Research article **Available online www.ijsrr.org** **ISSN: 2279–0543**

International Journal of Scientific Research and Reviews

Applications of Nanotechnology in the world of biology - A Scientific Review

Thiruvengadam S.[1]*, Mohan Kumar B. S.[1] and Yamini C.[1]

Department of Biotechnology, Rajalakshmi Engineering College, Rajalakshmi Nagar, Thandalam, Chennai-602105, India, *E-mail: thiruvengadam.s@rajalakshmi.edu.in

ABSTRACT

Nano biotechnology is the engineering, construction and manipulation of Nano entities using biological approaches or for the benefit of biological systems. The conflux of nanotechnology and biology can address various biomedical problems, and can revolutionize the field of health and medicine. They are currently utilized as a tool to explore the obscure areas of medical sciences in various ways like imaging, sensing, targeted drug and gene delivery and artificial implants. The technology is also researched to have a profound impact on food production and packaging. In biosciences, organic dyes have been replaced with nanoparticles in the applications that require high photo-stability as well as high multiplexing capabilities. Nanoparticles and Nano capsules have a great potential to modify customary agricultural practices by providing a better way to distribute pesticides and fertilizers in a controlled manner with high site specificity. This review provides a broad perspective on the types of nanoparticles, their synthesis and application of nanoparticles in the field of biotechnology.

KEYWORDS: Nanotechnology, Imaging, Sensing, Drug Delivery, Biosensor, Pesticides

***Corresponding author**

Thiruvengadam S.

Department of Biotechnology,

Rajalakshmi Engineering College,

Rajalakshmi Nagar,

Thandalam, Chennai-602105, India

E-mail: thiruvengadam.s@rajalakshmi.edu.in

1. INTRODUCTION

A nanoparticle (Nan powder, Nan cluster and Nan crystal) is a microscopic particle with at least one dimension less than 100 nm. Nanoparticle research is currently an area of intense scientific research, due to a wide variety of potential applications in biomedical, optical, and electronic fields [1]. Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures. A bulk material has constant physical properties regardless of its size, but at the Nano-scale this is often not the case. Nanotechnology is the engineering of functional systems at the molecular scale[2].In its original sense, 'nanotechnology' refers to the projected ability to construct items from the bottom up, using techniques and tools being developed today to make complete, high performance products. Although major progress has been achieved in recent years, modern medicine is limited by both its knowledge and its treatment tools. It is only in the last 50 years that medicine has started looking at diseases at the molecular level, and today's drugs are thus essentially single-effect molecules[3]. The potential impact of nanotechnology on medicine stems directly from the dimension of the devices and materials that can interact directly with cells and tissues at a molecular level. Applied nanobiotechnology in medicine is in its infancy. However, the current nanomedicine research is extraordinary which includes three major research areas: diagnostics, pharmaceuticals, prosthesis and implants. Today, nanomedicine is one of the dominant and leading fields of nanobiotechnology. Nanotechnology is having an impact on several aspects of food science, from how food is grown to how it is packaged. Companies are gaining interest in producing nanomaterials that brings a difference not only in the taste of food, health benefits and also in food safety. Nanotechnology is being employed in water treatment plant which includes the removal of industrial wastes from groundwater. NPs are used to convert the contaminating chemical harmless. Studies have shown that this method is cost-efficient than the conventional procedures followed to reach contaminates dispersed in underground water table. In textile industry, usage of nano-sized particles or fibers to weave the fabric shows improvement in fabric properties without any much significant physical changes than previously used techniques [4].

2. TYPES OF NANOPARTICLE

2.1 Liposomes

Liposome's are lipid-based liquid crystals, extensively has its application in the field of pharmaceutical and cosmetic. They are first developed NPs used for drug delivery but their incompetent in aqueous environments have led to replacement, or stabilization with the help of newer alternative NPs.

2.2 Micellar Nanoparticles

MNP has a breakthrough in transdermal therapeutics and the formulation candeliver a range of therapeutic compounds which vary broadly by physiochemical properties, one among them is MNP based emulsions (lotions). A high concentration of drug depot is created in the stratum corneum and epidermis. The patch technology also shows similar advantages that includes both avoiding gastrointestinal passage and hepatic first-pass effects. MNP drug delivery is an inexpensive and quick pharmaceutical development model.

2.3 Magnetic Nanoparticles

Magnetic NPs like Fe3O4 (magnetite) and Fe2O3 (maghemite) are biocompatible and has diverse application (eg. targeted cancer treatment (magnetic hyperthermia), magnetic resonance imaging (MRI)) etc.

2.4 Super paramagnetic nanoparticles

Super paramagnetic substances which are attracted in the magnetic field but do not retain residual magnetism after the removal of the field. NPs of iron oxide which falls within 5-100 nm range are selectively used in magnetic bio separations. Some typical techniques involve coating the antibodies over the particles for cell-specific antigen separation from the matrix [5].

2.4 Gold Nanoparticles

Gold Nanoparticles (AuNPs) are employed in immunochemical studies such as identifying protein interactions, detection of amino glycoside antibiotics (eg. Streptomycin, Gentamycin) and as tracer in DNA fingerprinting which track down the DNA presence in sample. Gold nanorods image cancer stem cells, diagnosis and also identify different classes of bacteria [6].

2.5 Silver Nanoparticles

Silver Nan particles (AgNPs) have proved to be most effective because of its good antimicrobial efficacy against bacteria, viruses and other eukaryotic micro-organisms. They are undoubtedly the most widely used nanomaterials among all which majorly includes the use as antimicrobial agents, in water treatment etc. Several studies have already reported the successful biosynthesis of AgNPs from various plants extracts such as Azadirachtaindica, Capsicum annuum and Carica papaya [6].

2.6 Dendrimers

The presence of multiple molecular "hooks" on the surfaces of molecules which called by the name dendrimers which can be tagged (eg. fluorescent dyes, enzymes etc.). The dendritic molecules were firstly developed around 1980 but recently gains attention by their biotechnological uses [5].

2.7 Solid lipid Nanoparticles

Solid lipid NPs are proposed alternative particulate drug carrier system for intravenous applications. They are spherical particles ranges in nanoscale which is stabilized in water or with the help of surfactant. A monolayer of phospholipids coating surrounds the hydrophobic core where the drug is dispersed. They have ability to deliver lipophilic and hydrophilic drugs or diagnostics.

2.8 Chitosan Nanoparticles

N-deacetylation of chitin results in chitosan which has been widely used in food and bioengineering industries, including the encapsulation of active food ingredients, in enzyme immobilization, and as a carrier for controlled drug delivery due to significant properties such as biodegradability, biocompatibility etc. Chitosan NPs are used to immobilize enzymes and encapsulate bioactive substances.

2.9 Nan capsules

Nan capsules range from 10-1000 nm. They closely resemble solid lipid NPs where the core is liquid/solid core in which the drug is dispersed and coated by polymer membrane which may be natural or synthetic. The protective coating is easily oxidized due to pyrophoric in nature and thus controls the release of active ingredients. Nan capsules are vesicular systems whereas nanospheres are uniformly dispersed matrix systems.

2.10 Polymeric Nanoparticles

Polymeric Nanoparticles (PNPs) range from 10-1000nm that has application in the area of drug delivery using particulate delivery systems. Pharmacokinetic and pharmacodynamic properties can be improved by the use of NPs in various types of drug molecules. They show great promise in drug delivery systems due to their controlled and sustained release properties, biocompatibility and sub cellular size.

3. SYNTHESIS OF NANOPARTICLES

Bimetallic NPs are synthesized by reduction method[7], co-reduction method[8] and reverse micelle synthesis method[9]. Three different methods such as wet impregnation, deposition-precipitation, and reverse micelle impregnation were adopted in the preparation of Ni-Pt bimetallic NPs[10]. Chau et al. (2013)[11] have suggested the Laser irradiation method for Pt-Au bimetallic NPs. Electrochemical synthetic method can be used to synthesize silver nanoparticles [12].

Table:1 Nanoparticles Companies and their Products

Field	Company	Products or Project
Nano Medicine	Cyt Immune	Gold nanoparticles for targeted delivery of drugs to tumors
	NanoBio	Nan emulsions for nasal delivery to fight viruses (such as the flu and colds) or through the skin to fight bacteria
Food technology	Nancor	Bottles, cartons and films containing clay nanocomposite that act as a barrier to the passage of gasses or odors
	Nano science Diagnostics	Rapid testing for contaminates in food
	Inmat	Nan composite coatings for transparent plastic films used in food packaging that provides a barrier to oxygen or moisture
Water treatment	SiREM	Iron nanoparticles to treat groundwater pollutants
	Campbell Applied Physics	working on Capacitive Deionization using carbon aerogel
	NanoH2O	Nanotechnology enhanced membranes for water desalination
Fabrics	Nano-tex	Fabric enhanced with nanowhiskersto resist water and stains
	BASF	Fabric enhanced with nanoparticles to dirt rinses off in rain
	Aspen Aerogel	Fabric enhanced with nonporous to insulates against heat or chill
	Nano Horizons	Fabric enhanced with silver nanoparticles to reduces odors
Nan electronics	California Molecular Electronics	Molecule sized switches and other devices
	Everspin Technologies	Magneto resistive Random Access Memory
	IBM	Nan photonics
	Kodak	Optoelectronics materials and devices
	Ime	Developing CMOS technology for IC's using sub-22nm geometry
	QD Vision	Developing quantum dot based displays
Sports	InMat	Nan composite barrier film in tennis ball and others
	Wilson	Tennis racquet frames containing silicon dioxide nanoparticles
	Eston Cycling	Bicycle parts made with carbon nanotubes

Dendrimers are generally synthesized by divergent[13] and convergent method[14]. In divergent the synthesis starts from the core of the dendrimer to which the arms are extended by adding building blocks in step-wise manner whereas in convergent method it is from the periphery which also helps in predicting the final generation number and requisite sizes beforehand for each generation.

Carbon nanotubes (CNTs) are synthesized mostly by arc-discharge technique which uses higher temperatures (above 1700 °C) for synthesis [15] with fewer structural defects due to expansion. Whereas the laser ablation method yields around 70% primarily single-walled carbon nanotubes (SWNT) whose diameter is determined by the reaction temperature [16]. Single-walled carbon nanotubes are also synthesized by a thermal plasma method. The fumes created by the flame which occurs during the process are found to contain SWNT, metallic and carbon NPs and amorphous carbon [17,18].

Biological synthesis of NPs evolved due to presence of toxic contaminants adsorbed on the NPs surface which may cause toxic effects. Researchers have used biological extracts for the synthesis of NPs, by adopting simple protocols, involved in the process of the reduction of metal ions by using biological extracts as a source of reductant either extracellularly or intracellularly [19,20].

4. APPLICATIONS OF NANOPARTICLES

4.1 Textile Industry

"Nano Textiles" has been a revolutionary due to its benefits and can be produced by a variety of methods and the key difference among them is whether synthetic NPs are either integrated with the fibers of the cloth or coated on the surface of finished goods and/or whether they are added to the nanoscale fibers or coating (Fig 1).

4.1.1 Stain and Water repellent fabrics

One of the most common applications of nanotechnology in the textile industry is to create stain and water-resistant fabrics. To achieve this, a billion of tiny fibers call themselves as “nanowhiskers” are embedded which increase the density of the fabric and also make it water proof. These Nan whiskers can repel stains because they form a cushion of air around each cotton fiber which can cohesively prop up a water droplet. Hence when something gets spilled on the surface of the fabric they roll off from the surface. This effectiveness of the fabric lasts for at least 50 home wash cycles. A corollary finish is that of using NPs to provide a “lotus plant” effect which causes dirt to rinse off easily, such as in the rain. Silicon dioxide (SiO2) NPs are used to induce super hydrophobicity on the surface of the fabrics.

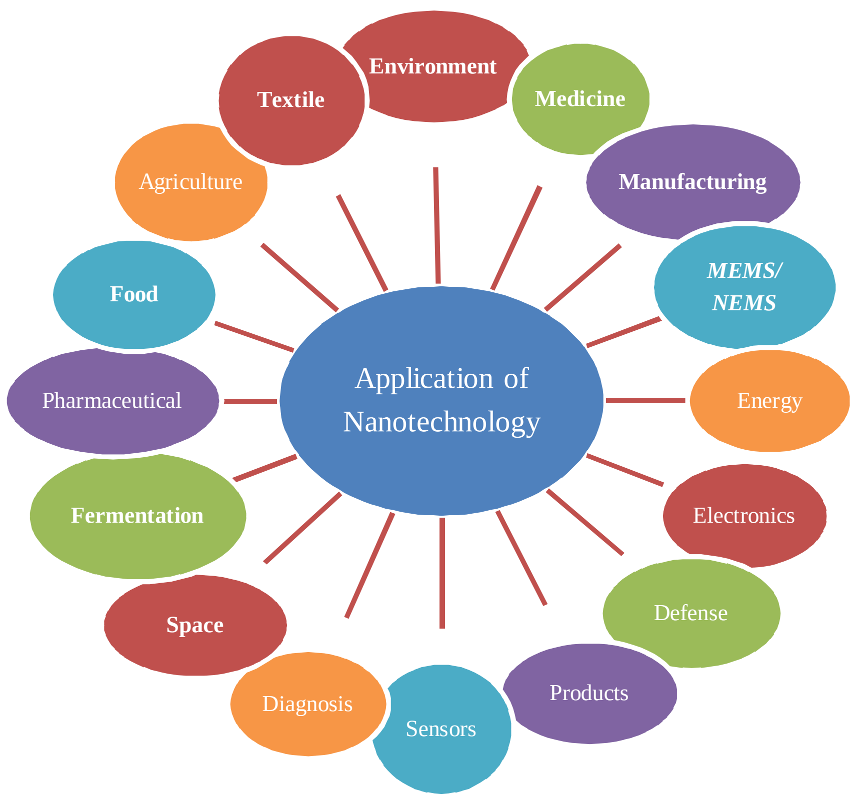

Fig 1. Different field of Nanotechnology Applications

4.1.2 Antimicrobial activity

Antibodies are considerably being replaced by NPs which seems to have a high potential in solving the emergence of bacterial multidrug resistance [21]. In particular, silver NPs have attracted much attention in the scientific field [22]. Silver in the past was used as an antiseptic and antimicrobial against Gram-positive and Gram-negative bacteria [23] due to its low cytotoxicity [24]. They possess a broad spectrum of antimicrobial activities [25]. Silver ions effect the K+ ions concentration bacteria thus, the bacterial plasma or cytoplasmic membrane, which is associated with its integrity [26]. When bacterial growth was inhibited, silver ions were deposited into the vacuole and cell walls as granules [27]. They inhibit cell division and damage the cell envelope and cellular contents of the bacteria [28]. In addition, silver ions can interact with nucleic acids [29] preferentially with the bases in the DNA rather than with the phosphate groups, although the importance of this mechanism in terms of their lethal action remains unclear [30]. The involvement of free-radical also plays a vital role in the antibacterial activity of silver NPs due to the interaction between reactive oxygen species (ROS) results in cell death. Bacterial DNA or mitochondria can be affected by ROS such as superoxide anion (O_2^-), hydroxyl radical (OH•) and singlet oxygen ($^1O_2$) with subsequent oxidative damage [31] showing good antibacterial and antiviral effects.

4.1.3 Self – cleaning surfaces

Titanium dioxide (TiO2) NPs because of their hydrophilicity and photo-catalytic reactions are used in the fabrication of self-cleaning surfaces i.e. can decompose organic structures (pollution). Adding Nano silica to Titania, demonstrated higher photo catalytic and super hydrophilic activity in comparison to pure TiO2. TiO2 is photo catalytic, in other words the oxygen radicals are produced under UV light irradiation that decompose or degrade organic material such as, for example, fats, oils, and soot or plant materials. TiO2 is especially reactive in Nano form and not spended during catalysis, i.e. effect is long-term. On self-cleaning surfaces like this, the organic dirt is dissolved and decomposed in the water film where the residue is removed by the next heavy shower of rain merely reducing the need of repeated cleaning process [32].

4.2 UV Protection

There are both organic and inorganic UV blockers. The UV absorbers come under organic blockers whereas the semiconductor oxides (TiO2, ZnO, SiO2, and Al2O3) come under inorganic blockers. When compared with organic UV absorbers, the inorganic UV agents are more preferred because of their unique features including, among others, non-toxicity and chemical stability under both high temperature and UV-ray exposure. Some investigators believe that TiO2 provides good UV protection by reflecting and/or scattering due to high refractive index [33,34], whereas others believe that it absorbs UV radiation because of its semi conductive properties [35,36,37] Still others claim that only Nano size TiO_2 absorb UV radiation, whereas the sub micrometer-size particles do very little and in micro size they do not [38]. The nanoscale TiO_2 also presents good affinity to fabrics because of its very large specific surface area and high surface energy and activity.

4.3 Fire retardant surfaces

Carbon nanotubes (CNTs) are commonly used as fillers to improve the mechanical, electrical, and flame-retardancy properties of nanocomposites [39]. CNT-containing nanocomposites absorb more radiation than polymers with increase in temperature during fires. The incorporation CNTs reduces polymer flammability by several mechanisms (limiting fuel transfer to the flame, formation of a protective char layer, etc.). The incorporation of a small amount (5wt. %) of nanometric TiO_2 or Fe_2O_3 enhance the thermal stability of poly methyl methacrylate (PMMA) nanocomposites [40]. The attributes of nanocomposites (PMMA- TiO_2, PMMA- Fe_2O_3) improved the flame retardancy by restricting the mobility of polymer chains.

4.4 Agriculture

The basic need of a human is food, clothes and shelter. Agriculture is one of the major sectors that fulfill the need of food. The demand for the food increases as the population increases. This is one of the concerning factors to accept the modern technique, the nanotechnology in particular. The use of NPs increases the production rate and yield, the efficiency of resource utilization, minimize waste production etc. Nanoparticles are used in:

- Cotton industry
- Honey bee culturing
- Silk worm industry
- Bio-fuel production.

4.4.1 The Detection of Plant Pathogens

To improve and protect the agricultural production, it is necessary to detect the pathogens in the early stage of the host plan. This type of detection is possible through a micro biosensor process. The biosensor is an analytical device that uses a biological recognition system to detect the pathogens in the host, if any. It poses a physiochemical transducer that helps to isolate the infected parts of the plants [41]. These biosensors are small, portable, rapid, specific, quantitative, reliable, accurate, reproducible, robust and stable. Thus, these sensors are good indicators at the agricultural field by which farmer get the proper information of the soil and plants of agricultural domain [42].

4.4.2 Recycling of Agricultural Waste

Atanu Bhattacharya., et.al. (2014) mentioned that biodegradable cellulose mats can be used to absorb fertilizers and pesticides from the agricultural field based on nano-science [42].

4.4.3 Enhancing Agricultural Yield

Zeolites are naturally occurring crystalline aluminum silicates that can significantly improve the water retention capacity of sandy soils and increase porosity in clay soils. The nano-porous zeolites have the capacity to slow-release of water and fertilizers for plants to maintain the efficient dosage, and also help to supply proper nutrients to the agricultural plants [42,43].

4.4.4 Nano-Pesticide

The NPs are used for controlling the micro-organism growth in agriculture. Chitosan, a linear cationic biopolymer, which has filmogenic properties and capable of forming matrices for transport of active substances. These are used to control the micro-organisms responsible for pre- and post-harvest diseases of agricultural products [44].

4.5 Environment

Nanotechnology is an emerging field that covers a wide range of technologies [45]. Nanotechnology aims to reduces the harm to the environment as well as remediation of environment. Nanotechnology in Environmental Engineering is to protect the environment from pollution control treatment and as a remedial measure to a long-term problem such as contaminated waste sites. Many Remediation Technologies have been developed to treat soil, wastewater and ground water contaminants using In-situ and Ex-situ methods. Nano-remediation methods involves in the application of reactive materials for the Transformation of pollutants and for detoxification. NPs are used in waste water treatment and ground water remediation.

Various NPs used are Dendrimers, Metal NPs, Carbonaceous NPs, Zeolite, Zero valent Ion and CNTs. NPs are highly reactive because of the high surface area. NPs are so tiny so their Movement is largely governed by Brownian movement. Thus, NPs remain suspended in solution longer to establish insitu treatment. NPs come in contact with the contaminant and NPs degrade the Contaminant typically through redox reaction. The target contamination may be Organic molecules such as pesticides and organic solvents such as Arsenic and /or lead.

4.5.1 Nanoparticles in Waste Water Treatment

Nano particles play an important role in the waste water treatment. Nanoparticles enhance the efficient elimination of germs and pollutants in the area of water purification. For detection and elimination of chemical and biological substances (metals and viruses, bacteria, parasites and antibiotic) Nan membrane and nanopowder are used. Metal-containing NPs, carbonaceous nanomaterials, zeolites and dendrimers are considered as functional materials for water purification treatment.

- Metal Nano particles

The affinity towards the target compound is increased by adding various chemical groups to NPs. NPs have a unique property to develop high capacity and selective sorbents for metal ions and anion [46]. For coliform found in waste water silver compounds have been used as antimicrobial compounds. In wound healing, Spherical or flake high surface area metal particles like silver (Ag) Nanoparticles, nanodots or nanopowder are having high antibacterial activity are used. Silver nanocrystals are incorporated in coatings, nanofiber, first aid bandages, plastics, soap and textiles, in self-cleaning fabrics. For removing tri-chloroethane (TCE) from groundwater Nanoparticles of gold coated with palladium act as effective catalysts [46]. To remove arsenic from water, Zinc oxide NPs has been used. A variety of irons containing minerals, such as akaganeite, feroxyhyte, magnetite etc. [46] are used on adsorption processes for wastewater treatment. Magnetite Nano particles are covalently modified with PEG for the removal of lead from Waste water. The elimination of the metal ions involves some general methods such as adsorption onto charcoal, chemical precipitation, ligand precipitation etc. [47].

- Dendrimers

A highly branched polymers with controlled composition and an architecture that consists of nanoscale features are Known as Dendrimers. A new class of nanoscale materials that can be carried as water-soluble chelators is Poly amidoamine (PAMAM) dendrimers usually by repeatedly attaching amidoamine monomers in their radial branched layers PAMAM macromolecules are synthesized. Different generations of PAMAM dendrimers are used for effective removal of copper from water [45].

4.5.2 Nano particles in Ground water Remediation

Iron NPs and CNTs are an attractive component for nanoremediation. Iron NPs was synthesized from Fe (II) and Fe (III) [48]. For in situ remedial treatment, the use of zero-valent iron has been expanded to include all different kinds of contaminants and by reductive dechlorination it removes the aqueous contaminants with dissolved oxygen. Iron also undergoes “Redox” reactions. For separation and immobilizations of Cr (VI) and Pb (II) from aqueous solution iron NPs are used. One of the persistent organic pollutants in the drinking water is Lindane, which could be degraded from water by FeS NPs. CNTs have cylindrical pores and carbon atoms on the surrounding walls interact with the adsorbent molecules which maintains the quality of water. CNTs show adsorption capability for removal of heavy metals such as lead oxidized CNTs and for the removal of organic pollutants like dichlorobenzene, trihalomethanes, nonanne and CCL with different modification and for the purification from water [45].

4.6 Food

Food is the most important among the basic needs for human as it is the nutritious substances that are needed in order to maintain life and growth. It is the source which can aid in developing and replacing cells, to produce energy to keep the body active and protected from infection and recover from sickness. NPs are used in the food to improve flavor, texture, enhance nutrient delivery, packaging (antimicrobial and green) and for identification and elimination of bacteria. Nano-silver is incorporated in food cutting boards, cleaning sprays, kitchenware, food storage containers and refrigerator compartments for its antimicrobial properties. NPs such as nano-clays are incorporated into plastic beer bottles to increase strength, make them more shatterproof, and extend shelf life by acting as a barrier to keep oxygen outside the bottle and carbon dioxide inside. Nano-chips or nano-sensors are commercially used to detect storage conditions conducive to spoilage (e.g., temperature or moisture problems) For example; nano-sensors are used on food pallets during transport in refrigerated trucks to detect temperature violations. Nano-encapsulating improves solubility of vitamins, antioxidants, healthy omega oils and other nutraceuticals.

4.6.1 Nanoparticles in food packaging

NPs are employed in new food packaging materials which improve mechanical barrier and antimicrobial properties to increase shelf life [49]. Besides antimicrobial characteristics, NPs can also help in extending shelf life even after opening by supporting antioxidants, enzymes, flavors, anti-browning agents and other materials [50]. Inorganic nano-materials of some metals and metal oxide such as; silver, iron, titanium dioxide, Zinc oxides, magnesium oxide as well as silicon dioxide and carbon NPs have been used as antimicrobial agents in food packaging and in some cases as food supplements [51].

4.6.2 Nanoparticles in extending the shelf life of fresh strawberries

LDPE/ZnO nano-composites are used to extend the shelf life of fresh strawberries. Strawberries have relatively high-water content, intense metabolic activity and susceptibility to microbial rot [52]. LDPE is widely used because of its properties such as acceptable flexibility, transparency, low cost, easy process ability and thermal stability [53]. ZnO NPs have several industrial uses due to its strong antimicrobial effect against a broad spectrum of microorganisms [54]. Since ZnO NPs are thermally stable and thermal processing is used to produce the LDPE film, melt mixing can improve the properties of nanocomposites [55].

4.6.3 Nano-Additives

Nano capsules such as liposomes, micelles etc., has better application as food additives, nutritional supplements, to mask the undesirable taste, enhance bioavailability and allow for better dispersion of insoluble additives without need for surfactants or emulsifiers [56]. NPs of silver, iron, calcium, magnesium, selenium and silica are used as additives to improve taste, flavor and for preservation. The polylysine is a nano-particle used as antioxidant to protect oil from oxidation as mentioned by Mahmound, et al. [57].

4.6.4 Nanoparticles in Sensory Food Analysis

Nano-sensors track down any physical, chemical or even biological changes during food processing phase. Smart packaging with specialized nano-sensors and nano-devices have been designed to detect toxins, food pathogens and chemicals [58]. For example, Immunosensing of staphylococcus sp. Enterotoxin B using poly (dimethylsiloxane) (PDMS) chips with reinforced, supported, fluid bilayer membranes(r-SBMs) and specific antibodies to the toxin [59].

4.7 Cosmetics

Cosmetics have become a part of basic needs in this virtual world. The formulation of cosmetics is not simple and contains a high number of ingredients and manufactured by time-consuming and tedious sample treatments [60,61] NPs have unique enhanced properties such as colour, transparency, solubility etc., which cannot be achieved when working with the bulk form of the material. Applications for these special properties have been suggested in many fields where the field of cosmetics is one of those most eager to make the most of the opportunities presented by nano-technology. Various types of NPs used in cosmetics are Nano emulsions, Liposomes, Nanocapsules, Solid lipid NPs, Nanocrystals, Dendrimers, Cubosomes, Hydrogels, Bucky balls. Liposomes are mainly composed of phospholipids, whereas niosomes use nonionic surfactants, such as polyoxyethylene alkyl ethers or esters [62]. Vesicle formulations are important in cosmetic applications because they may improve the stability and skin tolerance of ingredients, such as unsaturated fatty acids, vitamins or anti-oxidants and thereby contribute to the safety of cosmetics. Sunscreens contain insoluble, mineral-based materials whose performance depends on their particle size. Mineral particles, such as TiO2, reflect and scatter UV light most efficiently at a size of 60–120 nm. The surface of these particles is frequently treated with inert coating materials, such as aluminium oxide or silicon oils, in order to improve their dispersion in sunscreen formulations. Sunscreen products containing mineral UV filters protect consumers from the harmful effects of UV exposure, including skin ageing, herpes as well as skin and lip cancers. The transparency of titanium or zinc oxides results in better consumer acceptance/compliance and thus improves the protection of human skin against UV induced damage. Nano-emulsions have been considered as potential vehicles for the controlled delivery of cosmetics and personal care products [63]. Nano emulsions are oil-in-water (O/W) or water-in-oil (W/O), transparent or translucent, colloidal dispersions, usually in the 20-500 nm size range [64,65]. An advantage in using nano-emulsions compared to ordinary emulsion is their ability, as delivery systems, to improve the bioavailability and bio efficacy of lipophilic bio actives in their delivery [66]. No textural changes as creaming, sedimentation or flocculation occurs during storage and mostly homogenization appears to be the favored method of preparation of nano cosmetics. Nano-emulsions provide different visual aspects, richness and skin feel in a great variety of products.

4.8 Pharmaceuticals

'Pharmaceutical nanotechnology' combines the field of nano science with pharmacy which aids in drug delivery, diagnostic and varies other application. 'Nano medicine' as submicron size (<1um) modules which are used in treatment, diagnosis, monitoring, and control of biological system [67]. This field presents innovative revolutionary solutions against many diseases. Major limitations in drugs existing for therapy are:

- Instability in the solid and suspension state
- An unfavorable ratio between the amount of drug administered and the concentration at the target site is observed due to poor solubility, adsorption and low bioavailability.

Pharmaceutical nanotechnology has a vast scope in therapeutics and diagnosis. Current nanoapplications in pharmacy includes therapeutic (nanomedicine, tissue engineering, nanorobots etc.), advance diagnostic probes which provides accuracy (biosensor, biomarker, image enhancement device, etc.). A large number of nanosystems are implemented in pharmacy to date which bags in liposomes, dendrimers, metallic NPs, polymeric NPs, carbon nanotubes, quantum dots, nanofibres etc.

4.8.1 Pharmaceutical Nanotechnology Based Systems

Basic nano tools i.e. nanomaterials and nanodevices [67] plays a major role in the world of pharmaceutical nanotechnology. Nanomaterials are used in places such as dental implants, scaffolds for tissue-engineered products. The biocompatibility is enhanced by surface a modification which favours the interaction between the biomaterial and living cells. They are sub classified into two types namely nano crystalline and nano structured materials. Nanocrystalline materials can substitute bulk materials and easily manufactured. Raw nanomaterials have application in drug encapsulation, bone replacements, prostheses (e.g. artificial limbs, facial prosthetics and neuroprosthetics etc.) and implants. Nano structured materials provide special shapes or functionality which are also processed forms of raw nanomaterials (eg.CNT). Nanodevices are nanoscale miniature devices which include nano- and micro-electromechanical systems (NEMS/ MEMS), microfluidics, and microarrays (eg. Biosensors and detectors).

4.8.2 Colloidal Nano Particles in Cream Formulation

In order to minimize the impact of systemic toxicity of drugs in the treatment of local acute and chronic inflammatory reactions, the achievement of reliable and efficient delivery of therapeutics in/through the skin is highly recommended, for which colloidal NPs was formulated and compared with water-in-oil emulsion for topical administration and skin penetration routes. TEM results provide evidence that the cream formulation of amphiplilic NPs (PMNP) allows efficient penetration through the skin with a controllable kinetics on comparison to suspension formulation. PMNP character combined with cream formulation improves the intradermal penetration of NPs. Administration via aqueous solution favours in NPs capture by phagocytes, whereas cream formulation shows better uptake by all dermis cell types, including hematopoietic and non-hematopoietic cells. They also avoid their dispersion and migration to draining lymph nodes via afferent lymphatics by capturing in the dermal architecture [68].

5. OTHER APPLICATIONS

5.1 In Fermentation technology and downstream processing

Various NPs such as Magnetite NPs and Silver NPs are used. Magnetite NPs have a widespread biomedical application [69]. By co-precipitation Method, Magnetite NPs was synthesized, which is based on the precipitation of $Fe3+$, $Fe2+$ in basic aqueous Media. In aerobic bioprocess, the rate of oxygen utilization is a limiting factor; hence the availability of oxygen for high microbial activity in the medium is still crucial. Hence the effect of Magnetite examination on the oxygen transfer in erythromycin culture plays a very important role [69]. Using Magnetic solid phase extraction, NPs of Magnetite have been developed as an extractive technique to preconcentrate pollutants in sample. For the extraction and preconcentration of polychlorinated biphenyls from water and soil leachates, Magnetic solid phase extraction Methods were developed [70]. In Magnetic solid phase extraction, Magnetic sorbent is added to the solution, and Magnetite NPs are attracted to the Magnetic field created by a magnet on the wall of the flask, after the adsorption of the analytes or to the sorbent. In these methods Magnetite NPs were grafted to graphene or multi walled Carbon Nano tubes [71]. Silver NPs that containing Agar films have been used as a support for liquid membrane in Electro Membrane Extraction. For the determination of several analytes in a wide range of matrices Electro Membrane Extraction preconcentration procedure are used as mentioned by Cristina Roman Hidalgo., et.al. [71]. Silver NPs have received considerable attention owing to their attractive physical and chemical properties. The synthesis of NPs in colloidal solution requires adequate methods to control their size and shape, chemical reduction being the most used synthesis procedure. The insitu generated silver NPs in the synthesize film were characterized by means of Transmission Electron Microscopy [71].

5.2 Antimicrobial activity

The bimetallic (Ag, Au) nanocomposites has a great play in antimicrobial activity. In this paper, the bimetallic nanocomposites obtained from the synthesis of acrylamide (AM) - and 2-acrylamido-2-methyl-1-propanesulfonic acid (AMPS)-based hydrogel for antimicrobial applications were presented. The nanocomposite was confirmed by SEM, TGA/DSC, as well as XRD methods. The bimetallic nanocomposite hydrogel has shown a significant antibacterial activity on Bacillus [72]. The magnetic Fe-Ag NPs acted as the antibacterial and antifungal agents against a variety of microorganisms including disease-causing pathogens. The microscopic observations and phase analyses of prepared BNPs, ranging between 10 and 30 nm depending on the initial concentration of AgNO3, are firmly bound to Fe NPs, which prevent their release even during a long-term sonication as mentioned by Markova, et.al. [73]. In the Au-Ag core-shell NPs, the Au NPs act as the seeds for continuous deposition of silver atoms on its surface. The core-shell structure and morphology were characterized by UV-Vis spectroscopy, XRD, TEM, and EDX analyses. The core-shell BNPs showed antibacterial activity against both gram-negative and gram-positive bacteria at low concentration of silver present in the shell; TEM and flow cytometric studies showed that the core-shell BNPs attached to the bacterial surface cause membrane damage which leads to cell death. The enhanced antibacterial properties of Au-Ag core-shell BNPs were possibly due to the more active silver atoms in the shell surrounding gold core due to high surface free energy of the Ag atoms, owing to shell thinness in the bimetallic NP structure [74].

6. CONCLUSION

In summary, NPs have a wide range of applications and can be used in almost all the fields. Functionalized NPs can satisfy the needs for specific purposes due to their improved bioavailability, increased specificity and stability ensuring a long shelf life of the products. The vast benefits of NPs have made them a vital ingredient in scientific and technological advancements. There are around 20 clinically approved drugs containing NPs as of today. It can be expected that very soon these NPs will become the core of all materials and processes used in everyday life. From catering precise and explicit diagnostic techniques to providing sustainable energy, thereby meeting the energy demand crisis and improving the environment, NPs are the key to a better future.

7. ACKNOWLEDGEMENT

The authors acknowledge the valuable support given by our institution-Rajalakshmi Engineering College.

8. REFRENCES

1. Packia Lekshmi NCJ, Benarcin Sumi S, Viveka S, Jeeva S, Raja Brindha J. Antibacterial activity of Nanoparticles from Allium sp. Journal of Microbiology and Biotechnology Research. 2012; 2: 115-119.
2. Melgardt M de Villiers, Pornanong Aramwit, Glen S. Kwon. Nanotechnology in Drug Delivery. Spring AAPS Press, New York. 2008.
3. Oded Shoseyov, Ilan Levy NanoBioTechnology: BioInspired Devices and Materials of the Future. Humana Press, New Jersey. 2008.
4. Hawk's Perch Technical Writing on Nanotechnology, 2018. Available from: URL: www.understandingnano.com/nanotech-applications.html.
5. Shah MA, Bhat MA, J. Paulo Davim. Nanotechnology Applications for Improvements in Energy Efficiency and Environmental Management. Information Science Reference, IGI Global Publishers,USA, 2014.
6. Saba Hasan. A review on Nanoparticles:Their Synthesis and Types. Res. J. Recent. Sci. 2015; 2: 1-3.
7. Waseda Y, Atsush M. Morphology control of materials and nanoparticles: advanced materials processing and characterization. J Phys Chem. 2004; 98: 265.
8. Singh HP, Gupta N, Sharma SK, Sharma RK. Synthesis of bimetallic Pt-Cu nanoparticles and their application in the reduction of rhodamine B. Colloids Surfaces A. 2013; 416: 43-50.
9. Mhlanga SD, Coville NJ. Iron cobalt catalysts synthesized by a reverse micelle impregnation method for controlled growth of carbon nanotubes. Diamond Relat Mater. 2008; 82: 489-1493.
10. Cheney BA, Lauterbach OA, Chen JG. Reverse micelle synthesis and characterization of supported Pt/Ni bimetallic catalysts on Al_2O_3. Appl Catal A. 2011; 394: 41-47.
11. Chau JLH, Chen C-Y, Yang C-C. Facile synthesis of bimetallic nanoparticles by femtosecond laser irradiation method. Arab J Chem. 2017; 10: 1395–1401.
12. Ma H, Yin B, Wang S, et al. Synthesis of silver and gold nanoparticles by a novel electrochemical method. Chem Phys Chem. 2004; 24: 68–75.
13. Hodge P. Polymer science branches out. Nature. 1993; 9: 18–19.
14. Grayson SM, Frechet JMJ. Convergent dendrons and dendrimers: from synthesis to applications. Chem Rev. 2001; 9: 3819–3868.
15. Eatemadi, Ali, Hadis Daraee, Hamzeh Karimkhanloo *et al.* Carbon nanotubes: properties, synthesis, purification, and medical applications. Nanoscale research letters. 2014; 9: 1-13.
16. Collins PG, Avouris P. Nanotubes for Electronics. Scientific American, 2000; 283: 62–69.

17. Smiljanic, Olivier, Stansfield BL *et al*. Gas-phase synthesis of SWNT by an atmospheric pressure plasma jet. Chemical Physics Letters. 2002; 356: 189–193.
18. Feng Yang, Xiao Wang, Meihui Li *et al*. Chem. Res. 2016; 49: 606–615.
19. Sheny DS, Joseph M, Philip D. Phytosynthesis of Au, Ag and Au-Ag bimetallic nanoparticles using aqueous extract and dried leaf of *Anacardium occidentale*. J Spec Act A. 2011;79: 254-262.
20. Mondal S, Roy N, Laskar RA *et al*. Biogenic synthesis of Ag, Au and bimetallic Au/Ag alloy nanoparticles using aqueous extract of mahogany (*Swietenia mahogani* JACQ) leaves. Colloids Surfaces B. 2011; 82: 497-504.
21. Rai MK, Deshmukh SD, Ingle AP, Gade AK. Silver nanoparticles: The powerful nanoweapon against multidrug-resistant bacteria. J. Appl. Microbiol. 2012; 112: 841–852.
22. Jana S, Pal T. Synthesis, characterization and catalytic application of silver nanoshell coated functionalized polystyrene beads. J. Nanosci. Nanotechnol. 2007; 7: 2151–2156.
23. Lazar V. Quorum sensing in biofilms—How to destroy the bacterial citadels or their cohesion/power? Anaerobe. 2011; 17: 280–285.
24. Biel MA, Sievert C, Usacheva M, Teichert M, Balcom J. Antimicrobial photodynamic therapy treatment of chronic recurrent sinusitis biofilms. Int. Forum Allergy Rhinol. 2011; 1: 329–334.
25. Berger TJ, JA Spadaro, SE Chapin, RO Becker. Electrically generated silver ions: quantitative effects on bacterial and mammalian cells. Antimicrob.Agents Ch. 1996; 9: 357-358.
26. Miller LP, SEA McCallan. Toxic action of metal ions to fungus spores. J. Agric. Food Chem. 1957; 5: 116-122.
27. Brown T, D Smith. The effects of silver nitrate on the growth and ultrastructure of the yeast *Cryptococcus albidus*. Microbios Lett. 1976; 3: 155-162.
28. Richards RME, HA Odelola, B Anderson. Effect of silver on whole cells and spheroplasts of a silver resistant Pseudomonas aeruginosa. Microbios. 1984; 39: 151-157.
29. Yakabe Y, T Sano, H Ushio, T Yasunaga Kinetic studies of the interaction between silver ion and deoxyribonucleic acid. Chem. Lett. 1980; 4: 373-376.
30. Rahn RO, LC Landry. Ultraviolet irradiation of nucleic acids complexed with heavy stoms. II. Phosphorescence and photodimerization of DNA complexed with Ag. Photochem.Photobiol. 1973; 18: 29-38.

31. Corinne, Pellieux A Dewilde, C Pierlot, JM. Aubry. Bactericidal and virucidal activities of singlet oxygen generated by thermolysis of naphthalene endoperoxides. Methods Enzymol. 2000; 319: 197-207.

32. Fujishima A, Zhang X. Titanium dioxide photocatalysis: present situation and future approaches, Comptes Rendus Chimie. 2006; 9: 750-760.

33. Mossotti R, Innocenti R, Dimechelis R, Pozzo PD. In: Changes in the Properties of Wool Fibres by Using Alternative Materials, Proceedings of the 10th International Wool Textile Research Conference, Aachen, Germany. 2000; 11: 1–9.

34. Bohringer, B. In: UV Protection by Textiles, Proceedings of the 37th International Man-Made Fibres Congress, Dornbirn, Austria, 1998; 9:1031–1044.

35. Gupta KK, Tripathi VS, Ram H, Raj H. Sun Protective Coatings. Colourage. 2002; 6: 35 – 40.

36. Thiry MC. Testing antimicrobial performance. AATCC Review .2010; 12: 26–36

37. Wedler M, Hirthe B. UV-absorbing microadditives for synthetic fibers. Chemical Fibers Internaitonal, 1999; 49: 528

38. Hongying Yang, Sukang Zhu, Ning Pan , Studying the Mechanisms of Titanium Dioxide as Ultraviolet-Blocking Additive for Films and Fabrics by an Improved Scheme. Journal of Applied Polymer Science. 2004; 92: 3201–3210.

39. Kashiwagi T, Fangming Du, Jack F. Dougla *et al*. Nanoparticle networks reduce the flammability of polymer nanocomposites. Nat. Mater. 2005; 4: 928–933

40. Lewin, M. Endo, Catalysis of intumescent flame retardancy of polypropylene by metallic compounds, Polym. Adv. Technol. 2003; 14: 3-11.

41. Morrison DWG, Dokmeci MR, Demirci U, Khademhosseini A. Clinical Applications of Micro-and Nanoscale Biosensors. Biomedical Nanostructures Edited by KennethE.Gonsalves, CatoL. Laurencin, Craig R. Halberstadt, Lakshmi S. Nair, JohnWiley & Sons, Inc. 2007.

42. Atanu Bhattacharya, Raman Chandrasekar, Asit Kumar Chandra et al. Application of nanoparticles in sustainable agriculture: Its current status. Short Views On Insect Biochemistry and Molecular Biology.2014; 2: 42-448.

43. Harja M, Bucur D, Cimpeanu SM, Cinocintal C, Gurita AA. Conversion of ash on zeolites for soil application. J. Food, Agriculture and Environment. 2012; 10: 1056-1059.

44. Octavio Cota-Arriola, Mario Onofre Cortez-Rocha, Armando Burgos-Hernandez et al. Controlled release matrices and micro/nanoparticles of chitosan with antimicrobial potential:

development of new strategies for microbial control In agriculture. Journal of the science of food and agriculture. 2013; 93: 1525-1536.

45. Mansoori GA, RohaniBastami T, Ahmadpour A, Eshaghi. Environmental Application Of Nanotechnology. Annual Review of Nano Research. 2008; 2: 1-7.
46. Dhermendra K Tiwari, Behari J, Prasenjit Sen. Application of Nano particles In Waste Water Treatment. World Applied Sciences Journal. 2008; 3: 417-433.
47. Nejat Sadati Behbahani, Kobra Rostamizadeh, Mohammad Reza Yaftian, Abbasali Zamani, Hamideh Ahmadi. Covalently Modified Magnetite Nanoparticles With PEG: preparation & characterization as Nanoadsorbents for Removal of lead from wastewater. Journal of Environmental Health science & Engineering. 2014; 12: 103-114
48. CS Rajan. Nanotechnology in Ground Water Remediation. Int. J. Environ. Sci. Technol. 2011; 2: 182-187.
49. Mihindukulasuriya SDF, Lim LT. Nanotechnology development in food packaging: A review. Trends Food sci. Technol. 2014; 40; 149-167.
50. Weiss J, Takhistov P, Mc Clements DJ. Functional materials in food nanotechnology. J. food Sci. 2006; 71:107-116.
51. Sekhon BS. Food nanotechnology-an overview. Nanotechnol.Sci. Appl. 2010; 3:1 -15.
52. Aryow Emamifar, Mehri Mohammadizadeh. Preparartion and application of LDPE/ZnO nanocomposites for extending shelf life of fresh strawberries. Food Technol. Biotechnol. 2015; 53: 488-495.
53. Del Nobile MA, Conte A, Buonocore GG *et al*. Active packing by extrusion processing of recyclable and biodegradable polymers. J Food Eng. 2009; 93: 1-6.
54. Jones N, Ray B, Ranjit KT Manna AC. Antibacterial activity of ZnO Nanoparticle suspensions on a broad spectrum of microorganisms. FEMS Microbiol Lett. 2008; 279:71-76.
55. Damm C, Neumann M, Munsted H. Properties of nanosilver coatings on polymethyl methacrylate. Soft Mater. 2006; 3:71-88.
56. Duran N, Marcato PD. Nanaobiotechnology perspectives role of nanotechnology in food industry: a review. Int.J.Food Sci.Technol. 2013; 48:1127-1134.
57. Mahmound M Berekaa. Nanotechnology in food industry; advances in food processing, Pacaging and Food Safety. Int.J.Curr.Microbial.APP.Sci. 2015; 4:345-357.
58. Lerner MB, Goldsmith BR, McMillion R *et al*. A carbon nanotube immunosensor for salmonella. AIP adv. 2011; 1: 042127 1-2 .

59. Dong Y, Philips KS, Cheng Q. Immunosensing of staphylococcus exterotoxin B (SEB) in milk with PDMS microfluidic systems using reinforced supported bilayer membranes(r-SBMs). Lab on a Chip. 2006; 6: 675-681.
60. Lavilla I, Cabaleiro N, Costas M, de la Calle I, Bendicho C. Ultra sound assisted emulsification of cosmetic samples prior to elemental analysis by different atomic spectrometric techniques. 2009; 80: 109-116.
61. Salvador A, March JG, Vidal MT, Chisvert A, Balaguer A. General overview on analytical methods for cosmetic ingredients. In Analysis of Cosmetic Products. 2007; 72-82.
62. Junginger HE, Hofland HEJ, Bouwstra JA. Liposomes and niosomes: interactions with human skin. Cosmet Toiletries. 1991; 106: 45–50.
63. Al-Edresi S, Baie S. Formulation and stability of whitening VCO-in-water-cream. Pharmaceutical Nanotechnology. 2009; 373: 74-178.
64. Porras M, Solans C, González C, Martínez A, Guinart A, Gutierrez JM. Studies of formation of W/O nano-emulsion. Colloids and Surfaces A: Physic chemical and Engineering Aspect . 2009; 249: 115-118.
65. Sagalowicz L, Leser ME. Delivery systems for liquid food products. Curr. Opin. Colloid Interface Sci. 2010; 15: 61-72.
66. Guglielmini G. Nanostructured novel carrier for topical application. Clinical Dermatology. 2008; 26: 341-346
67. Jain NK. Pharmaceutical Nanotechnology. J Nanomedic. 2007; 2: 210-215.
68. Santini B, Zaroni T, Marzi R *et al.* Cream formulation impact on topical administration of engineered colloidal nano particles. 2015; 5: 1-14.
69. Ghazal Labbeiki, Hossein Attar, Amir Heydarinasab, Sayed Sorkhabadi, AlimoradRashidi. Enhanced Oxygen Transfer Rate and Bio process yield using Magnetite Nano particles in Fermemation media of Erythromycin. DARU J. Pharm. Sci. 2014; 22: 66-72
70. Rosa Ana Perez, Beatriz Albedo, Jose Luis Tadeo, Encarnacion Molero, Consuelo Sanchez Brunette. Application of Magnetic Iron Oxide Nano particle for the Analysis of PCB's and soil leachates by gas chromatography. Anal BioanalChem. 2015; 407: 1913-1924.
71. Cristina Roman Hidalgo, Maria Ramos Payan, Juan Antonio Ocana Gonzalez. Agar flims containing Silver Nanoparticles as new supports for Electromembrane Extraction. Anal Bioanal Chem. 2015; 407: 1519-1525.
72. Reddy RP, Varaprasad K, Reddy NN, Raju MK, Reddy SN. Fabrication of Au and Ag bi-metallic nanocomposite for antimicrobial applications. J Appl Polym Sci. 2012; 2: 1357-1362.

73. Markova Z, Siskova KM, Filip J. Air stable magnetic Fe-Ag nanoparticles for advanced antimicrobial treatment and phosphorus removal. Environ Sci Technol. 2013; 47: 5285-5293.
74. Banerjee M, Shilpa S, Arun C, Sankar GS. Enhanced antibacterial activity of bimetallic gold-silver core-shell nanoparticles at low silver concentration. Nanoscale. 2011; 3: 5120-5125.