Basic Concepts and Medicinal Applications of Nanotechnology

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DOI:10.48047/ecb/2023.12.si4.761

Abstract

Nanotechnology is a promising science based on length scales (between 1-100 nanometers). It is not a single entity but an interdisciplinary domain which incorporates physics, chemistry, material science, electronics, and biotechnology. Nanoscale particles, materials and devices can be fabricated using either "bottom-up" or "top-down" fabrication approaches. The top- down approach involves the breaking down of bulk material into nanosized units through techniques like photolithography, nanomolding, dip-pen lithography, nanofluids and precision engineering. Conversely, contemporary and commonly used bottom-up approach for synthesis of nano -substances is concerned with build-up of nanostructures atom by atom or molecule by molecule through various physical, chemical processes, self assembly and positional techniques. Newer Green technology uses the plant extracts or live plants or their parts to synthesize inorganic as well as organic nanoparticles. Green synthesis enjoys advantages of being environment- friendly synthesis process, high scalability, simple one-pot reaction overcoming limitations and cumbersome process of fabrication by physical and chemical means In medicine, the enormous implications for diagnostic, therapeutic use to improve drug-delivery, bioavailability, efficacy and decrease in adverse effects compel their wide use in various diseases like cancer, infections, inflammation and delayed would healing. The wider applicability, easier and eco friendly nature has ascertained the further development of nanotechnology in times to come.

Keywords: Nanotechnology, Green synthesis, Fabrication approaches, Silver and Gold nanoparticles, Applications.

1. Introduction

Nanotechnology is a science based on length scales (in nanometers). The concept of Nanotechnology was introduced by Nobel laureate Richard P. Feynman during his famous lecture ''There's a Plenty of Room at the Bottom," in 1959 **Feynman R. (1960)** .The term "Nanotechnology" was later on coined by a Japanese scientist, Norio Taniguchi **Sanjeer M (2022)** and popularized by Erik Drexler **Drexler K E (1981)** .The term "nanotechnology" is a combination of the Greek words "Nano", "Techne" and "logos," which mean' dwarf', "manmade" and "language/ study," respectively. Thus the etymology of Nanotechnology itself shows that it is not nature derived. It should also be noted that nanoscience and nanotechnology are fundamentally different yet related terms as the former is the science of studying and developing materials in nanoscale measuring 1nm-100nm (as per United States nanotechnology initiative **https://www.nano.gov. (2021),** and the latter is the application of this study in different fields. Often these terms are used interchangeably in practice. The preparation of nanosize particles by employing diverse synthetic strategies, particle structure and size modification techniques change the physicochemical properties of bulk materials **Chandrakala et al. (2022)** . They are then utilized in diverse applications for the benefit of mankind by virtue of their high surface to volume ratio with enhanced capability to interact with the molecular or cellular process and the possibility to influence their functions **Nath D and Banerjee P (2013)** .

A greater number of biological systems such as Ribosome, Lysosome, DNA and Virus found on earth are at the nanoscale level, again, highlighting the importance of structures in nanoscale and technology based on it in our life **Bayda et al. (2019)**. In field of medicine some of the advantages of nanomaterials are tissue-specific targeting, dose and toxicity reduction, as well as increased bioavailability, drug efficacy, enhanced drug stability, controlled release inside cell and reduction of secondary adverse effects **Shah B R and Mraz J (2020)**. By incorporating biological principles, a scientist can get in-lab results using chemistry, physics, nanotechnology and engineering principles for the production and characterization of nanoscale biological molecules and devices using biological systems **Roco M C. (2003).**

Nanoscale materials and devices can be fabricated using either "bottom-up" or "top-down" fabrication approaches. The top-down approach is essentially the breaking down of bulk material to get nano-sized particles. Top-down nanofabrication technologies, include photolithography, nanomolding, dip-pen lithography and nanofluids **Pappas N A(2004).**This can be achieved by using advanced techniques such as precision engineering and lithography which have been developed and optimized by industry during recent decades. While most contemporary technologies rely on the ''top-down" approach, bottom-up(also called molecular) nanotechnology holds greater promise for breakthroughs in, medicine and healthcare **Birol H et al. (2013)** .

Bottom up approach includes build-up of nanostructures from the bottom: atom-by-atom or molecule-by-molecule by physical and chemical processes using controlled manipulation of self-assembly of atoms and molecules **Ferrari M. (2005)** . Chemical synthesis is a technique of producing rough materials which can be used either directly in product in their bulk disordered form, or as the building blocks of more advanced ordered materials. Similarly self-assembly is another bottom-up technique in which atoms or molecules organize themselves into ordered nanostructures by chemical-physical interactions between them.

TRADITIONAL AND CONTEMPORARY METHODS FOR THE SYNTHESIS AND CHARACTERIZATIONS OF NANOMATERIALS:

For several years, scientists have constantly explored different synthetic methods to synthesize nanoparticles. The traditional physical method such as laser ablation, lithography and high-energy irradiation involves the use of costly equipment, high temperature and pressure, large space area for setting up of machines **Chandrasekaran R (2016)** . Likewise , chemical (another traditional) method such as chemical reduction, electrochemistry, and photochemical reduction **Soni M (2018)** involves use of toxic solvents, high pressure and high temperature **Mubayi A et al. (2012)** shown in (figure

1A).These nanoparticles are then characterized by different spectroscopic techniques as shown in (figure 1B).

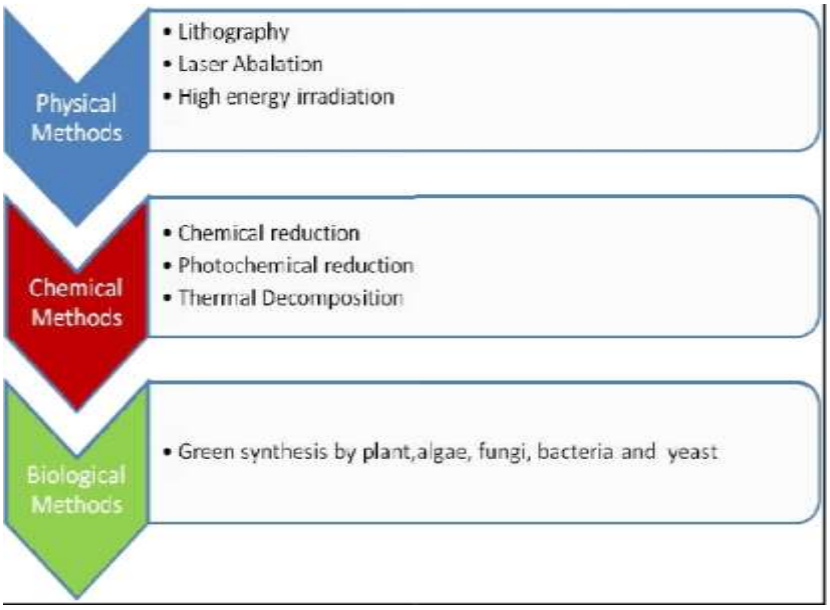

Figure 1A. Main Methods used for the Synthesis of Nanomaterials **Osagie C et al.(2021)**

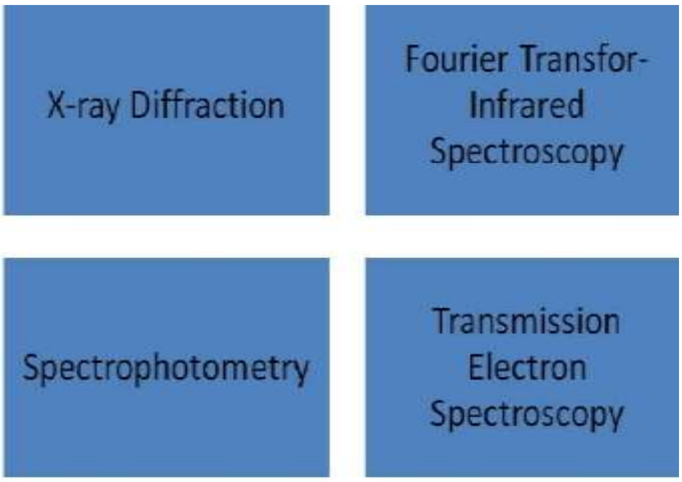

Figure 1 B. Methods used for the Characterizations of Nanomaterials **Osagie C et al.(2021)**

Researchers have not only been able to synthesize nanoparticles but also obtained particles of exotic shapes and morphologies through Green Approach **Savithramma N et al (2011)** .The environment and eco friendly approach for synthesis of nanoparticles using microorganisms and different plants is commonly referred to as Green Approach holding immense potential. These biological systems can transform inorganic metal ions into metal nanoparticles via the reductive capacities of the proteins and metabolites present in these organisms **Jegadeeswaran** P **et al (2011)** . For example, silver nanoparticles (AgNPs) have been reported to be synthesized from various parts of herbal plants viz. bark of Cinnamon **Won SW et al.(2009)**, Neem leaves **Tripathi et al.(2009)**, , Tannic acid **Watcharaporn K et al.(2014)**, and various plant leaves **Song J Y and Kim B S (2009).**In recent times, several groups have been reported to achieve success in the synthesis of Au, Ag and Pd nanoparticles obtained from extracts of plant parts, e.g., leaves **Shankar et al. (2003).**, lemongrass **Shankar et al. (2004).**, neem leaves **Parashar U K et al. (2009)** and others as shown in (figure 2).

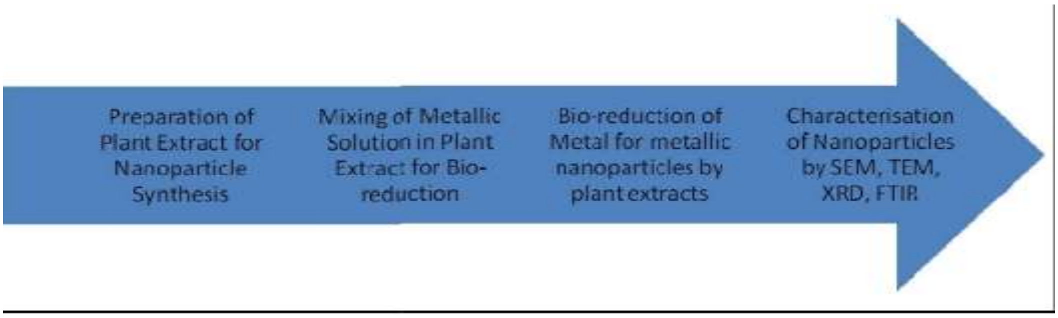

Figure 2. Steps Involved in the Green Synthesis of Nanoparticles **Parashar U K et al. (2009)**

Bio-inspired methods are economical and restrict the use of toxic chemicals as well as high pressure, energy and temperatures . Nanoparticles may be synthesized either intracellularly or extracellularly employing yeast, fungi bacteria or plant materials. Parameters such as the concentration of the involved materials, the order and volume of adding materials to the system, stir rate, time of stirring and temperature affect nanoparticle size and stability **Jyothi NVN et al. (2010) ; Aravand MA et al (2008).**

With particularly the source of plant extract being the most vital factor affecting the morphology of synthesized nanoparticles. Also, this is so because different plant extracts contain different concentrations of biochemical reducing agents. The change in concentration of biochemical reducing agents differs regionally as well as seasonally in most plant extracts. This variation will lead to difference in nanoparticle synthesized in every batch **Phillip D. (2011).** To overcome this difficulty researchers have now progressed to different level in plant mediated synthesis of nanoparticles, with involvement of plant tissue culture. Successful development of silver nanoparticles, from in vitro plant and callus culture has been reported from Costus speciosus **Malabadi RB et al. (2012).**

In addition to plant extracts, live plants can be used for the synthesis. While live plants are especially suited for making nanoparticles that must be free of toxic contaminants as required in therapeutic applications, plant extract based synthesis can provide nanoparticles of a controlled size and morphology **Kulkarni N and Muddapur U (2014)** . Living Plant mediated synthesis of metal nanoparticles is gaining importance owing to its simplicity, rapid rate of synthesis of nanoparticles of diverse morphologies and elimination of elaborate maintenance of cell cultures and ecofriendliness.

Categories of nanoparticles

On the basis of the final product, nanoparticles are broadly classified into two categories, inorganic nanoparticles and organic nanoparticles. Inorganic nanoparticles include metal nanoparticles (Ag, Au, Pt, and Pd), magnetic nanoparticles and semi-conductor nanoparticles(TiO2, SiO2, ZnO2) **Mittal J et al (2014)** and organic nanoparticles include carbon nanoparticles. Commonly used inorganic nanoparticles are discussed as follows.

a)Gold nanoparticles (AuNPs)

AuNPs are a fascinating class of nanomaterials that can be used for a wide range of biomedical applications, including bio-imaging, lateral flow assays, environmental detection and purification, data storage, drug delivery, biomarkers, catalysis, chemical sensors, and DNA detection .**Boisselier and Astruc (2009); Saha K et al. (2012) ; Corti CW et al. (2004); Das SK et al.(2010).** By treating gold (III) chloride trihydrate (HAuCl4) with a hot aqueous extract of the Ganoderma spp. mycelia., water-soluble ,non-cytotoxic and biocompatible AuNP with an average size of 20 nm. are synthesized. So it is essential to validate whether as-prepared AuNPs are toxic or biocompatible, because biomedical applications of any nanomaterial involve intentional exposure to nanoparticles. Therefore, understanding the properties of nanoparticles and their effects on the human body are crucial before they are clinically applied **Parab HJ et al (2011)** .

The leaf, root, latex, seed, and stem of various plants are being used for metal nanoparticle synthesis(Table1).The key active agents in some of these synthesis are believed to be polyphenols .

Table 1: Applications of Green Synthesized Au Nanoparticles Using Various Plants Parts

Plant	**Plant Part**	**Size (nm)**	**Morphology**	**Applications**
Curcumaekwangsiensis	Leaf aqueous extract	8–25	Spherical	Cytotoxicity, antioxidant, and anti-human ovarian cancer activities **Chen J et al .(2021)**
Gelidiumpusillum	Seaweed extract	12± 4.2	Spherical	Anticancer activity **Jeyarani S et al (2020)**
Litsea cubeba	Fruit extract	8–18	Spherical	Catalytic reduction of 4-nitrophenol **Doan VD et al.(2020)**
Desmodiumgangeticum	Leaf extract	16± 4	Spherical	Antioxidant **Ghosh NS et al. (2020)**
Hibiscus sabdariffa	Flower extract	15–45	Spherical	Antiacute myeloid leukemia **Zangeneh MM et al. (2020)**
Menta piperita	Leaves	15	Spherical	Antibacterial activity **MubarakAli et al. (2020)**
Trigonella foenum-	Seeds	15–25	Spherical	Size-dependent

graecum				catalytic activity **Aromal SA. Philip D. (2012)**
Tanacetum vulgare	Fruit	11	Triangular	**Dubey SP et al. (2020)**
Mangifera indica	Leaves	17–20	Spherical	**Philip D (2010)**
Zingiber officinale	Roots	5–15	Spherical	Drug delivery, gene delivery or as biosensors **Kumar KP et al. (2011)**
Rosa hybrid	Petal	10	Spherical, Triangular and Hexagonal	Antibacterial activity **Singh A et al. (2013)**
Dalbergia coromand eliana	Roots	10.5	Spherical	Catalytic reduction potential against Congo red and methyl orange **Umamaheswari C et al. (2018)**
Malvaceae plant Cor chorusolitorius	leaf extract	37–50	Quasi-Spherical	Antiproliferative Effect in Cancer Cells **Ismail EH C et al. (2018)**
Thyme	Flower extract	35	Spherical	Antibacterial, antioxidant and cytotoxicity properties **Hamelian M et al. (2018)**
Croton Caudatus Geisel	Leaf extract	20	Spherical	Antibacterial, anti-fungal, Free radical scavenging ability and cytotoxicity activity **Dey S et al . (2015)**

b) Silver Nanoparticles (AgNPs)

The most exploited use of silver nanoparticles is their antimicrobial and anti-inflammatory capacity **Prabhu S and Poulose EK (2012)** . This motivates its use in a large number of biomedical and environmental applications as well as a growing list of consumer products. Due to strong antimicrobial activity, AgNPs are also used in clothing, food industry, sunscreens, as well as in pest and diseases management in agriculture **Abou El-Nour et al. (2010)**.

Silver nanoparticles also find applications in human healthcare such as coating contact lenses, cardiovascular implants, wound dressing, clinical diagnosis and treatment, bone cement and other implants, medical catheters, bandages, endodontic filling materials, dental instruments and targeted drug delivery **Ge L et al .(2014)** .

Though there are many mechanisms attributed to the antimicrobial activity shown by silver nanoparticles, the actual and most reliable mechanism is not fully understood or cannot be generalized as the nanoparticles are found to act on different organisms in different ways .

Extracts of a diverse range of plant species have been successfully used in making Ag nanoparticles (Table 2). The easy availability, scalability, environmentally benign nature, various options available, and the advantage of quicker synthesis make plant extracts the best and an excellent choice for nanosilver synthesis
Moringa oleifera (M. oleifera; Family: Moringaceae; English name: drumstick tree) leaves have also been reported to possess antitumor, cardioprotective, hypotensive, wound and eye healing properties. Synthesis of AgNPs in cold condition has been reported, reducing the silver ions present in the silver nitrate solution by the aqueous extract of M. oleifera leaves. The capping around each particle provides regular chemical environment formed by the bio-organic compound present in the M. oleifera leaf broth, which may be chiefly responsible for the particles to become stabilized. Applications of such eco-friendly nanoparticles in bactericidal, wound healing and other medical and electronic applications, makes this method potentially stimulating for the large scale synthesis of nanomaterials **Mubayi A et al.(2012).**

Table 2 : Applications of Green Synthesized Au Nanoparticles Using Various Plants Parts

Plant	**Plant Part**	**Size (nm)**	**Morphology**	**Application**
Argemone maxicana	Leaf Extract	30	-	Antibacterial and Antifungal **Singh A et al .(2010)**
Acalypha indica	Leaf Extract	20-30	-	Antibacterial **Krishnaraj C et al .(2010)**
Mangifera indica	Leaf Extract	20	Triangular, Hexagonal and nearly Spherical nanoparticles	-
Cassia fistula	Leaf Extract	50–60	-	**Lin L et al .(2010)**
Catharanthus roseus	Leaf Extract	48-67	Crystalline[59]	**Mukunthan KS et al .(2011)**
Clerodendrum inerme	Leaf Extract	5-60	-	Treating skin ailments **Farooqui MDA et al .(2010)**
Murrayakoenigii	Leaf Extract	10-25	Spherical	**Christensen L. (2011)**
Aloe vera	Leaf Extract	15.2	-	**Chandran SP et al .(2006)**
Piper betle	Leaf Extract	3-37	Crystalline	**Mallikarjuna K et al .(2012)**
Ocimum tenuiflorum	Leaf Extract	25-40		Antibacterial **Patil RS et al .(2012)**

Coleus aromaticus	Leaf Extract	44	-	Antibacterial **Vanaja M and Annadurai G (2012)**
Apiin(henna leaves)	Leaf Extract	21	Quasi-Spherical	Hyperthermia of cancer cells and in IR-absorbing optical coatings **Kasturi J et al .(2009)**
Emblica officinalis	Fruit extract	10-20	-	Transmetallation **Ankamwar B et al .(2005)**
Carica papaya	Fruit extract	15	Cubic structure	Antimicrobial **Jain D et al .(2009)**
Tanacetum vulgare	Fruit extract	16	-	**Dubey SP et al .(2010)**
Cinnamon zeylanicum	Bark extract	31 - 40	Crystalline	Antibacterial **Sathishkumar M et al .(2009)**
Jatropha curcas	Seed extract	15 - 50	Spherical/ Crystalline	**Bar H et al .(2009)**
Syzygiumcumini	Leaf and seed extract	73 - 92	Spherical	**Kumar V et al .(2009)**

2. Applications of nanotechnology

Nanotechnology has myriad roles in investigation, diagnosis and therapy through nanosensors, nanomaterials and nanodevices. Applications of nanotechnology in different medicinal sectors are discussed as follows –

Tool in Forensic Investigations

Nano Sensors have become one important novel tool to the forensic scientist in criminal investigations **Prasad V et al. (2020).** For the detection of morphine, cobalt oxide nanoparticles, graphene and ionic liquid crystal modified on a carbon paste electrochemical sensor was fabricated in the study conducted by **Atta et al. (2019)** . **Dashtian et al. (2016)** detected morphine in urine samples using new imprinted polymer-supported on multiwalled carbon nanotubes magnetized with Fe_3O_4 nanoparticles (MWNT-Fe_3O_4-NPs) which yielded satisfactory response feasible for analysis of morphine in urine and water. Subsequently, magnetic solid phase extraction based silane-modified magnetic nanoparticles by HPLC/diode array detection (DAD) was applied for the detection of ultra-trace amounts of morphine in human hair samples for the diagnosis of morphine addiction **Boojaria A et al. (2015)**

Nanotechnology has also been used for the detection of illegally added dexamethasone to cosmetic products which has adverse effects such as skin atrophy, cutaneous reactivity, and some systematic side effects such as hypertension, diabetes mellitus etc. For its detection, a quick and efficient screening method has been developed by the preparation of magnetic molecularly imprinted polymers for selective dexamethasone recognition, extraction and determination **Du W et al (2018).** To extract the DNA for quality PCR, magnetic nanoparticles, silica based magnetic nanoparticles and copper nanoparticles are used on biological evidences (significant body fluids and skeletal remains) **Lad A N et al.(2016)** .

In recent times, there have been novel nanotechnology applications in fingerprint development such as zinc sulfide/cadmium selenide nanoparticles are used to enhance and visualize finger marks under UV light **Kaushik M et al. (2017)** . Similarly, the silver physical developer (Ag-PD), silica nanoparticles (SiO_2-NPs) and aluminum oxide nanoparticles are also used in fingerprint development **Prasad V et al. (2020)** .

Antimicrobial Activity

Though the exact mechanism behind antimicrobial activity of metallic nanoparticles is not clear, there are many concepts on the action of nanoparticles to cause the antimicrobial effects. Silver nanoparticles have the ability to bind with the bacterial cell wall and consequently penetrate it, thereby causing structural changes in the cell membrane leading to increased permeability of the cell membrane and consequently the death of the cell **Fajardo C et al. (2022)** . Free radicals are also formed by the silver nanoparticles and it may be considered to be another mechanism for bacterial cell death.(as suggested by study of electron spin resonance spectroscopy) .

As is known there is a natural tendency of a soft acid to react with a soft base **Morones J R et al.(2005)** . The cells are extensively made up of sulfur and phosphorus which are soft bases and silver is a soft acid. DNA has sulfur and phosphorus as its major components; the nanoparticles can act on these soft bases and destroy the DNA which would definitely lead to cell death **Hatchett DW. White HS. (1996).** The interaction of the silver nanoparticles with the sulfur and phosphorus of the DNA can lead to problems in the DNA replication of the bacteria and thus terminate the microbes. Besides these, the reactive oxygen species produced by the contact of silver nanoparticles with bacterial cell inhibit respiratory enzyme and attack the cell itself.

It has also been found that the nanoparticles can moderate the signal transduction in bacteria. There is well-proven information that phosphorylation of protein substrates in bacteria influences bacterial signal transduction. Dephosphorylation is noted only in the tyrosine residues of gram negative bacteria. The phosphor tyrosine profile of bacterial peptides is altered by the nanoparticles. It was found that the nanoparticles dephosphorylate the peptide substrates on tyrosine residues, which leads to signal transduction inhibition and thus the stoppage of growth. It is, however, necessary to understand that further research is required on the topic to thoroughly establish the claims .

Metal NPs have different modes of action against bacteria, of which, one of the strongest effects is against the cell membrane and cell wall by attaching to them by electrostatic interaction and being able to disrupt them. They can also disrupt the ion transport by association with ions and ion channels. NPs can cause double strand breaks of the DNA, interfere with the ribosome assembly and the enzymatic activity, via electrostatic interactions. Metal NPs are also known to trigger a higher oxidative stress state increasing the amount of reactive oxygen species (ROS) which can damage proteins, lipids, and DNA. Colloidal silver nanoparticles are one of the main nanotechnology based products used against a wide spectrum of pathogens, including viruses, parasites, fungi, and bacteria **Nangmenyi G et al.(2014)** .

The antimicrobial activity is related to the oxidation capacity to DNA and proteins with highly damaging effects. For example, silver nanoparticles can destroy strains of methicillin-resistant S. aureus **Nangmenyi G.et al (1905)** .

Antiviral Activity

AgNPs also act as anti-viral agents, due to their inhibitory efficacy against numerous viruses, including certain strains of hepatitis, corona virus, influenza, herpes, recombinant respiratory syncytial virus and human immunodeficiency virus **Brown AN et al. (2012).**It is widely accepted that AgNPs contribute towards the inhibition of virus because of effective interactions with sulfhydra, amino, carboxyl, phosphate and imidazole groups **Yuan YG et al. (2018)** .

Anticancer activity

Cancer is a conjunction of diseases characterized by the abnormal growth of tissue that might lead to the development of tumors that can spread into other tissues and cause severe effects in the patient, with complications and severities potentially causing death **Y Li et al. (2016)** . Current approaches such as chemotherapy and radiotherapy, although functional, are not completely effective and present significant drawbacks in the form of severe side effects, such as immune suppression, anemia, sickness, or even death **Pavlopoulou A et al .(2016)** . As a consequence, significant efforts have been made towards the development of new approaches. Consequently, the use of nanotechnology has become more popular, as it can be applied towards cancer treatment and overcome substantial drawbacks (of the traditional treatment options) without experiencing toxicity to healthy tissues **Mostafavi E. (2019)** . For instance, different NPs have been shown to effectively encapsulate chemotherapy drugs and deliver them directly to the tumor site, diminishing (or in some cases, completely eradicating) the possible side effects **Ahmed S E. et al (2018)** .

Moreover, the use of NMs allows for a more efficient permeability to the tumor site, when compared to the free drugs **Asadi N et al. (2018)** and **Vahed Z et al . (2019)** . NPs can also be functionalized to target specific cancerous cells by attaching different molecules, such as aptamers, proteins or antibodies, and the NPs can specifically bind to the carcinogenic structures **Wang J et al. (2018).**

Anti-cancer activities of silver nanoparticles are also being widely studied AgNPs have the ability to stimulate the production of ROS and thus destroying the mitochondrial respiratory chain of cancer cells **Balmain A. (2003)** .Some researchers have reported that AgNPs induced acytotoxic effect against leukemic cells. Guo et al. studied the PVP-coated AgNPs could effectively reduce the activity of acute myeloid leukemia (AML) cells and stimulate DNA damage and apoptosis through the generation of ROS and the release of silver ions.

El-Deeb et al.reported that AgNPs used for the treatment of colon carcinoma Caco-2 cells with concentrations up to 39 µg/mL cause 60% inhibition of Caco-2 cell proliferation **El-Deeb NM et al. (2015)** . AgNPs have exhibited cytotoxic effect to MCF-7 breast cancer cells at 20 µg/mL for 48 h **Chung IM et al. (2016)** and also suppressed lung cancer cells, H1299 in which 50% of cells were killed at 5 µg/mL **He Y. et.al. (2016)** . In colon cancer cells, AgNPs have shown effective killings at 5 to28 g/mL in cell lines such as HCT116 **Gurunathan S. et. al. (2018),** Caco-2 **Böhmert L. (2015**) and HT-29 **Mani S. Et.al. (2019)** . Additionally they have been shown to have great potential to act as a nanocarrier to deliver anti-cancer drugs to cancer cells Chugh H. Et.al. and Mathur.P et al (2018) . This evidence strongly supports the potential use of AgNPs for cancer chemotherapy **Hsin YH. (2019).** K. X. Lee et al. prepared AgPCA (PCA: protocatechuic acid) by using Garcinia mangostana fruit peel extract. They reported AgNPs loaded with PCA (AgPCA) resulted in 80% of inhibition at 15.6 µg/mL as compared to AgNPs which only killed 5% of HCT116 colorectal cells at the same concentration **Lee KX. (2014)** . Thus nanomaterials can be employed to act itself or to deliver therapeutic molecules to modulate essential biological processes like autophagy, metabolism or oxidative stress, exerting anticancer activity **Sadaf S . (2014).**

Anti-Diabetic Activity

Govindaraju et al. (2020) synthesized guavanoic acid functionalized gold nanoparticles and its anti-diabetic activity was studied in-vitro by using L6 rat skeletal muscle cell lines. The active nanoparticles of guanonic acid were found to enhance the insulin-dependent glucose uptake **Govindaraju K. (2020)** .
Anti-inflammatory and promotion of wound healing -AgNPs have the ability to penetrate epithelial cells and inflammatory cells resulting in better efficacy and better durability in the treatment. They also have the best selection of target sites such as inflammatory cells or tissues **Agarwal H. (2019**).

Initial studies have suggested that the acceleration of wound healing in the presence of nanoparticles is due to the reduction of local matrix metalloproteinase (MMP) activity and the increase in neutrophil apoptosis within the wound. It has been suggested that the MMP can induce inflammation and hence cause non-healing of wounds **Bonoiu A. (2009).**

A reduction in the levels of pro-inflammatory cytokines was also validated in a mouse model with burn injury when silver nanoparticles were introduced **Khayal E. (2019).** It was also found that silver nanoparticles can inhibit the activities of interferon gamma and tumour necrosis factor alpha, which are involved in inflammation **Prabhu S. (2012)** . Though these studies prove that silver nanoparticles are involved in the anti-inflammatory effects, the precise mechanism of action remains to be determined.

Enhanced and targeted drug delivery
The advantages of using nanoparticles for the drug delivery result from their two main basic properties. First nanoparticles, because of their small size can penetrate through smaller capillaries and are taken up by cells, which allow efficient drug accumulation at the target sites. Second, the use of biodegradable materials for nanoparticle preparation allows sustained drug release within the target site over the period of days or even weeks.

Metal Nano Particles (MNPs) are extensively utilized as drug delivery carriers for various therapeutic agents(antibodies, nucleic acids, chemotherapeutic drugs, peptides, etc.). Most of the MNPs like silver, gold, palladium, titanium, zinc, and copper nanoparticles possess enhanced tunable optical properties. The coating of MNP surface has been optimized to control the drug loading, drug delivery, and drug release in the target area **Tan G. (2012)** Improved drug efficiency and bioavailability - Nanoparticles also increase the therapeutic efficiency as well as bioavailability. They reduce fed/fasted variability, increase drug stability and bioavailability of drugs that are either unstable or have unacceptably low bioavailability in non-nanoparticulate dosage form **Nissinen T.(2016)** .

CONCLUSION:

Thus, though by definition, Nanotechnology means related to smaller scales (1-100nm) but actually it has made colossal impacts to benefit the mankind because of its multidisciplinary nature and multisectorial infiltration. In medicine it has helped through biosensors in the diagnosis of diseases, through nanomaterials and nanodevices to improve drug delivery to target sites, increase the efficacy of drugs and cost effectiveness of treatment of diseases as diverse as cancer, infection, diabetes. While nanotechnology is still in developmental phase but it has been proved beyond doubt that in future the nanoscience and technology based on it will continue to flourish even more astoundingly.

Conflict of interest

The authors have no conflicts of interest regarding this investigation**.**

Acknowledgments

Nil

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