkinson's disease and parkinsonism. *Am. J. Med.* 2019;132:802–807. doi: 10.1016/j.amjmed.2019.03.001. [PubMed] [CrossRef] [Google Scholar]

24. Barcia E., Boeva L., García-García L., Slowing K., Fernández-Carballido A., Casanova Y. Nanotechnology-based drug delivery of ropinirole for Parkinson's disease. *Drug Deliv.* 2017;24:1112–1123. doi: 10.1080/10717544.2017.1359862. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
25. Muthu M.S., Avinash Kulkarni S., Liu Y., Feng S.-S. Development of docetaxel-loaded vitamin E TPGS micelles: Formulation optimization, effects on brain cancer cells and biodistribution in rats. *Nano Diam.* 2012;7:353–364. doi: 10.2217/nnm.11.111. [PubMed] [CrossRef] [Google Scholar] [Ref list]
26. Arias J.L., Clares B., Morales M.E., Gallardo V., Ruiz M.A. Lipid-based drug delivery systems for cancer treatment. *Curr. Drug Targets.* 2011;12:1151–1165. doi: 10.2174/138945011795906570. [PubMed] [CrossRef] [Google Scholar]
27. Folkman J. Role of angiogenesis in tumor growth and metastasis. *Semin. Oncol.* 2002;29:15–18. doi: 10.1053/sonc.2002.37263. [PubMed] [CrossRef] [Google Scholar]
28. Wicki A., Witzigmann D., Balasubramanian V., Huwyler J. Nanomedicine in cancer therapy: Challenges, opportunities, and clinical applications. *J. Control. Release.* 2015;200:138–157. doi: 10.1016/j.jconrel.2014.12.030. [PubMed] [CrossRef] [Google Scholar]
29. Wang W., Chen T., Xu H., Ren B., Cheng X., Qi R., Liu H., Wang Y., Yan L., Chen S., et al. Curcumin-loaded solid lipid nanoparticles enhanced anticancer efficiency in breast cancer. *Molecules.* 2018;12:1578. doi: 10.3390/molecules23071578. [PMC free article] [PubMed] [CrossRef] [Google Scholar]
30. Riganti C., Gazzano E., Gulino G.R., Volante M., Ghigo D., Kopecka J. Two repeated low doses of doxorubicin are more effective than a single high dose against tumors overexpressing P-glycoprotein. *Cancer Lett.* 2015;23:219–226. doi: 10.1016/j.canlet.2015.02.008. [PubMed] [CrossRef] [Google Scholar]
31. Naruphontjirakul P., Viravaidya-Pasuwat K. Development of doxorubicin—Core Shell chitosan nanoparticles to treat Cancer; Proceedings of the 2011 International Conference on Biomedical Engineering and Technology; Kuala Lumpur, Malaysia. 4–5 June 2011. [Google Scholar]
32. Di H., Wu H., Gao Y., Li W., Zou D., Dong C. Doxorubicin-and cisplatin-loaded nanostructured lipid carriers for breast cancer combination chemotherapy. *Drug Dev. Ind. Pharm.* 2016;42:2038–2043. doi: 10.1080/03639045.2016.1190743. [PubMed] [CrossRef] [Google Scholar]
33. Chan M., Huang W., Wang J., Liu R., Hsiao M. Next-Generation Cancer-Specific Hybrid Theranostic Nanomaterials: MAGE-A3 NIR Persistent Luminescence Nanoparticles Conjugated to Afatinib for In Situ Suppression of Lung Adenocarcinoma Growth and Metastasis. *Adv. Sci.* 2020;7:1903741. doi: 10.1002/advs.201903741. [PMC free article] [PubMed] [CrossRef] [Google Scholar] [Ref list]
34. Wang L., Jia E. Ovarian cancer targeted hyaluronic acid-based nanoparticle system for paclitaxel delivery to overcome drug resistance. *Drug Deliv.* 2016;23:1810–1817. doi: 10.3109/10717544.2015.1101792. [PubMed] [CrossRef] [Google Scholar] [Ref list]
35. Guo Z., Sui J., Ma M., Hu J., Sun Y., Yang L. pH-Responsive charge switchable PEGylated ε-poly-l-lysine polymeric nanoparticles-assisted combination therapy for improving breast cancer treatment. *J. Control. Release.* 2020;326:350–364. doi: 10.1016/j.jconrel.2020.07.030. [PubMed] [CrossRef] [Google Scholar] [Ref list]
36. Chen S., Huang S., Li Y., Zhou C. Recent advances in epsilon-poly-L-lysine and L-lysine-based dendrimer synthesis, modification, and biomedical applications. *Front. Chem.* 2021;9:169. doi: 10.3389/fchem.2021.659304. [PMC free article] [PubMed] [CrossRef] [Google Scholar] [Ref list]

37. Zhou J., Zhang Z., Joseph J., Zhang X., Ferdows B.E., Patel D.N., Chen W., Banfi G., Molinaro R., Cosco D., et al. Biomaterials and nanomedicine for bone regeneration: Progress and future prospects. *Exploration.* 2021;2:20210011. doi: 10.1002/EXP.20210011. [CrossRef] [Google Scholar] [Ref list]
38. Hussein-Al-Ali S.H., Hussein M.Z., Bullo S., Arulselvan P. Chlorambucil- iron oxide nanoparticles as a drug delivery system for leukemia cancer cells. *Int. J. Nanomed.* 2021;16:6205. doi: 10.2147/IJN.S312752. [PMC free article] [PubMed] [CrossRef] [Google Scholar] [Ref list]
39. Tewabe A., Abate A., Tamrie M., Seyfu A., Siraj E.A. Targeted drug delivery—From magic bullet to nanomedicine: Principles, challenges, and future perspectives. *J. Multidiscip. Healthc.* 2021;14:1711. doi: 10.2147/JMDH.S313968. [PMC free article] [PubMed] [CrossRef] [Google Scholar] [Ref list]
40. S. Dolati, S. Sadreddini, D. Rostamzadeh, M. Ahmadi, F. Jadidi-Niaragh and M. Yousefi, Utilization of nanoparticle technology in rheumatoid arthritis treatment, *Biomed. Pharmacother.*, 2016, **80**, 30–41
41. S. Xiao, Y. Tang, Z. Lv, Y. Lin and L. Chen, Nanomedicine–advantages for their use in rheumatoid arthritis theranostics, *J. Controlled Release*, 2019, **316**, 302–316
42. G. R. Burmester and J. E. Pope, Novel treatment strategies in rheumatoid arthritis, *Lancet*, 2017, **389**(10086), 2338–2348 .
43. P. Imming, C. Sinning and A. Meyer, Drugs, their targets and the nature and number of drug targets, *Nat. Rev. Drug Discovery*, 2006, **5**(10), 821–834.
44. L. R. James, Z.-Q. Xu, R. Sluyter, E. L. Hawksworth, C. Kelso and B. Lai, *et al.*, An investigation into the interactions of gold nanoparticles and anti-arthritic drugs with macrophages, and their reactivity towards thioredoxin reductase, *J. Inorg. Biochem.*, 2015, **142**, 28–38
45. G. M. Chalbatani, H. Dana, E. Gharagouzloo, S. Grijalvo, R. Eritja and C. D. Logsdon, *et al.*, Small interfering RNAs (siRNAs) in cancer therapy: a nano-based approach, *Int. J. Nanomed.*, 2019, **14**, 3111
46.S. Dhanasekaran and S. Chopra, Getting a handle on smart drug delivery systems—A comprehensive view of therapeutic targeting strategies, *Smart Drug Delivery System*, 2016, vol. 1, pp. 31–62
47. S. T. Jahan, S. Sadat, M. Walliser and A. Haddadi, Targeted therapeutic nanoparticles: an immense promise to fight against cancer, *J. Drug Delivery*, 2017, **2017**, 9090325
48 .R. S. Kadam, D. W. Bourne and U. B. Kompella, Nano-advantage in enhanced drug delivery with biodegradable nanoparticles: contribution of reduced clearance, *Drug Metab. Dispos.*, 2012, **40**(7), 1380–1388
49. A. A. Yetisgin, S. Cetinel, M. Zuvin, A. Kosar and O. Kutlu, Therapeutic nanoparticles and their targeted delivery applications, *Molecules*, 2020, **25**(9), 2193
50 C. T. Pham, Nanotherapeutic approaches for the treatment of rheumatoid arthritis, *Wiley Interdiscip. Rev.: Nanomed. Nanobiotechnol.*, 2011, **3**(6), 607–619