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PRINCIPLES AND CURRENT APPLICATIONS OF NANOTECHNOLOGY – A REVIEW

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Abstract

Nanotechnology is an enabling technology that deals with nanometer (nm) sized material. Nanotechnology is one of the most important scientific fields today since it combines knowledge from the fields of Physics, Biochemistry, Materials science, Chemistry, Biology, Medicine, Informatics and Engineering. It is considered as an emerging technology due to the possibility to advance well-established products and to create new products with totally new characteristics and functions with vast potential in a wide range of applications. Nanoparticles are considered as building blocks of the next generation of technology with applications in many sector. Nanomaterials are at the leading edge of the rapidly developing field of nanotechnology and its unique size-dependent properties make these materials superior and indispensable in many areas of human activity. Nanoparticles are extremely tiny with a size in the range of 10 to 1000 nm. They exhibit more surfaces to volume ratio and due to this they show extraordinary properties which are different from bulk materials. It plays a major role in the development of innovative methods to produce new products to substitute existing production equipment and to reformulate new materials and chemicals with improved performance resulting in less consumption of energy and materials and reduced harm to the environment as well as environmental remediation. Nanotechnology based nanoparticles have various applications in Agriculture, Environmental chemistry, Food science, Veterinary medicine, Marine, Medicine detection, Industries and many others. This brief review tries to summarize the most recent developments in the field of applied nanomaterials, in particular their application in various sectors, and discusses their commercialization prospects.

Key words: Nanotechnology, Nanoparticles, Nanomaterials, Nanofertilizer and Nanoelectronics.

1. Introduction

Nanotechnology is the study of materials which are altered into one billionth of a meter i.e., 10^{-9} m, which is about one hundred thousand times smaller than the diameter of a human hair, a thousand times smaller than a red blood cell. Nanotechnology is called as interdisciplinary subject which opens a new door of many applications. Nanotechnology with materials having special properties than their macroscopic or bulk counter parts, has promised applications in various fields. Nowadays we are using, eating, wearing, applying on our face, all these products are incorporate by the nanoparticles, nanomaterials, nanocomponents in one form or another. Nanosensors and Nanorobots could improve the performance of spaceships, spacesuits, and the equipment used to explore planets and moons (Asim Kumar and Madan Jee, 2013).

Nanotechnology or Nanoscience or Nanoscaled Technology was commonly considered to be at a size below 0.1 μm or 100 nm.

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In various fields, Nanotechnology is considered an promising technology due to the possibility to advance well established products and to create novel products with totally new characteristics and functions with enormous potential in a wide range of applications (Md Fakruddin *et al*., 2012). Nanotechnology gives new way for fundamental research into successful innovations. Nanotechnology can help in solving serious civilization problems such as energy adequacy, climate change and leads to new, useful and sometimes unexpected applications. Novel inventions makes the products that performs better, such as metals, ceramics, polymers, smart textiles, cosmetics, sunscreens, electronics, paints and varnishes which are marketedly available products which have very broad applications. So, nanomaterials must be examined for possible property on health as a matter of precaution and their possible environmental impacts and also nanotechnology used to detect and eliminate the pathogens (Saurabh Singh *et al*., 2014). The development of nanolevel structures results in distinctly different properties. The advances of nanotechnology in nanostructured materials are used in electronic and mechanical devices, in optical and magnetic components, quantum computing, tissue engineering and other biotechnologies. Innovative solar cell technologies that uses nanomaterials and composite systems such as organic photovoltaics offer great technological potential due to their attractive properties (Logothetidis, 2012).

Nanotechnology is an interdisciplinary field that plays a major role in different applied sciences like chemistry, physics, biology, medicine and engineering and this processed with operating at a scale range of less than 100 nm. For example a leukocyte has the size of 10000 nm, a bacteria has the size of 1000 – 10000 nm, a virus has the size of 75 – 100 nm, a protein has the size of 5 – 50 nm and a Deoxyribonucleic acid (DNA) has the size of ~2 nm (Saurabh Singh *et al*., 2014).

The fascinating properties of nanoparticles are largely due to its contribution made by small bulk of material (Nanomaterial). Nanoparticles are attributed qualitatively different physico-chemical characteristics from micron sized particles. Presently, nanoparticles are used for their unique reactive individuality purposes. It may be expected that they can be implanted inside body, its biochemical reaction time is much shorter and faster and also when designed to avoid the body's defense mechanisms. It is more sensitive than typical drug delivery. Nanoparticles act as a nanorobots to make repairs at the cellular levels. Because, nanoparticles are usually forms the core of nano biomaterial and it can be used as a suitable surface for molecular assembly and may be composed of polymeric or inorganic materials (Monalisa Jena *et al*., 2013).

Nanoparticles are the simplest form of structures with sizes in the nanometer range. In principle, any collection of atoms bonded together with a structural radius of < 100 nm can be considered a nanoparticle. This include, metal clusters (agglomerates of metal atoms), large molecules, such as proteins and even hydrogen-bonded assemblies of water molecules which exist in water at ambient temperatures. Nanotechnology have various applications such as in agriculture (Grain spoilage detection sensor, Nanopesticides, Nanofertilizer and bioprocess engineering), Environmental chemistry (Nanoremediation and Ground Water Remediation), Food science, Veterinary medicine, Marine, Medicine detection (Cardiac therapy, Dental care, Diagnostic techniques, Skin therapy and Cancer therapy) and Tissue engineering, Industries (Cosmetics, Textiles and Nanoelectronics) and many others. Nanotechnology is currently being used for a extensive variety of applications and more than six hundred nanotechnology - enabled consumer products are in the market (Jean Buzby, 2010). The present review paper briefly explains the application of nanotechnology in various sectors.

2. History of Nanotechnology

Nanotechnology has potential properties to remove obvious boundaries between biology, physics and chemistry upto some extent, and shape up our modern ideas and perceptive the

reason, many new challenges and directions may also arise in education, research and diagnostics. So, Nanotechnology is considered has to be a novel scientific approach that involves materials and equipments capable of manipulating physical as well as chemical properties of a substance at cellular levels (Md Fakruddin *et al*., 2012). The development in the field of nanotechnology was started in` the early stage of 1958 and the various stages of development have been summarize below.

Year wise development of Nanotechnology (Anna Pratima Nikalje, 2015)

1959 - R. Feynman initiated through process
1974 - The term nanotechnology was used by Taniguchi for the first time.
1981 - IBM Scanning Tunneling Microscope
1985 - "Bucky Ball"
1986 - First book on nanotechnology Engines of Creation published by K. Eric Drexler, Atomic Force Microscope
1989 - IBM logo was made with individual atoms
1991 - S. Iijima discovered Carbon Nano tube for the first time.
1999 - 1st nano medicine book by R. Freitas "Nano medicine" was published
2000 - For the first time National Nanotechnology Initiative was launched
2001 - For developing theory of nanometer-scale electronic devices and for synthesis and characterization of carbon nanotubes and nano wires, Feynman Prize in Nanotechnology was awarded
2002 - Feynman Prize in Nanotechnology was awarded for using DNA to enable the self-assembly of new structures and for advancing our ability to model molecular machine systems.
2003 - Feynman Prize in Nanotechnology was awarded for modeling the molecular and electronic structures of new materials and for integrating single molecule biological motors with nano-scale silicon devices.
2004 - First policy conference on advanced nanotech was held. First center for nano mechanical systems was established, Feynman Prize in Nanotechnology was awarded for designing stable protein structures and for constructing a novel enzyme with an altered function.
2005 to 2010 - 3D Nano systems like robotics, 3D networking and active nano products that change their state during use were prepared.
2011 - Era of molecular nano technology was started.

3. Classification of Nanomaterials

Nanomaterials can be classified on the basis of dimension wise into following categories:

a) Nano rods, nano wires have dimension less than 100 nm.
b) Tubes, fibers, platelets have dimensions less than 100 nm.
c) Particles, quantum dots, hollow spheres have 0 or 3 Dimensions < 100 nm.

Nano materials can also be classified on the basis of phase composition wise into following categories: (i) Single phase solids: Crystalline, amorphous particles and layers. (ii) Multi-phase solids: Matrix composites, coated particles and also colloids, aero gels, Ferro fluids, etc (Anna Pratima Nikalje, 2015).

4. Nanotechnology - At a Glance

Nanotechnology is the most promising technology in 21st century. It refers to the design, development and application of materials and devices made functionally with nanometer scale range. Nanotechnology deals with physiological processes of biological subjects including microorganisms by implementing many useful tools. Nanotechnology is diverse to completely new approaches based upon molecular self-assembly, from developing new materials with nanoscale dimensions to investigating the control matters on in the atomic scale level. This idea will be applied in the fields of science as organic chemistry, molecular biology, semiconductor physics, microfabrication, etc (Md Fakruddin *et al*., 2012).

5. Agricultural Application of Nanotechnology

Nanoparticles may become part of intelligent technological systems to capably apply production inputs, such as fertilizers and pesticides for specific temporal and spatial scales. Nanotechnology helps for monitoring environmental conditions and delivering nutrients or pesticides and also this technique are used in crop development, food process engineering, etc.

5.1. Grain spoilage detection sensor

Grain spoilage is the major problem arrived in crop production. This spoilage is due to the difference in the atmospheric climate and pathogens. Fabric sensor is a special sensor that helps the farmer which indicates the arrival of pathogens during crop development and sending alerts *via* mobile phone (Vijayalakshmi *et al*., 2015).

5.2. Nanopesticides

Nano encapsulated pesticides are effectively used without causing much damage to the environment. Likewise, several nano pesticides are developed which are biosafety and has a molecular interaction with plant, soil and environment with very limited dosage. Silver nanoparticlesis, a kind of antimicrobial substance has been used as fungicides (Vijayalakshmi *et al*., 2015).

5.3. Nanofertilizer

Nanoparticles of Fe, Zn, Mn and Cu oxides may have the potential for increasing plant growth when they are applied to soils (Chinnamuthu and Murugesa Boopathi, 2009).

5.4. Bioprocess Engineering

Nanocapsules to improve bioavailability of neutraceuticals in standard ingredients such as cooking oils and also used as flavor enhancers. Nanocapsule infusion of plant based steroids to replace a meat's cholesterol. Nanoparticles are selectively bind and remove chemicals or pathogens from food (Vijayalakshmi *et al*., 2015). All these processes are done using the development of nanocomposites which was coated over food packaging by placing antimicrobial agents directly on the surface of the coated film (Patra and Gouda, 2013).

6. Application of Environmental Chemistry

Nanoparticles are the key players that give many benefits through their nano-enabled applications. Nanomaterials provides an increasing efforts to use nanotechnology in environmental engineering to protect the environment by pollution control, treatment of drinking water and contaminated waste sites. This technique has proved to be an effective substitute to the conventional practices for site remediation.

6.1. Nanoremediation

Nanoremediation methods involve application of reactive materials for the detoxification and transformation of pollutants. This eco-friendly technology was used to protect the environment from pollution.

6.2. Ground water remediation

Nanomaterials such as zero valent iron (nZVI) and carbon nanotubes (CNT) in environmental cleanup like ground water remediation for drinking and reuse (Mansoori *et al*., 2008).

7. Nanomaterials and their Environmental Applications

7.1. Applications of Titanium Dioxide (TiO_2) Based Nanoparticles

Semiconducting, photocatalytic, energy converting, electronic and gas sensing properties of TiO_2 materials is responsible for the removal of various organic pollutants from the environment. Diazinon and Imidacloprid as N-heterocyclic aromatics are the two major agricultural pollutants were mineralized and degraded by immobilized TiO_2 nanoparticles. Photodegradation of direct azo dyes (Direct red 23 and Direct blue 53) can be done by using silver nanoparticles doped TiO_2. This material can be used for the extraction of phenols and removal of heavy metal cations (zinc, cadmium, chromium, copper, lead, palladium and mercury) from the wastewater. The properties of Mesoporous Anantase nanocrystal and

Mesoporous titania nanohybrid was used to remove methyl orange from the agricultural soil pollutants (Mansoori *et al*., 2008).

7.2. Iron Based Nanoparticles

Iron Based Nanoparticles provides high flexibility nature properties. Zero-valent powder iron (ZVI or FeO) was used for the removal of nitrate in water (Rajan , 2011). ZVI nanoparticle is more capable than the other nanoparticles for removal of perchlorate by perchlorate reduction method and also for the removal of Ba^{2+} ion from the aqueous solution. Colloidal zerovalent powder iron was used to remove the Herbicide Molinate compound. CMC (Carboxy Methyl Cellulose) stabilized ZVI nanoparticles are used for the removal of perchlorate pollutant (Mansoori *et al*., 2008).

7.3. Bimetallic Nanoparticles

Ground and surface waters were mainly contaminated by the increasing presence of nitrate in water. The deposition of minute amounts of a second metal (Pd, Pt, Ag, Ni & Cu) on iron has been shown to accelerate the denitrification process. Bimetallic nanoparticle (Pd/Au) which are used to reduce the chlorinated compounds present in surface water and ground water. Sodium carboxy methyl cellulose (CMC) was bimetallic with Fe-Pd as a stabilizer and used for the degradation of lindane and atrazine from the chlorinated herbicides. Bimetallic Cu/Fe nanoparticle having ability to remove Nitrate compound (Mansoori *et al*., 2008).

7.4. Nanoclays

Nanoclays are layered minerals that can able to absorb positive and negative ions and water molecules. Nanocomposite of iron oxide and silicate was used for degradation of azo dye orange (II). Organoclays (dithiocarbamate-anchored polymer/organosmectite) used for the removal of heavy metal ions from aqueous media (Mansoori *et al*., 2008).

7.5. Micelles (Self-assembled surfactants)

Micelles are a surface active agent that contains both hydrophobic groups (tails) and hydrophilic groups (heads). So, that it is usually soluble in both organic solvents and water. Surfactant-enhanced remediation techniques have used for the removal of polycyclic aromatic hydrocarbon (PAHs) pollutants present in the soil (Mansoori *et al*., 2008).

7.6. Nanomembrane and Nanosieve

Nanomembrane is a semi-permeable and selective barrier between retentive and permeate phases and used for filtration of dissolved solutes in a fluid or the separation of a gas mixture. Natural Organic Matter (NOM) such as humic acid and fulvic acid are widely distributed in soil, natural water and sediments. Nanofiltration (NF) is a process carried out with membrane permeability of nanomembrane used for the fractionation of Natural Organic Matter (NOM) from RO (desalination of seawater) and UF (ultrafiltration) process.

Mixed matrix composite membranes that are fabricated by encapsulating the molecular sieves into the polymer matrix have developed with a thin zeolite beta-polysulfone mixed matrix selective layer for the separation of He/N_2 and O_2/N_2 (Mansoori, 2008).

8. Application in Food Science

Nanomaterials are devised system which are able to find the presence of gases, aromas, chemical contaminants and pathogens or respond to changes in environmental conditions and also has the potential to improve food safety and reduce the frequency of food-borne illnesses. Silver has being used as an antimicrobial agent in food and beverage storage applications (Timothy Duncan, 2011). When packaging materials like Fresh products or meats which are either spoiled or unpalatable exhibit odors, colors or other sensory characteristics which can be easily discerned by consumers.

9. Application in Marine Science

Marine ecosystem has variety of living resources that are rich source of bioactive compounds with remarkable impact in the field of pharmaceutical, industrial and biotechnological

product developments. Nanotechnology has emerged as a potential source of novel solutions to clean up oil spills through nanomaterials. Aerogels, Filters, Nanodispersants (Micelles forming colloidal solution), Magnetic polymer nanocomposites, Carbon nanotube sponges, Nanostructured hydrophobic organoclays are used for the decomposition of oil contaminated water (Chinnappan Ravinder Singh *et al*., 2015).

10. Nanotechnology in Medicine and Drug Discovery

Nanotechnology in medicine involves applications of nanoparticles and nanorobots to make repairs at the cellular levels. Nanoparticles help to cure people faster and without the side effects. Nanotechnology in medicine is now focusing on areas like tissue regeneration, bone repair, immunity and even cures for such ailments like cancer, diabetes and other life threatening diseases. Nanorobots (computational genes) introduce into the body to repair or detect damages and infections.

Nanoparticles can be used for the better deliver drugs to tiny areas within the body due to its particle size and surface properties. They control and maintain the release of the drug during drug targeting. Nanoparticles can act as a physiological barrier in the body, because of its efficient characteristics in delivery of drug to various parts of the body. It provides more efficient drug distribution. Gold nanoparticles are promising probes for biomedical applications because they can easily detect the cancer. Nanoparticles enhance the stem cells ability to stimulate regeneration of damaged vascular tissue and reduce muscle degeneration in stem cell therapy. The new containers are coated with silver nanoparticles that keeps foods fresher three or even four times longer than normal. And also the containers are used to store fruits, vegetables, herbs, breads, cheeses, soups and sauces. Vaccines are prepared with nanopaticles that are used to boost the speed of the immune response and it allowing immune cells to react to the protein and initiate a protective immune response (Abhilash, 2010).

10.1. Cardiac therapy

Nanotechnology is currently offering promising tools for the cellular level and treat challenging cardiovascular diseases. Nanocrystals and Nanobarcodes are capable of monitoring complex immune signals in response to cardiac or inflammatory events (Md Fakruddin, 2012).

10.2. Dental care

The benefit of nanodentistry in natural tooth maintenance could also be significant. Covalently bonded artificial materials like sapphire may replace upper enamel layer to boost the appearance and strength of teeth (Wei Wang *et al*., 2015).

10.3. Drug delivery

Nanoparticles are used to deliver drugs, heat, light or other substances to specific types of cells (such as cancer cells). Particles are engineered so that they are attracted to diseased cells, which allow direct treatment of those cells. This technique reduces damage to healthy cells in the body and allows for earlier detection of disease (Monalisa Jena *et al*., 2013).

10.4. Diagnostic and imaging techniques

Quantum Dots (qdots) may used for locating cancer tumors in patients and in the near term for performing diagnostic tests in samples (Satvekar *et al*., 2014). Quantum Dots are spherical, fluorescent nanocrystals are widely used as an alternative to conventional flurophores and for the development of biosensors to detect biomolecules such as proteins, neurotransmitters, enzymes and amino acids (Satvekar *et al*., 2014)..

10.5. Skin therapy

Applications of nanotechnology in dermatology include sunscreens, moisturizers, anti-aging formulations, phototherapy, anti-sepsis, skin cancers, hair and nail care, etc (Tasleem Arif, 2015).

10.6. Cancer therapy

Nanoshells that concentrate the heat from infrared light to destroy cancer cells with minimal damage to the healthy cells (Hardik *et al*., 2011).

Nanoparticles deliver chemotherapy drugs directly to cancer cells to minimize damage to normal cells. Nanocarrier systems can be designed to interact with cancer cells to induce desired response (Chetan Anajwala *et al*., 2010) and it shows new way for more effective diagnosis and therapy of cancer.

10.7. Nanomaterials for medical diagnosis

Nanomaterials exhibit higher properties that are very different than their bulk materials, so that it is mainly used in diagnostic techniques. Because of their small size, nanomaterials can easily interact with biomolecules and gaining access to so many areas of the human body system. Nanomaterials give the opportunity to interact with cells at the molecular scales in real time, and also during the earliest stages of an disease (Satvekar *et al*., 2014).

10.8. Magnetic Nanoparticles (MNP)

It is mainly consist of magnetic element such as iron, nickel, and their derivatives. It enhances the sensitivity and effectiveness of biosensor to reduce sample preparation requirements. Magnetic sensors such as magnetic relaxation switch assay sensors, magneto-resistive sensors and magnetic particle relaxation sensors have been developed recently (Satvekar *et al*., 2014).

10.9. Carbon Nanotube (CNT)

CNT are long, hollow cylindrical carbon structures composed of one, two or several concentric graphite layers capped with fullerenes hemispheres which is used in the diagnosis of cancer, and infectious diseases. For example, when it binds with a protein, the nanotubes change their electrical resistance which can determine the presence of a particular protein, for example serum protein biomarkers that can indicates breast cancer (Satvekar *et al*., 2014).

10.10. Graphene oxide (GO)

Hybridized carbon sheets of GO, which is attached with antibody that will binds to the cancer cells which then tag the cancer cells with fluorescent molecules to make the cancer cells stand out in a microscope (Satvekar *et al*., 2014).

10.11. Porous nanomaterial

The porous nanomaterials are particularly capable for fabrication of optical biosensors as it is used in wide range of physical properties such as high purity, tunable porosity, nanoscale structuring, high photochemical, physical rigidity and thermal stability (Satvekar *et al*., 2014)..

10.12. Gold Nanoparticles (AuNPs) and Silver Nanoparticles (AgNPs)

Gold nanoparticles are used in biosensors as their optical characteristics can change upon binding to certain molecules, permitting the recognition and quantification of analyte. For example, the sensitive DNA detection can be exploited by gold nanoparticles. The silver nanorods are used in a diagnostic system to separate viruses, bacteria and other microscopic components of blood samples and this method has been done in less than an hour (Satvekar *et al*., 2014).

11. Nanotechnology in Ophthalmology

It includes the treatment of oxidative stress; measurement of intraocular pressure, theragnostics (use of nano particles for treatment of choroidal vessels), to prevent scars after glaucoma surgery, and for treatment of retinal degenerative disease using gene therapy (prosthetics) and regenerative nano medicine. Nanomaterials are used to help in various unsolved problems such as sight-restoring therapy for patients with retinal degenerative disease. A novel nanoscale-dispersed eye ointment (NDEO), which were coupled with medium-chain triglycerides (MCT) as a liquid lipid used for the treatment of severe evaporative dry eye has been successfully developed recently (Anna Pratima Nikalje, 2015).

12. Applications of Nanotechnology in Veterinary medicine

Nanotechnology has the potential impact on veterinary medicine include disease diagnosis

and treatment delivery systems, new tools for molecular and cellular breeding, the security of animal food products, modification of animal waste, pathogen detection, and many more (Vikrama Chakravarthi and Sri Balaji, 2010). Nanosensors are used for the detection of diseases in animals. The real challenge to veterinary medicine that provide maximum benefits to animals health (Neeraj Dilbaghi, 2013). Nanotechnology provides improving pet health care and visualizes the quality of animals life.

13. Industrial applications of Nanotechnology

13.1. Cosmetics

Nanotechnology in cosmetics is used to make fragrances last longer, sunscreens more effective and anti-ageing creams etc. In recently, emulsion-based wet wipes for such applications as baby care and make-up removal (Nirvesh Chaudhri *et al*., 2015).

13.2. Textiles

Nanotechnology in the textile industry has become multifunctional and produces fabrics with special functions, including antibacterial, UV protection, easy-clean, water- and stain repellent and anti-odour, flexibility etc (Anna Pratima Nikalje, 2015). Clay nanoparticles are resistant to heat and ability to block UV light Chitosan and silver are used as antibacterial, Polybutylacrylate used for increase durability, Nanoporous hydrocarbon on nitrogen coating used for improved staining or reduce fade in clothes. Nanotechnology has created antibacterial cotton used for antibacterial textile. This technique has been advanced by a focus on inorganic nanostructured materials that acquire good antibacterial activity and application of these materials to the textiles (Anna Pratima Nikalje, 2015).

13.3. Nanoelectronics

The production of displays with very low power consumption can be accomplished through carbon nanotubes. Nanomaterials are used to increasing the density of memory chips. It also reduces the size of transistors used in integrated circuits. Using nanosized magnetic rings to make Magnetoresistive Random Access Memory (MRAM) which research has indicated that it may allow memory density of 400 GB per square inch (Asim Kumar and Madan Jee, 2013).

14. Other Applications of Nanotechnology

14.1. Tissue engineering

Scaffolds and growth factors are produced by Nanotechnolgy to reproduce or repair damaged tissue by artificially stimulated cell proliferation, in organ transplants or artificial implants therapy which can lead to life extension (Anna Pratima Nikalje, 2015).

14.2. Antibiotic resistance

Zinc Oxide nanoparticles can decrease the antibiotic resistance and enhances the antibacterial activity of Ciprofloxacin against microorganism by interfering with various proteins that are interacting in the antibiotic resistance or pharmacologic mechanisms of drugs (Anna Pratima Nikalje, 2015).

14.3. Immune response

Bucky balls device have been used to alter the allergy/immune response (Anna Pratima Nikalje, 2015).

14.4. Nano pharmaceuticals

Nanotechnology can be used to detect diseases at much earlier stages and the diagnostic applications by using nanoparticles in pharmaceuticals. Nanopharmaceuticals are an emerging field that used nanotechnology for therapeutic delivery system work at the nanoscale, delivering the dose of a particular active agent to the specific disease, less toxic systemic side effects, enhance the drug formulation and drug target discovery and also for drug discovery process cost effective (Anna Pratima Nikalje, 2015).

15. Toxicity of Nanoparticles

Nanoparticles can produce free radicals and cause cell toxicity when it exposed under UV light rays. If nanoparticles can be inhaled and

eaten accidentally or absorbed *via* skin, they could cause skin and lung damage (Md Fakruddin *et al*., 2012). Administration of continuous TiO_2 nanoparticles can lead to brain damage and reduce the sperm production. If ingested, the nanoparticles can reach the circulation and reach different organs and systems and possibly result in toxicity (Alka Lohani, 2014).

16. Challenges for Nanotechnology

Nanoscale machines can be incorporated into biological systems at the cellular level. It may positively change many ideas and hypotheses in the treatment of critical cardiovascular diseases. This approach can be a real milestone of success in achieving cardiac drug therapy for the administration of cardiovascular diseases. To enhance the development of methods to detect and measure the toxicity of engineered nanomaterials within next 5 to 15 years and also to predict the effects of nanomaterials to the humans and environment. It includes some uncertained effects of innovation, scalability, funding, scarce resources, patience etc (Md Fakruddin *et al*., 2012).

17. Conclusion and Future Prospects of Nanotechnology

Nanotechnology is having a large impact on development in various sectors like Agriculture, Environmental chemistry, Marine, Industries and Medical field etc. Nanotechnology holds a lot of promise in terms of potential applications and products. There is no doubt that in the next few years, nanotechnology will penetrate into every area in this world. Nanotechnology is a choice of area of creation in various new materials and potentially useful in many fields (such as medicine, electronics, biomaterials and energy production). It may give highly potential properties to the global economics. It may lead to innovations by playing a major role in various biomedical applications such as drug delivery, gene therapy, drug therapy, disease diagnosis, biomarkers and biosensors. Nanotechnology based imaging techniques for monitoring cellular activities in tissues are coming soon. Advances in nanomedicines have given up its application as diagnostic and regenerative medicine in future. It would be more faster method to diagnosis a particular disease before spreading in other parts of the body (Md Fakruddin *et al*., 2012).

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