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Current uses and applications of Nanotechnology and its future prospects

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ABSTRACT
Nanotechnology is a reassuring subject of multidisciplinary exploration and showed a broad range of opportunities and applications in numerous fields such as agriculture, medicine, pharmaceuticals, microchips, nanolithography, healthcare, textile industry and various biomaterials. The major application of nanotechnology is applied in drug delivery system and their therapies at molecular level as well as cellular level. In literature, applications of nanoparticles (e.g. carbon rods, nanoboats etc.) and its uses along with itsadvantages of nanotechnology are boundless. The most familiar example in case of nanotechnology is seen in developing countries where major challenge is to develop crops which are pest and drought resistant, which also increases yield. Expenditure and funding in agriculture and food nanotechnologies carrygreat advantage because of the unrealized advantages from enhanced food quality and safety to decreased agricultural inputs and enhanced fining and nutrition. In this review, we mentioned various strategies along with its mechanism of nanotechnology and applied as novel drug delivery system with numerous potential of nanoparticles in sustainable management of agriculture and helpful in crop improvement and its productivity. In addition, we also focused on medicinal plants which can be used for biogenic synthesis of colloidal gold and silver nanoparticles as compared to other microbes and fungi. These biogenic nanomaterials have shown prominent ability as wound healing agents.
Keywords: *Nanotechnology, Nanorobots, Carbon rods, Nanoparticles, medicinal plants, nanocarriers, drug delivery.*

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INTRODUCTION

Nanomedicine and nano delivery system, considered as novel approach usingparticles in the range of nanoscale are employed to set up advice pertaining to diagnose diseases or deliver some therapeutic agents atspecificlocation or sites using administrative methodology[1]. So, nanotechnology provides diverse advantages incontrolling and managing chronic human ailmentswhich is mainly targeted through site-specific regions.In literature, various magnificent uses are reported in case of nanomedicine (biological, chemotherapeutic, immunotherapeutic agents etc.) is mainly used in the treatment of different ailments[2].It has been studied that micro-organisms possess protecting agents called biofilms which can cover the antibiotics. Formation of biofilms can take place when the micro-organisms get attached with the moist surface and may form the jelly/slummy like substance. Biofilms act as encapsulation for microorganisms and play an important role for its protection and these are generally made up of extracellular polymeric matrix[3].Normally when the biofilm surrounds the microorganisms, its physiological nature changes and it may have increased the life of microorganisms and allow them to opt for numerous and longer life cycles. Biofilm which surrounds the microorganisms can play a very crucial role for the activation of innate immune defence system of the host[4]. Therefore, biofilm may increase the endurance period of microorganisms which may exist within the host.In other words, it may act as resistance for microorganisms as it does not permit the antibiotics to hit the surface of microorganism because of the complex structure of biofilm.In contrast, biofilms are impermeable in nature that means it doesn't allow the entry of antibiotics in microbes and played a very important role in the treatment of several microorganisms that cause the infectious disease[5].In this regard, various studies were conducted e.g. *Staphylococcus aureus,* resistant to methicillin which is mainly covered through biofilms. There are several kinds of polysaccharides which protect the microorganisms by suppressing the activity of neutrophils towards the microbes. In other words, pathogens which were earlier considered as extracellular can act as intracellular after its conversion with the help of biofilm and these may have helped the microbes to pierce inside the host.

Therapeutics plants having rich ingredients are employed for the development of drugs and medicines. In this regard, studies were conducted on medicinal plants with reference to its extraction of active moieties (using different solvent system e.g. methanol, ethanol, ethyl acetate etc.) and applied them as effective therapy against various infectious diseases[6].The paramount objective of medicinal plant treatment is to suppress the growth and activity of microorganisms which are responsible for causing diseases. Although persistent use of medicinal plant treatmentmakesmicroorganisms moreresistant towards them. In other words, pathogens areactiveonly for a limited period of time and its concentration is very less and is reported in the range of nano scales called as nanoparticles and this technique is called as nanotechnology[7]. In recent times, nanotechnology has emerged as a promising field and plays an important role in advanced medicinal science.

In literature, several nanoparticles are reported from micro-organisms including medicinal plants and showed its effectiveness against various diseases. So, these nanoparticles (i.e. natural as well as inorganic materials) showed its effectiveness for the development of drugs and medicines and also reported its antibacterial and antibiofilm properties[8, 9]. Apart from all this, nanoparticles have different mechanisms to control the activity of biofilm growth and it stops microbial growth. Nanoparticles interact with the biofilm, and get attached to the surface of biofilm and further penetrate through it towards the microorganisms. Specifically, nanoparticles penetrate into the biofilm layer, denatures the protein, damage cell physiology, haltenzyme activity and prevent or inhibit the replication of DNA[10].

Nanoparticles are very mobile in the free state, have extensive surface area and may possess quantum effects. Thus, they have a vast range of compositions, depending on the use and the product. Nanoparticles find its application in engineering, chemistry, and in biology and environmental remediation. The fascinating property of nanoparticle is it that it can manipulate materials to a great extent. Due to their sub-microscopic size, they have distinctive material characteristic, and find applications such as in catalysis and in engineering. Nanoparticles are of different types based on their capability which are as follows: semi-conducting, polymeric, carbon based and ceramic. They can also be categorized as hard and soft nanoparticles. Examples of hard nanoparticles include titania, silica and fullerenes whereas liposomes, nanodroplets and vesicles are soft nanoparticles [11, 12].

NANO BASED DRUG DELIVERY SYSTEM

Nano based drug delivery system considered as one of the novel approach especially for drug delivery mechanism**[13].**So, these nano sized materials may overcome the drawbacks and short comings of traditional drug delivery system. This approach was selected due to the properties of nano sized delivery system which are as follows:

- Delivering drugs using high concentrations to specific sites in terms of its distinctive size including high loading capabilities.
- Drugs deliver i.e. nanosized particle mayincreases the whole surface area of the drugs allocating speedy suspension in the blood.
- Shows EPR (enhanced permeation and retention) effect, i.e., enhanced permeation through the barriers due to small size and retention due to poor lymphatic drainage.
- Reduction in dosage of drug formulation and also showing fewer side effects.

Recently, various studies were conducted related to delivery systems using therapeutic agents andalso applied some natural bioactive components againstdifferent diseases.In literature, differenttypes of drug delivery systems are reported profitablybut having some challenges and problems[14].

Designing of drugs is a propitious property which mainly characterizes the disclosure of new drugs and it's predicted on the basis of an immunobiological target molecule. Due to recent advancement in the field of computer science including its advancement with respect to its experimental methods for purification of peptides/protein/amino acids. Natural materials in the form of nanoparticles can impart feasible and interesting ideas to address challenges faced in drug designing and discovery [15].

Every drug delivery system having its physical, biological and chemical properties and showing some affinity for drugs through chemical inter linkage for e.g. hydrogen and covalent bonds or through some physical interconnections e.g. van der Waals force, electrostatic force etc. It was found that a cross linkable lipid shell (CLS) that contains docetaxel and wortmannin for controlling the drug discharge kinetics was designed which was found to be effective *in vivo* and as well as *in vitro* conditions. Some mechanisms like diffusion, solvent, chemical reaction and stimuli-controlled release represent the release of drugs using nanocarriers [16]. In literature, biopolymeric substances are applied and used in the form of nanoparticles which are widely used or reported in case of drug delivery system. Some of these materials along with its properties are mentioned below.

- *Xanthan gum* (high molecular weight heteropolysaccharide; pharmaceutical excipient), polyanionic polysaccharide which exhibits bio adhesive and non-toxic properties. In literature, scientists have formulated a carrier using xanthan gum thiolate with L-cysteine to release tannin in the buccal mucosa pertaining to treat sialorrhea. This thiolation of xanthan gum resulted in enhanced adhesion on the buccal mucosa as compared to original xanthan gum. Furthermore, xanthan gum thiolate has a greater uptake of saliva whereas tannic acid dries the oral mucosa. Thus, in this manner, this system would be a productive way of lowering the salivary flow of people suffering from sialorrhea. Some properties of xanthan gum include that it is both soluble in hot and cold water and in general it is not affected by changes in pH value. It also dissolves in all acids and bases and its solutions exhibit thaw stability. Apart from pharmaceutical uses, xanthan gum is used in gluten free baking, stabilizing emulsions and foams, in molecular gastronomy for specification and for thickening sauces without altering taste [17].
- *Chitosan* is an important derivative(polymer) of chitin which is biocompatible and biodegradable used for wound dressing applications. It exhibits muco adhesive properties that could be utilised to act in the tight epithelial junctions. It has been used widely as a carrier in nanoparticle for drug delivery through several routes includingbuccal, nasal, eye, intestines and pulmonary system. Nanoparticles (NP) made with chitosan and chitosan derivatives exhibit a positive surface charge and mucoadhesive properties that can adhere to mucus membranes and release the drug payload in a sustained release manner. Chitosan-based nanoparticlehasseveral applications in non-parenteral drug delivery for the treatment of gastrointestinal diseases, cancer, pulmonary diseases, drug delivery to the brain and ocular infections. In addition, chitosan shows minimum toxicity both *in vitro* and some *in vivo* models [18].
- Recently, *metallic nanoparticles* are growing in several applications related to medicine e.g. biosensors, bioimaging, hyperthermia and sustained drug delivery. They bind to drugs, antibodies and other ligands and make promising systems in biomedicine. Some of the widely used metallic nanoparticles are gold, silver, copper and iron. Other metallic nanoparticles used are zinc oxide, platinum, palladium, cerium dioxide, selenium and gadolinium [**19**].
- *Cellulose nanoparticles*are used in nano deliverydue to their exceptional structural features and properties like renewability, biocompatibility and biodegradability. Cellulose and its derivatives are widely used in the drug delivery system originally for modifying solubility and gelation of the drugs. Cellulose is the most bountiful carbohydrate present in the environment. Itexhibits high tensile strength due to the presence of firm hydrogen bonds between the individual chains in cellulose microfibrils [20].
- *Liposomes* (spherical in shape; combination of steroids and phospholipids and size range i.e. 40-50nm) are a type of nanoparticle that are being used commercially to deliver antifungal drugs, vaccines and cytotoxic drugs. They are also used for cancer therapy, pharmaceutical industry, cosmetic industry and for the transport of different molecules inside the body. In short, liposomes are a great formulation for improvised drug delivery mechanism where its membrane structure its totally analogous with the cell membrane and enhanced its incorporation of drugs and considered them as better drug delivery vehicles. All these properties make liposomes widely usable in drug delivery and in various fields like biomedicine and nanotechnology [21].
- Inorganic nanoparticles used in drug delivery process includes gold, silver, silica and iron oxide nanoparticles. The usage of inorganic nanoparticles is not too extensive because only few of them are approved for clinical use whereas most of them are still under clinical trial stage. Metallic nanoparticles like gold and silver have specific properties like SPR (surface plasmon resonance) that other nanoparticles like dendrimer, micelles and liposomes lacks. They show various benefits such as excellent biocompatibility and versatility when it comes to functionalization of the surface. It has been studied that silver nanoparticles possess antimicrobial activity apart from drug delivery process. In another study, the iron oxide nanoparticles were processed using laser pyrolysis and were covered with violamycine B1, and anthracycline antibiotics and tested against the MCF-7 cells for its cytotoxic nature and the anti-proliferation characteristics in addition with its comparison with the commercially available iron oxide nanoparticles [22].

NANOPARTICLES AND AGRICULTURAL SECTOR

One of the major role of nanoparticles[16-22] which are commercially used and applied in agriculture sector. Out of these some are listed below as:

a) Polymeric nanoparticles: during the delivery of agrochemicals at slow and controlled manner but by the polymeric nanoparticles. Polymeric nanoparticles show many kinds of its specific qualities

such as superior biocompatibility and have minimal impact on non- targeted organisms. Kind of polymeric nanoparticles used in field of agriculture are polyethylene glycol, poly (epsilon-caprolactone), and poly (γ-glutamic acid)**.**

b) Silver nanoparticles: because of its own antimicrobial activity it is extensively used against a wide range of phytopathogens. Silver nanoparticles also help to enhance the plant growth**.**

c) Nano alumino-silicates: due to highest demand of alumino-silicate many chemical companies formulate it as an efficient pesticide.

d) Titanium dioxide nanoparticles: they act as biocompatible and are used as a disinfecting agent for water**.**

e) Carbon nanomaterials: to improve the seed germination several kind of Carbon nanoparticles are used such as graphene, graphene oxide, carbon dots, and fullerenes. There are some other which are utilized in this field itself such as zinc oxide, copper oxide nanoparticles, and magnetic nanoparticles**.**

AGRICULTURAL NANOTECHNOLOGY FOR THE ENHANCEMENT OF CROP PRODUCTIVITY

a) Nano pesticides and nano herbicides: they are formulated by exploiting the nanotechnological potential that helps in potential drug deliver mechanisms. These nano based materials increases the efficacy of herbicides formulations. The mechanism of action that is followed is, the targeted weed absorbs the nanoparticles that enters through the root system which in turn inhibits the glycolysis in the plant. Leading to weed starvation that ends up by killing it. Capsulations enhances the procedure by controlled release of particles. Poly (epsilon caprolactone) is a potent polymer used for encapsulation. Example- a polymeric nanoparticle containing atrazine herbicide was prepared and characterized for its efficiency. It was then found out that the polydispersity index was enhanced leading to the stability of drug up to 3 months in the soil [23].

b) Nanomaterials for disease management: nanoparticles possess certain natural medicinal applications. An example of plants that are treated with certain nanoparticles to manage their diseases are- Rice(*oryza sativa)* uses MWNTs nanoparticles by culturing the plants through MS media. It helps in decreasing superoxide dismutase (SOD) activity. Nanoparticles interact with plants through direct contact that influences their thermal, electrical and chemical properties. When tomato plants are exposed to multiwalled carbon nanotubes there a significant growth in seed germination is noted**[24].**

c) Nano fertilizers: scientist have developed nano fertilizers based on the same action mechanism as that of the nano herbicides. some examples of nano-fertilizers that have enhanced the agricultural applications are as follows- NKP fertilizer, it contains a nano-coating of sulphur (100mm layer), chitosan (78mm), genetic material delivery DNA, it contains nano-coating of gold (10-15mm) and starch (50-100mm)[11-18].

d) Nanotechnology in seed development: the germination of seed had shown increased effect with the involvement of nanoparticles. The seed germination is a sensitive phase of plant cycle which is majorly influenced by seed development. The applications of multiwalled carbon nanotubes has seen to positively influenced seed germination of different crop varieties including tomato, corn soyabean and starch. Nano particles of zeolite and fe/SiO_2 have seen potential affect in development of seeds and their germination. [12-16].

e) Nano biosensors: precision farming is an output of utilizing nano biosensors. It had helped in maximizing the output through minimized inputs. It makes use of computers, global satellites and their positioning systems that helps in creating correct environmental balances in the field. The use of biotechnology and nanotechnology have helped in creating the sensors that are more sensitive to their functions. For example, the use of nano sensors that utilizes carbon nanotubes12 or utilizes nano-cantilevers 13 are though small in size but are accurate enough to measure individual proteins or even small molecules [5-11].

EXAMPLES OF NANOPARTICLES FROM MEDICINAL PLANTS

Panax ginseng **(**family*Araliaceae*), is a medicinal plant that has established its name around the world due to anti-cancer, anti-therapeutic properties and immunomodulatory effects. This plant shows excellent bioactivity in-vitro but has poor bioavailability due to gastric digestion problems when given orally. Therefore, the role of nanotechnology plays a very essential role in creating nanoparticles or 'nano-ginseng' particles which have problem to have enormous benefits in cancer studies, biological treatment.

Fig.1. ***Panax ginseng***

and diagnosis of various diseases. Major benefits of nanomaterial-based medicines are that it is used as carriers in carbon nanotubes for metabolite enhancing of genosides. Genosides are bioactive compounds including saponins, flavonoids, polyphenols and other volatile oils. *P.ginseng* leaves are also used as mediated gold particles which are used in cosmetic industries for creating anti-ageing and whitening products. Auric chloride and silver nitrate are reduced at 80˚C which leads to the formation of gold and silver nanoparticles. Both gold and silver nanoparticles show anticoagulant properties and inhibition against biofilm produced by *S. aureus* and *Pseudomonas aeruginosa***[25].**

Dioscorea bulbifera **(family** *Dioscoreaceae*), is a potent medicinal plant which has been used in Indian and Chinese cultures from many years*. D. bulbifera* is rich in flavonoids, phenolics, reducing sugars, starch, ascorbic acid and citric acid. Biosynthesis of these particles is a quick process and nanoparticles are usually obtained in 5 hours. These particles also show antimicrobial activity against Gram negative and positive bacteria. The combination of silver nanoparticles and antibiotics have shown great results in nanotechnology by creating the control of antibiotic-resistant micro-organism and therapeutic management techniques for infection control. Antioxidant and antibiotic properties already exist in the extract of this plant and anti-inflammatory, plasmid curing, anticancer, properties also shown by the biofilm compound of this plant itself **[34].** Aucore Ag shell nanoparticle are also synthesized from these extracts. Highestbiofilm inhibition activity also shown by these biofilms. This leads to the death of cells **[26]** (**Fig. 2**).

Fig.2.*Dioscorea bulbifera*

Drosera binata **(**family *Droseraceae*), commonly known as forked sundew and is a native plant of Australia and New Zealand. This plant contains secondary metabolites present in its extract which when cultured in vitro show effective results against *S.aureous*. *Staphaylococcus aureous* is the most common infections agents involved in development of skin infection which are associated with antibiotic resistance against burn wounds. Silver nanoparticles (AgNPs) are very effective against multiple fungi and bacteria species. These silver nanoparticles are up to 100nm and affect cellular components like cell wall, membrane proteins and nucleic acid in bacteria and fungi. They include some carnivore species which also have medicinal properties and its in-vitro cultures show high multiplication. A single *D.binata* leaf produces 325 plantlets in a year. **[27]** (**Fig. 3**).

Fig.3. ***Drosera binata***

Plumbago zeylanica **(family** Plumbaginaceae), commonly known as Ceylon Leadwort, doctor bush, or wild leadwort. It is perennial herb and is native to Asia. It is being used in Ayurveda from ancient times because it possesses anti-microbial, anti-tumor, anti-fungal, anti-inflammatory and anti-cancer like pharmaceutical properties. Silver nanoparticles are synthesized by mixing aqueous extract from aerial parts and silver nitrate solution for 24 hrs. Analysis of nanoparticles is done by UV-Vis spectroscopy or by Scanning electron microscope (SEM). They have several advantages such as cost effective, compact for medicinal and pharmaceutical applications. Therefore, there is a need of further research on this field to know biological effects which can be benefit in treatment of various diseases. These nanoparticles affect biofilms produced by *S. aureus*, *Acinetobacter baumannii,* and *Escherichia coli*. They showed antimicrobial and antibiofilm properties against these microbes [**7**] (**Fig. 4**).

Fig. 4. ***Plumbago zeylanica***

Ruta graveolens (family*Rutaceae*) commonly known as rue, is an ornamental plant and herb. It is a native of Balkan Peninsula. It contains bioactive compounds like, acridone alkaloids (furaciridone, Grau acridone, quinoline) coumarins such as graudliferone, reticulin, isorutarin. Its essential oils are used to treat dermatitis and phototoxic reactions and severe renal and hepatic toxicity. It helps in green synthesis of zinc oxide nanoparticles by using aqueous stem extract of *Ruta Graveolens* which act as reducing agent. Zinc oxide nanoparticles contain antibacterial and antioxidant properties. These nanoparticles can be analysed by UV visible spectroscopy, Scanning electron microscopy (SEM)and transmission electron spectroscopy (TEM). They are effective against strains like *Klesbilla, aerogens, Pseudomonas aeruginosa, Escheria coli.,*and gram positive *Staphylococcus aureus***[28].** (**Fig.5).**

Fig. 5. ***Ruta graveolens***

FUTURISTIC STRATEGIES AND POLICY OPTIONS FOR SUSTAINABLE FARMING USING AGRICULTURAL NANOTECHNOLOGY

Sustainable agriculture is said to be a stabilized ecosystem method where abiotic and biotic living organisms live in a balanced manner i.e. maintain a sustainable environment as per the food chain and related energy balances. The goal of nanotechnology in agriculture is to provide benefits like new tools, improved food quality, and safety, increase yield and productivity without contaminating soil and water resources, and contribute to the betterment of farmers and human health [**23-28**].

- Nanotechnology plays an important role in enhancing productivity by the systematic use of nutrients, controlling pesticide use, and monitoring the water quality for sustainable development in agriculture.
- In studying the interaction between nanoparticles in different transport mechanisms taking place inside plant body and by controlled green synthesis of nanoparticles.
- Crop production through nanoparticles and evaluation of it having negative side effects and impacts on environmental conditions.
- The use of nano fertilizers to fulfil the need for nutrients like zinc, silica, and iron is found to be the major reason for alkalinity in soil and limiting agricultural productivity. Portable and user-friendly nano biosensors are also being used for quick analysis of soil, water, and pesticides.

Some of the policy options for the application of nanotechnology for sustainable development of agriculture are listed below:

- Developing special institutions with expertise for the proper evaluation for biosafety of nanoparticles
- Biosensors play a very effective role in insect pest control; consumers can use technology to get the actual state of a food product by intelligent food packaging methods incorporated with nano biosensors.
- More open debates and discussions should be done with consumers, researchers, and farmers to discuss the impact of this technology on humans, the economy, science, and agriculture.
- More collaborative research and sharing of resources for the development of a better research system
- For the effective use of nano-based products, farmers should be educated by skilled professionals to minimize field problems.

CONCLUSION

Biofilms produced by micro-organisms can harbour human infectious agents and spread many infectious diseases. Biofilms have high corrosively, high resistance against antibiotics and lack machine stability and are very dangerous when invade human cells. Biofilm associated infections are very common in the field of medicine, as they restrict the penetration of antibiotics. Recent developments in nanotechnology and novel approaches provided by this field of technology have not only helped in dispersing and preventing biofilm associated infections but have provided techniques to fight against diseases. In addition, synthesis of these nanoparticles from plant extracts also reported in the literature and these are energy efficient, cost effective and have high penetrating power which helps them to penetrate into the biofilm layer and attack microbial surface. They do not affect human health and does not cause any damage to organs. Nanoparticle are commercially viable, economic, environment friendly and enhance the efficiency of antibiotics by having antibiofilm, antibacterial, antimicrobial, anticancer, and antioxidant activities.

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