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A Review on Current Advancements in Nanotechnology

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Mini Review

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ABSTRACT

Nanoparticles are becoming key components in a wide range of applications. Nanoparticle exploration is as of now a territory of extraordinary logical examination, because of a wide assortment of potential applications in biomedical, optical, and electronic fields. Research encompasses numerous disciplines, e.g. nanotechnology, molecular engineering, medicine, pharmaceutical drug manufacture, biology, chemistry, physics, optical components, polymer science, mechanical engineering, toxicology, cosmetics, energy, food technology and environmental and health sciences. This article emphasizes on the wide applications and uses of the nanoparticles in different fields. The use of nanotechnology in medicine and more specifically drug delivery is set to spread rapidly. Currently many substances are under investigation for drug delivery and more specifically for cancer therapy. This article also provides the cons of nanoparticles and their risks in regard of dietary aspects. The point of this survey is firstly to give a note of nanomaterial application to science and pharmaceutical, also to attempt to diagram the latest advancements in this field.

Introduction

Nanoparticles are particles between 1 and 100 nanometers in size. In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties [1]. Nanoparticles have one dimension that measures 100 nanometers or less The properties of numerous customary materials change when shaped from nanoparticles. This is commonly on the grounds that nanoparticles have a more noteworthy surface range every weight than bigger particles which makes them be more responsive to some different atoms. Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures [2]. The interesting and sometimes unexpected properties of nanoparticles are not partly due to the aspects of the surface of the material dominating the properties but its bulk properties. Nanoparticles have wide applications in different fields as shown in the Figure 1. Nanoparticles have a very high surface area to volume ratio. This provides a tremendous driving force for diffusion, especially at elevated temperatures. Biodegradable polymeric nanoparticles have the potential to be safer alternatives to viruses for gene delivery; however, their use has been limited by poor efficacy in vivo. Nanoparticles often possess unexpected optical properties as they are small enough to confine their electrons and produce quantum effects. As indicated by the FDA [3], these nanomaterial can have totally diverse synthetic, physical or natural properties when contrasted with the same material at a bigger, ordinary size.

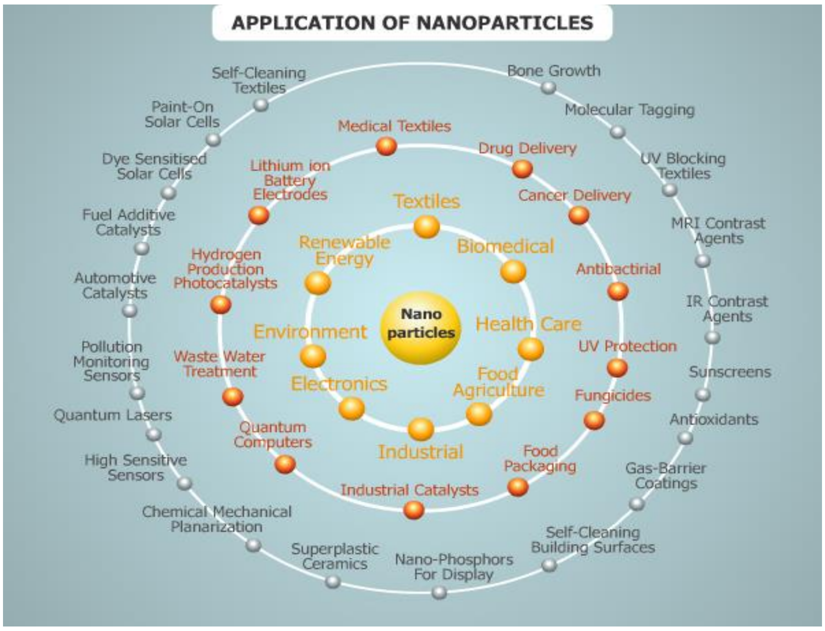

Figure 1: Applications of Nanoparticles

Methods for Formation of nanoparticles

Free nanoparticles are framed through either the separating of bigger particles or by controlled gathering procedures.
There are two methods for the assembling of nanoparticles:
The “top-down” approach includes the separation of extensive bits of material to create the obliged nanostructures from them. This system is especially suitable for making interconnected and incorporated structures, for example, in electronic hardware [4-6].
In the “bottom-up” approach, single atoms and molecules are assembled into larger nanostructures [7]. This is a capable strategy for making indistinguishable structures with nuclear exactness, despite the fact that to date, the man-made materials produced are still much easier than nature's unpredictable structures.

As the use of nanoparticles in different areas is expanding, the need for nanoparticles with a well-defined morphology in high quantities and a low price is increasing. As the main point for this high demand is the large specific surface area of nanoparticles, different approaches have been designed to increase the surface area. Chemical modification [8] and encapsulation of nanoparticles is the most common practice and an area where valuable innovations are seen. The surface modification can be for the following reasons:

- reactive nanoparticles should be passivized
- aggregative nanoparticle in a medium where the nanoparticles are to be dispersed are stabilized
- the nanoparticle for applications such as molecular recognition are functionalized
- assembly of nanoparticles is promoted

Grafting thiolated surfactants [9,10] or polymers, adsorption of charged surfactants, charged ligands or polymer brushes, attachment of biological molecules such as DNA, proteins, antigens or coating a continuous polymer film on nanoparticles are the most commonly used surface modification methods.

Nanoparticle Applications in Medicine

The surface change of protein filled nanoparticles [11-13] have shown to affect the ability of the nanoparticle to stimulate immune responses. Researchers are now thinking that these nanoparticles may be used in inhalable vaccines.

Scientific communities are developing ways to use carbon nanoparticles called Nano diamonds in medical applications [14]. Nano diamonds with protein molecules attached can be used to increase bone growth around dental and joint implants. Researchers are testing the use of chemotherapy drugs attached to Nano diamonds to treat brain tumors. Other researchers are investigating the use of chemotherapy drugs attached to Nano diamonds to treat leukemia.

Another self-collecting nanoparticle has been produced that objectives tumors, to help specialists analyze malignancy prior. The new nanoparticle supports the adequacy of MRI [15-18] examining by particularly searching out receptors that are found in malignant cells. The nanoparticle is covered with an exceptional protein that searches for particular signs given off by tumors. When it discovers one, it starts to communicate with the dangerous cells; this cooperation strips off the protein covering, creating the nanoparticle to self-amass into a much bigger molecule so it is more unmistakable on the sweep.
Another kind of nanoparticle has demonstrated potential for more successful conveyance of chemotherapy to treat growth. In research center studies, analysts created and tried another sort of nanoparticle that can convey bigger measures of a medication [19] and won't release the medication as the molecule courses through the circulation system on its way to the objective.

Nanoparticle has potential for more effective delivery of chemotherapeutic drugs to treat cancer[20-26]. In recent studies, researchers developed a novel nanoparticle that can deliver huge amounts of a drug and will not leak the drug as the particle circulates through the blood stream before reaching the target [27].

Silver nanoparticle [28] solutions are used to treat mouth infections. The silver nanoparticles could be suspended in new medicines and used in hospitals as preventive care. The silver added to mouth washes help denture wearers prevent the growth of biofilms [29-31]. Professor Henriques believes that the silver nanoparticles could even be built into dentures, creating a shield against fungal and bacterial growth in the mouth.
Researchers are developing a technique to release insulin that utilizes sponge-like matrix that contains insulin along with Nano capsules [32-36] containing an enzyme. When the glucose level rises the nanocapsules release hydrogen ions, which bind to the fibers making up the matrix. The hydrogen ions make the fibers charged, repelling one another and creating spaces in the matrix through which insulin is released.
The nanoparticles contain nitric oxide gas [37], which is known to destroy bacteria. Studies on mice have shown that these nanoparticle release nitric oxide gas at the site of staph abscesses significantly reduced the infection.

Researchers have demonstrated a new method to use nanoparticles for early diagnosis of infectious disease. The nanoparticles attach to molecules in the blood stream indicating the initial stage of an infection. When the sample is scanned for Raman scattering the nanoparticles [38-40] enhance effect of the Raman signal, providing the clear detection of the molecules indicating an infectious disease at a very early stage.

Advantages of using Nanoparticles in drug discovery

Molecule size and surface qualities of nanoparticles can be effectively controlled to accomplish both aloof and dynamic drug focusing on after parenteral organization [41-43]. They control and maintain discharge of the drug during the transportation and at the site of limitation, adjusting organ dissemination of the drug and ensuing way of the medication so as to accomplish increment in drug helpful adequacy also, lessening in symptoms. Site-particular focusing on can be accomplished by connecting focusing on ligands to surface of particles or utilization of attractive direction. The framework can be utilized for different courses of organization including oral, nasal, parenteral, intra-visual and so on. Nanoparticles can better convey drugs to minor territories inside of the body. Building on this scale empowers scientists to exercise choice furthermore, already inconceivable control over the physical properties of polymers and different biomaterials [44-49]. Nanoparticles overcome the resistance advertised by the physiological boundaries in the body since proficient conveyance of medication to different parts of the body is straightforwardly influenced by molecule size. Nanoparticles help in proficient drug conveyance to enhance fluid solvency of ineffectively dissolvable medications that improve Bioavailability for timed discharge of medication particles, and exact drug focusing on. The surface properties of nanoparticles can be adjusted for focused on drug conveyance for e.g. little particles, proteins, peptides, and nucleic acids stacked nanoparticles are not perceived by safe framework and proficiently focused on to specific tissue sorts. Focused on Nano drug transporters [50-52] lessen drug harmfulness what's more, give more effective medication conveyance. Nano-carriers holds guarantee to convey biotech medications over different anatomic furthest points of body.

Nanoparticle Applications in Manufacturing Materials

Silicate nanoparticles are used to provide a barrier to gases (for example oxygen), or moisture in a plastic film used for packaging [53]. This could slow down the process of spoiling or drying out in food.

Zinc oxide nanoparticles [54] are used in industrial coatings as dispersions to protect wood, plastic, and textiles from exposure to UV rays.

Silicon dioxide crystalline nanoparticles [55-58] can be used to fill gaps between carbon fibers, whish help in strengthening tennis racquets.

Nanotechnology is applied in the production, processing, safety and packaging of food. It is possible that nanotechnology allows the manipulation of the molecular forms of food to provide more capability, lower price and higher sustainability than at present [59]. A nanocomposite covering procedure ought to enhance sustenance bundling by putting against microbial operators straightforwardly on the surface of the covered film and could build or decline gas penetrability as needed for distinctive items. They can likewise enhance the mechanical and warmth resistance properties and bring down the oxygen transmission rate. It should also be possible to apply nanotechnology to the detection of chemical and biological substances for sensing biochemical changes in foods, extending to the whole food chain in the future

Nanoparticles and the Environment

Scientists provided the usage of photocatalytic copper tungsten oxide nanoparticles to break down oil into biodegradable compounds [60-63]. These nanoparticles provide high surface area for the reaction that is activated by sunlight and can work in water, making them useful for cleaning up oil spills.

Researchers are using gold nanoparticles bounded in a porous manganese oxide at a room temperature catalyst to breakdown volatile organic pollutants in air. Iron nanoparticles are used to clean up carbon tetrachloride pollution in ground water [64]. Iron oxide nanoparticles are also used to clean arsenic from water wells.

Nanoparticle Applications in Electronics

Researchers used nanoparticles called nanotetrapods studded with nanoparticles of carbon to develop low cost electrodes for fuel cells. This electrode may be used to replace the expensive platinum needed for fuel cell catalysts.

A catalyst using platinum-cobalt nanoparticles has been developed for fuel cells that enhances more catalytic activity by twelve times than pure platinum [65]. In order to achieve this performance, researchers anneal nanoparticles to form them into a crystalline lattice like structure, reducing the spaces between platinum atoms on the surface and enhancing their reactivity.

Researchers have demonstrated that sunlight concentrated on nanoparticles could produce steam with high energy efficiency [66]. The "solar steam device" is intended to be used in areas of developing countries without electricity for applications such as purifying water or disinfecting dental instruments.

Semiconductor nanoparticles are applied in a low temperature printing process that enables the manufacturing of low cost solar cells.

The Dangers of Nanoparticles

Nanoparticles may lead to cell damage in humans' intestinal tracts.

Nanoparticles have been reported to cause cell damage in humans' intestinal tracts, then get passed back into environment. New research suggests that nanoparticles in food, medicine and body care products cause cellular damage in the human intestinal tract [69-71]. Over time, these particles also pass back into the environment then into sewage waters, ultimately affecting aquatic life.

Nanoparticles (untested) in dietary aspects

Nanotechnology is the method of manipulating matter at the molecular level. The fact remains that nanomaterial is untested and presents several safety concerns [72-74], mainly the potential to bypass the blood-brain barrier as well as the placenta increase bioavailability of chemicals and toxinswhich migrate throughout the body to organs and tissues. Since nanoparticles differ in total surface area compared to their larger counterparts, they are more reactive and have greater toxicity than that would occur at normal size.

Nanoparticles destroy useful microbial flora in soil

Uncontaminated soil contains beneficial microbes [75], some of which are necessary to help plants in absorbing nitrogen. But when nanoparticles enter the soil, these microbes are largely killed. The end result is plants that lack nitrogen, and thus lack the ability to grow properly and maintain necessary levels of vital nutrients.

Sunscreen made with nanoparticles may lead to skin cancer

Many sunscreens now contain nanosize particles of titanium dioxide or zinc oxide, around 100,000 times smaller than the width of a human hair. The reason for using nanotechnology is to make the sunscreens less oily and easier to rub into the skin [76]. Recent studies indicated that zinc oxide nanoparticles penetrate healthy human skin to reach the blood and urine, kill brain stem cells in mice, and destroy colon cells in even minute concentrations. They also cite studies finding that nanoscale titanium dioxide produce gene changes in pregnant mice and has been linked to Alzheimer's, autism and epilepsy.TiO_2 nanoparticles induce single and double-strand DNA breaks and cause chromosomal damage and inflammation, all of which increase the risk of cancer. TiO_2 nanoparticles accumulate in different organs and as there is no way to eliminate them internally. And because the particles are so tiny, they can go anywhere even glide through cells to potentially disrupt body functions on a sub-cellular level.

Nanoparticle toxicity analysis toward its in vivo applications

The smaller the nanoparticle the greater the toxicity caused. This is due to the fact that small nanoparticles are easily and readily absorbed into the cell and thus into some vital parts of the body. Larger nanoparticles may therefore be comparatively less toxic because their cellular uptake and absorption is less and limited at that same concentration.

In order to consider and predict possible nanoparticles toxicity in *in vivo* applications, few things should be carefully studied and examined.

In vitro studies for cytotoxicity [77-80]ought to carefully be utilized to extrapolate expected results in *in vivo* studies. Nanoparticles in in vivo framework would encounter a great deal more complicated because of a wide variety of proteins and little biomolecules present around them. In light of these neighboring biomolecules, nanoparticles can be degraded, inundated by phagocytic cells, or voyaged far from the target site by lymphatic framework. Measure reactions got from very much controlled environment, for example, in refined plate may not generally introduce the same results got in vivo environment. Hence, it will be insufficient to reach any determinations from the in vitro test for nanoparticle reactions in vivo framework until taking after trials at any rate in animal model is performed.

Next, limitations of current assays performed for cytotoxicity or inflammatory responses[81-84] of cells in relative to the nanomaterials should be carefully examined and further endeavors to advance technologies for better assaying nanoparticles should be invested. Studies related to *in vitro* cytotoxicity and the inflammatory response to nanoparticles have adopted conventional assays. These reports have provided little insight and information about how individual cells react when exposed to nanoparticles. And even the analysis of these assay results is prone to some error because cells may behave uniquely depending on the assays that are employed.

The limitations of current cytotoxicity and immune response assays for the assessment of nanoparticles can be listed as follows. First, the cells cannot be recovered after the single assay results are obtained; thus the possibilities for time-dependent monitoring of changes in a cell's activity are limited. Second, the assays' readings are averaged from all the cells present. Therefore, a single cell's responses to the nanoparticles cannot be recorded individually from the assay. Third, nanoparticles inside a cell may provide some interference due to fluorescence signal produced by the dye that is used in the assay. Additionally, nanoparticles [85] may interact with the dyes and may bind to them altering their absorption and hence the florescence is also interrupted [86-88]. Nanoparticles can also be adsorbed to the proteins and other biomolecules in the cell culture medium, which can cause interference with the particles and normal interactions with cells. Furthermore, nanoparticles bound to cytokines released from the cells may artificially reduce an assay's positive signal. Flow cytometry is a commonly used method in biological response assays, but this technique requires that cells to be detached from the cell culture plate, but this might affect the cells' mortality. Because of these limitations, there is an emergent requirement to develop and stabilize a solid assay that helps to overcome the above-mentioned problems with conventional assays and would evaluate the biological responses to nanoparticles.

For assessing cytotoxic [89-92] and inflammatory responses to nanoparticles in a multiplexed manner cutting-edge single-cell assay techniques have been developed. The multiplexed analysis strategy will be used in safety studies of various nanoparticles. Time-dependent analysis of a single cell's responses to nanoparticles may elucidate the mechanism of toxicity for nano-sized particles. Such single-cell analyses may be used in with conventional bulk assays. The approaches discussed will benefit nanotoxicological studies and help the broader nanotechnology community by providing proof of concept for an efficient analytical tool[93-95] with which to investigate the safety of nanoparticles at the single-cell level in a multiplexed fashion.

Conclusion

Nanoparticles are mostly used extensively for applications in drug discovery, drug delivery, diagnostics and for many others in medical field. Nanoparticles have been also used in manufacturing processes, food industry and electronic Industry [96,97]. The kind of perils that are presented by utilizing nanoparticles for medication conveyance are past that postured by ordinary risks forced by chemicals in conveyance networks. A theoretical comprehension of organic reactions to nanomaterial is expected to create and apply safe nanomaterials [98-102] in medication conveyance later on. Besides a close coordinated effort between those working in medication conveyance and molecule toxicology is essential for the trading of ideas, strategies and ability to go places with this issue.

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