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NANOMATERIALS AND THEIR ADVERSE AFFECTS IN VARIOUS FIELD

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ABSTRACT

The rapid advancement and integration of nanomaterials into various industries, including medicine, cosmetics and environmental engineering, has raised significant concerns regarding the adverse effects of nanomaterials on human health and the environment. This review explores the potential risks associated with the widespread use of nanomaterials, highlighting their unique physicochemical properties that contribute to their biological interactions. This review describes the advantages as well as the disadvantages of different kinds of nanomaterials, it describes how nanomaterials used in the decade years, present use and future development, in what categories nanomaterials are divided into and use of them. The review also highlights recent advancements in synthesis techniques aimed at enhancing the purity, yield and functionality of nanomaterials. Emphasis is placed on the need for continued innovation in synthesis strategies to meet the growing demands of nanotechnology while ensuring environmental and human safety. It highlights the diverse applications and distinctive characteristics of nanomaterials that contribute to their widespread utility. In medicine, nanomaterials are employed for targeted drug delivery, imaging and diagnostic applications, capitalizing on their high surface area and functionalizability. In electronics, they enable the development of smaller, faster and more efficient devices, due to their superior electrical and thermal conductivity. Despite their beneficial applications, the findings underscore the urgent need for comprehensive risk assessment frameworks and regulatory policies to mitigate potential hazards. Future research directions are proposed to address gaps in understanding the long-term implications of nanomaterial exposure, aiming to ensure safe and sustainable use of nanomaterials. The toxicity of a metallic nanomaterial may differ depending on the oxidation state, ligands, solubility and morphology, and on environmental and health conditions.

KEYWORDS

Nanomaterials, Classification, Synthesis and Adverse effect.

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INTRODUCTION

Nanomaterials are distinct structures with sizes ranging from 1 to 100nm. The word "nano" comes from Greek word "Nanos" meaning dwarf. Nanomaterials are primarily in powder form and consist of nanoparticles. Due to the fact that particle size differs significantly from the macroscopic structures of the same material, nanomaterials exhibit unique chemical and physical properties. This involves the precise manipulation of particles, leading to the creation of nanostructured materials with novel characteristics and applications. The field of nanotechnology and nanoscience is rapidly advancing through research and development in this area[1]. Nanoparticles have garnered considerable attention in the field of biological applications due to their distinct physicochemical properties. The therapeutic impact of metal- and metal oxide-supported nanomaterials has been noteworthy in the realm of medical science. Numerous endeavours have been undertaken to explore the antibiotic resistance and antimicrobial activity of metal-supported nanoparticles. In light of this, the review delves into the role of various types of metal-supported nanomaterials in diverse domains such as antifungal, antibacterial, anticancer, and more. Given the significant ongoing research and applications, it is anticipated that metal-supported nanomaterials will not only play a remarkable role in the medical field but also in other crucial areas[2].

Nanomaterials have made their way into various industries including energy, environment, food, medicine and more. They continue to attract attention in both scientific and commercial realms. The size-dependent properties of nanomaterials have been discovered, leading to valuable chemical and physical characteristics. The first group of nanomaterials consists of pure metal-based nanoparticles, also known as metal nanoparticles (e.g., silver, copper, gold, titanium, platinum, zinc, magnesium, iron, and alginate nanoparticles). The other category includes metal oxide nanoparticles such as titanium dioxide, silver oxide, zinc oxide, and others[3]. The most common nanoparticles used in the food industry are metal nanoparticles used for packing materials, storage, shape at the nanoscale for nanosensor manufacturing, united active nanoparticles for migration properties, nanopore filters for purification and nanoencapsulated additives and nanosized food and nutrients used as supplements[4]. The prevalence of the illness resulting from food contamination has risen over the past ten years. Nanotechnology has emerged as one of the most rapidly advancing technologies in recent years. Globally, approximately 400 companies have developed their applications utilizing nanomaterials in the food industry[5]. The main aspect of food packaging is to preserve it from many things like insects, microorganisms, physical damage, and dirt. The nano sensors can also notify the state of the food during transport and storage, which will be very beneficial. Because of these many reasons, the world's largest food packaging companies are studying and researching it to explore the potential of polymer nanotechnology.

It has been reported that global supply of nanoenabled packaging for food and beverages is approximately 20 billion in 2020[5]. Different nanomaterials are zinc, titanium, silicon, and silver, but silver nanoparticles are most productive as they have properties like antibacterial and antiviral and are used as drug disinfectants[6]. Each nanomaterial has a different chemical structure, properties, and characteristics. So, each nanomaterial has a different application in food packaging. Silver nanoparticles, starch, and nanozinc oxide have a large surface area than macroparticles and microparticles[7]. The nanomaterial is defined as a material with any external dimension in the nanoscale or having an internal structure or surface structure in the nanoscale, approximately 1-100nm size range[8]. Nanomaterials pose significant health risks due to their unique properties Studies highlight potential toxic effects like oxidative stress, DNA damage and inflammation. Nanoparticles can enter the body through inhalation, ingestion or skin contact, lead contact and even genotoxity. It is essential to comprehend the various pathways through which nanomaterials can enter the body and cause harm in order to effectively evaluate and minimize their negative effects on human health and the environment. Research indicates that nanoparticles can potentially induce toxicity in various organs, including the brain, liver and lungs, which are commonly studied as primary target sites. Reproductive toxicity is gaining recognition as a significant aspect of nanotoxicology. Nevertheless, the reproductive effects of nanoparticles have only begun to be thoroughly investigated in recent years.

HISTORY AND DEVELOPMENT OF NANOMATERIALS RESEARCH

Nanoparticles and structures have been used by humans in fourth century AD, by the Roman, which demonstrated one of the most interesting examples of nanotechnology in the ancient world. The Lycurgus cup, from the British Museum collection, represents one of the most outstanding achievements in ancient glass industry. It is the oldest famous example of dichroic glass. Dichroic glass describes two different types of glass, which change colours in certain lighting conditions. This means that the Cup have two different colours: The glass appears green in direct light and red-purple when light shines through the glass[9]. In the year 1990, researchers examined the cup through transmission electron microscopy (TEM) in order to elucidate the phenomenon of dichroism. The dichroism observed, characterized by two distinct colors, can be attributed to the presence of nanoparticles measuring 50-100nm in diameter. X-ray analysis revealed that these nanoparticles are composed of an alloy of silver and gold (Ag-Au), with a ratio of approximately 7 parts silver to 3 parts gold, and also contain around 10% copper (Cu) dispersed within a glass matrix. The absorption of light at a wavelength of approximately 520 nm by the gold nanoparticles results in the manifestation of a red color. The red-purple colour is due to the absorption by the bigger particles while the green colour is attributed to the light scattering by colloidal dispersions of Ag nanoparticles with a size > 40nm. The Lycurgus cup is recognized as one of the oldest synthetic nanomaterials. A similar effect is seen in late medieval church windows, shining a luminous red and yellow colors due to the fusion of Au and Ag nanoparticles into the glass[10].

MODERN ERA OF NANOMATERIALS

Nanotechnology has advanced significantly from the initial concepts proposed by Feynman to the year 1981, when physicists Gerd Binning and Heinrich Rohrer developed the Scanning Tunneling Microscope (STM) at IBM Zurich Research Laboratory[11,12]. The STM uses a sharp tip that moves so close to a conductive surfaces that the electron wave functions of the atoms in the tip overlap with the surface atom wave functions[13]. STM has been widely used in semiconductor research to study the structural and electronic properties of semiconductor surfaces such as investigating doping profiles etc. The Scanning Tunneling Microscope is constrained by the necessity of an electrically conducting sample surface, which restricts the range of materials that can be analyzed using this tool. Additionally, the scanning speed of the STM is notably slower in comparison to optical or electron microscopes. In 1970 R. W. Henson proposed the C60 structure and made a model of it. In 1985, Harold Kroto, Robert Curl and Richard Smalley from Rice University discovered fullerenes in the sooty residue created by vapourising carbon in a helium atmosphere. C60 and C70 are formed when graphite is evaporated in an inert atmosphere. The term identified their structure as the now familiar ‘buckyballs’[14]. A few years later, in 1991, Iijima *et al*, observed of hallow graphitic tubes or carbon nanotubes by Transmission Electron Microscope (TEM) which form another member of the fullerene family[15]. The strength and flexibility of carbon nanotubes make them potentially useful in many nanotechnological applications. Currently, carbon nanotubes are use as composite fibers in polymers and baton to improve the mechanical, thermal and electrical properties of the bulk product. They also have potential applications as field emitters, energy storage materials, catalysis, and molecular electronic components. In the meantime, nanoscience progressed in other fields of science like in computer science, bio and engineering. Nanoscience and technology progressed in computer science to decrease the size of a normal computer from a room size to highly efficient moveable laptops. Electrical engineers have advanced in developing intricate electrical circuits at the nanoscale level. Furthermore, significant improvements have been observed in smartphone technology and other contemporary electronic devices used in everyday life. Advanced machine-learning algorithms and predictive analytics can greatly aid in designing more efficient nano carriers. These algorithms offer predictive insights into future data and have primarily been utilized to predict cellular uptake, activity, and cytotoxicity of nanoparticles[16].

FUTURE TRENDS AND OUTLOOK

The global nanomaterials market size was estimated at USD 8.0 billion in 2020 and is expected to reach USD 9.4 billion in 2021. It also is expected to expand at a compound annual growth rate (CAGR) of 14.1% from 2021 to 2028. Over the course of the projected period, the market is anticipated to be driven by the excellent physio-chemical characteristics and expanding use of nanomaterials in the electronics, healthcare, aerospace, and textiles industries[17,18]. Many research studies have presented the development of a myriad of nanomaterials for water treatment. Still, currently only titanium dioxide and aluminium oxides are used in significant amounts, although carbon nanotubes and graphene are expected to be employed in more significant amounts by 2031. We analyze and evaluate nanomaterials and trends in applications that may have notable environmental impacts. Nanomaterials are progressively integrating into our everyday routines and are already widely utilized in items like sunscreens (titanium dioxide/zinc oxide nanoparticles), current and future generation batteries, and quantum dots. Sunscreens containing TiO_2 nanoparticles provide similar UV protection. Engineered nanofibers are already used to make clothing water-resistant, stain-resistant, and wrinkle-free[17,18].

CLASSIFICATION OF NANOMATERIALS

The nanoparticles are generally classified into the organic, inorganic and carbon based:

Organic nanomaterials

Dendrimers, micelles, liposomes and ferritin, etc. are commonly knows the organic nanoparticles or polymers. These nanoparticles are biodegradable, non-toxic, and some particles such as micelles and liposomes have a hollow core also known as nanocapsules and are sensitive to thermal and electromagnetic radiation such as heat and light[19]. These unique characteristics makes them an ideal choice for drug delivery. The drug carrying capacity, its stability and delivery systems, either entrapped drug or adsorbed drug system determines their field of applications and their efficiency apart from their normal characteristics such as the size, composition, surface morphology, etc. Because they are effective and can be injected into particular body parts, organic nanoparticles are most frequently utilized in the biomedical industry. This is known as targeted drug delivery[20]. Organic nanoparticles can be prone to degradation or aggregation, which can affect their performance and stability. Organic nanoparticles can be more expensive to produce than inorganic nanoparticles, which can be a significant factor in their adoption. Organic nanoparticles can have a limited shelf life due to their sensitivity to environmental factors such as light, heat, moisture[21,22]. These advantages and disadvantages highlight the importance of careful design and engineering of organic nanoparticles to ensure they are effective and safe for their intended applications.

INORGANIC NANOMATERIALS

Inorganic nanoparticles are tiny particles that are made up of inorganic materials, often ranging from 1 to 100. Metal and metal oxide based nanoparticles are generally inorganic nanoparticles[23]. They have their unique properties due to their small sizes, making them useful in various fields like medicine, electronics and environmental remediation. Examples include quantum dots, gold, silver nanoparticles that are shown in Figure No.2. Inorganic nanoparticles can be synthesized with precise control over their size, shape and composition, allowing for tailored properties to meet specific application requirements. They also come with some disadvantages -certain inorganic nanoparticles may pose health and environmental risks due to their potential toxicity. For instance, some metal nanoparticles can accumulate in living organisms and cause adverse effects.

METAL BASED

Metal based nanoparticles are tiny particles. The commonly used metals for nanoparticle synthesis are aluminium (Al), cadmium (Cd), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), silver (Ag) and zinc (Zn). The nanoparticles have distinctive properties such sizes as low as 10 to 100nm, surface characteristics like high surface area to volume ratio, pore size, surface charge and surface charge density, crystalline and amorphous structures, shapes like spherical and cylindrical and colour, reactivity and sensitivity to environmental factors such as air, moisture, heat and sunlight etc[23]. They exhibit unique properties due to their small size, which make them useful in various fields like medicine, electronics, catalysis and environmental remediation. Their size and surface chemistry can be tailored for specific applications, such as drug delivery, sensing, or enhancing chemical reactions.

METAL OXIDES BASED

Metal oxides nanoparticles consist of metal atoms bonded with oxygen atoms, forming compounds like Aluminium oxide (Al_2O_3), Cerium oxide (CeO_2), Iron oxide (Fe_2O_3), Magnetite (Fe_3O_4), Silicon dioxide (SiO_2), Titanium oxide (TiO_2), Zinc oxide (ZnO)[24]. This tunability enables the design of materials with enhanced catalytic activity, optical properties, electrical conductivity and biocompatibility. Despite their potential benefits, challenges such as synthesis scalability, stability and toxicity need to be addressed to realize the full potential of metal oxide nanoparticles. Nevertheless, ongoing research continues to explore novel synthesis methods, characterization techniques, and applications to harness the capabilities of these versatile nanomaterials.

Carbon Based

Carbon based nanoparticles are nanostructures composed primarily of carbon atoms, including, fullerenes, graphenes, carbon nano tubes (CNT), carbon nanofibers, carbon black and sometimes activated carbon in nano size and are shown in Figure No.3.

Fullerenes

Fullerenes (C60) is a carbon molecule that is spherical in shape and made up of carbon atoms held together by sp2 hybridization. About 28 to 1500 carbon atoms forms the spherical structure with diameters up to 8.2nm for a single layer and 4 to 36nm for multi-layered fullerenes[24].

Graphene

Graphene is an allotrope of carbon. Graphene is a hexagonal network of honeycomb lattice made up of carbon atoms in a two dimensional planar surface. Generally the thickness of the graphene sheet is around 1nm[24].

Carbon nanotubes

Carbon Nano Tubes (CNT), a graphene nanofoil with a honeycomb lattice of carbon atoms is wound into hollow cylinders to form nanotubes of diameters as low as 0.7nm for a single layered and 100nm for multi-layered CNT and length varying from a few micrometres to several millimetres. The ends can either be hollow or closed by a half fullerene molecule[24].

Carbon nanofibres

The same graphene nanofoils are used to produce carbon nanofiber as CNT but wound into a cone or cup shape instead of a regular cylindrical tubes[24].

Carbon black

An amorphous material made up of carbon, generally spherical in shape with diameters from 20 to 70nm. The interactions between the particles are so high that they bound in aggregates and around 500nm agglomerates are formed[24].

SYNTHESIS OF NANOMATERIALS

Synthesis of nanomaterials involves various methods to create nanoscale structures with specific properties. These methods can be categorized into top-down and bottom-up approaches.

Top-down approach

This method involves reducing bulk materials into smaller structures. Techniques include mechanical milling, nanolithography, laser ablation, sputtering and thermal decomposition. Mechanical milling is a top-down method used to produce nanomaterials by grinding, crushing, or fracturing larger particles into smaller ones. It involves placing bulk materials (often in powder form) in a high-energy ball mill and subjecting them to intense mechanical forces, such as impact and shear, created by the milling media[24]. This process can lead to the formation of nanoscale particles with enhanced properties due to increased surface area and altered crystal structure. Nanolithography is a technique used in the top-down approach to create nanostructures with high precision and resolution. It involves patterning surfaces at the nanometer scale to define features and structures. The main advantages of nanolithography is to produce from a single nanoparticle to a cluster with desired shape and size. The disadvantages are the requirement of complex equipment and the cost[25]. Laser ablation is a reliable top-down method that provides an alternative solution to conventional chemical reduction of metals to synthesis metal based nanoparticles. As Lasis provides a stable synthesis of nanoparticles in organic solvents and water that does not require any nanoparticle agent or chemicals it is a ‘green’ process[24]. Sputtering is commonly used in the synthesis and fabrication of nanomaterials, particularly in the production of thin films and coatings with nanoscale features. In thermal decomposition at elevated temperatures, the precursor undergoes thermal decomposition, breaking down into smaller molecules or atoms. This decomposition process is often accompanied by chemical reactions that result in the formation of the desired nanomaterial.

Bottom-up approach

Nanomaterials are built from atomic or molecular level components, allowing precise control over their properties. Techniques include chemical vapor deposition, sol-gel synthesis, and self-assembly. Sol-gel processes are commonly used in the synthesis of nanomaterials. This method involves the transformation of a solution (sol) into a gel-like material (gel) and then into a solid material. It is extensively used in the fabrication of semiconductor devices, thin film solar cells, carbon-based nanomaterials and other advanced materials for electronics, optics, and energy storage applications. Pyrolysis is another technique used in the synthesis of nanomaterials. It involves the decomposition of organic or inorganic precursors at high temperatures in the absence of oxygen. The advantages of pyrolysis are simple, efficient, cost effective and continuous process with high yield[24].

CHARACTERISTICS OF NANOMATERIALS

Some key characteristics of nanomaterials are determined include:

Size: Nanomaterials typically have dimensions ranging from 1 to 100 nanometers, imparting unique size-dependent properties.

Surface Area

Nanomaterials possess a high surface area-to-volume ratio, leading to enhanced reactivity, adsorption capacity, and interactions with surrounding environments.

Quantum Effects

At the nanoscale, quantum effects become significant, influencing the optical, electrical, and magnetic properties of nanomaterials.

Mechanical Properties

Nanomaterials may exhibit improved mechanical properties such as increased strength, flexibility, and hardness compared to bulk materials.

Thermal Properties

Certain nanomaterials demonstrate enhanced thermal conductivity, making them suitable for applications in thermal management and insulation.

Electrical Properties

Nanomaterials can have altered electrical conductivity, resistivity, and band gap properties, enabling applications in electronics, sensors and energy devices.

Chemical Properties

Nanomaterials exhibit high reactivity, surface functionalization capabilities, and unique redox behavior, making them valuable for catalysis, sensing, and environmental remediation. Corrosive, anti-corrosive, oxidation, reduction and flammability characteristics of the nanoparticles determine their respective usage[24].

Physical Properties

The physical properties include optical such as the colour of the nanoparticle, its light penetration, absorption and reflection capabilities and UV absorption and reflection abilities in a solution or when coated onto a surface[24].

Self-Assembly

Some nanomaterials have the ability to self-assemble into ordered structures, offering opportunities for controlled fabrication and nanotechnology applications.

Other properties like hydrophilicity, hydrophobicity, suspension, diffusion and settling characteristics has found its way in many modern everyday things. These characteristics make nanomaterials highly versatile and valuable across various fields, including electronics medicine, energy, environmental science and materials engineering.

APPLICATION OF NANOMATERIALS

Some of the significant applications in different fields are as follows:

MEDICINE

It can be applied to medical applications such as imaging, diagnosis, and treatment. Nanoscale drug delivery systems can improve the efficacy and target specificity of drugs. The total drug consumption and side effects are significantly lowered by placing the drug in the required area in required dosage. This method reduces the cost and side effects. The reproduction and repair of damaged tissue (Tissue engineering) can be carried out with the help nanotechnology. The traditional treatments such as artificial implants and organ transplants can be replaced by tissue engineering. One such example is the growth of bones carbon nanotube scaffolds[26]. The use of gold in medicine is not new. In Ayurveda an Indian medical system, gold is used in several practices. One common prescription is the use of gold for memory enhancement. To enhance the mental fitness of a baby gold is included in certain medical preparations[27].

Food packaging/drinks

In this field, nanobiosensors could be used to detect the presence of pathogens in food or nanocomposites to improve food production by increasing mechanical and thermal resistance and decreasing oxygen transfer in packaged products. For example, a nanocomposite coating in a food packaging process can directly introduce the anti-microbial substances on the coated film surface[25].

Cosmetics

Nanoparticles are used in cosmetics, sunscreen and skincare products for their ability to provide UV protection, improve skin penetration, and enhance product stability helping to prevent skin damage and reduce the damage of skin cancer. They can create smoother, more even formulations, reducing the visibility of fine lines and wrinkles. Nanoparticles also provide a lightweight, non-greasy feel, making cosmetics more comfortable to wear. Some lipsticks also use iron oxide nanoparticles as a pigment.

Construction

Nanomaterials such as nanosilica, nanotitania and carbon nanotubes are added to concrete mixtures to improve strength, durability and resistance to cracking. These nanoparticles enhance the hydration process, reduce porosity and increase the density of concrete, resulting in structures that are more robust and long-lasting. Nanotechnology is used to develop advanced insulation materials with superior thermal performance and moisture resistance. Nanomaterials like carbon nanotubes and graphene are incorporated into composite materials used in construction to enhance their mechanical properties.

Electronics

Carbon nanotubes are close to replacing silicon as a material for making smaller, faster and more efficient microchips and devices, as well as lighter, more conductive and more stronger quantum nanowires. Graphene's properties make it an ideal candidate for the development of flexible touchscreens. Nanomaterials can be used in electronic devices as smartphones, laptops, and televisions to enhance performance and reduce power consumption. High resolution displays are created, the storage capacity and efficiency of rechargeable batteries are improved.

Household

Nanoparticle-based coatings are used on surfaces like countertops, floors, and furniture to provide scratch resistance, water repellency, and antimicrobial properties. Nanomaterials are used in air purifiers and filters to capture and remove pollutants, allergens and pathogens from indoor air.

Renewable energy

A new semiconductor developed by Kyoto University makes it possible to manufacture solar panels that double the amount of sunlight converted into electricity. Nanotechnology also lowers cost, produces stronger and lighter wind turbines, improves fuel efficiency and, thanks to the thermal insulation of some nano components, can save energy. Nanomaterials are also used in fuel cells, solar cells batteries, and capacitors.

Textiles

Nanotechnology makes it possible to develop smart fabrics that don't stain nor wrinkle, as well as stronger, lighter and more durable materials to make motorcycle helmets or sports equipment. Nanoparticles are incorporated into fabrics to create water-repellent coatings, moisture-wicking finishes and antimicrobial treatments, keeping athletes dry, comfortable, and odor-free during intense physical activity.

Sports/outdoor

Nanomaterials are utilized in the manufacturing of sporting equipment such as tennis rackets, golf clubs, bicycles, and skis to improve strength, stiffness, and impact resistance. Carbon nanotubes and graphene, for example, are integrated into composite materials to make lightweight yet strong components that offer better performance and durability.

Environmental remediation

To clean up pollutants and contaminants by using nanoparticle -based catalysts and nano filters that can purify contaminated water, air and soil by removing pollutants and pathogens. Nanoparticles like nanoscale zero-valent iron (nZVI) and titanium dioxide are employed to degrade contaminants, remove pollutants, and mitigate environmental damage.

Agriculture

The role of agriculture in nanomaterials involves various applications such as enhancing crop growth through nanofertilizers, improving soil quality with nano-based soil amendments, increase tolerance to biotic and a biotic stress ensuring healthier crops and higher yields.

ADVERSE EFFECTS OF NANOMATERIALS

HEALTH CONCERNS ASSOCIATED WITH NMs

The toxicity phenomenon is a very complicated issue that is dependent on lots of physiochemical parameters, hence different metallic and non-metallic NMs with their special nature would have various toxicity mechanisms and indicate alterations in toxicity amount. However, there are highly biocompatible nanomaterial types that can interact with the body without causing any unwanted/undesirable event (e.g., toxicity, immune reaction, thrombosis, cancer)[28]. Although current research has revealed that many key metabolites in the process of immune metabolism can affect the function of immune cells, the research in this field is still in its infancy. Currently, several issues need to be addressed before the clinical transformation of NMs for immune metabolic reprogramming, including their physicochemical properties, safety and efficacy, route of administration, timing of administration[29].

In general, the blood, liver, spleen, and kidneys are the primary hosts for NMs. After intravenous injection, AuNPs of different sizes (10, 50, 100 and 250nm) showed size-dependent toxicity and accumulation in rats. The larger particles were detected only in the blood, liver and spleen, while the smallest NMs could accumulate in all organs, including the brain[30]. Numerous studies have confirmed that the metabolic pathways associated with immune effects and the energy required to produce these effects can regulate the activation of immune responses[31]. The liver is the main detoxification organ in the human body and hepatic storage can reduce the systemic toxicity of nanoparticles to some extent, these nanomaterials tend to be digested or metabolized in the liver and then nanoparticles and stopped in the body to reduce toxicity[29]. Therefore, the accumulation of metal and metal oxide NPs in metabolic organs can also be considered a protective mechanism. The degradation of NPs mainly depends on the phagocytic activity of Kupffer cells in the liver. One day after injection, Au NPs were found in almost all Kupffer cells. Transmission electron microscopy showed that they accumulated in the vesicular lysosomal/endosomal structures of macrophages[32]. Other types of metal nanoparticles may also have adverse effects on the body by regulating immune metabolism. Ag NPs are widely used due to their unique antibacterial properties. However, exposure to Ag NPs can also cause adverse effects, including inflammation, accumulation and cell damage in various organs[29].

ENVIRONMENTAL RISKS OF NANOMATERIALS

AIR

Nanomaterials can be formed in urban areas, several combustion sources (engines, biomass, burning power generation plants) are directly emitting carbonous nanomaterials to the atmosphere. They classify as nanosized pollutants in industrialized areas[33].

Soil

Metal nanoparticles from the utilized biomass can be transferred to soil by nanomaterials sorption. Therefore, the high Ag concentration in the resulting biomass might restricts agricultural use; the concentration would act as an inhibitor of bacterial growth (including the beneficial microorganisms present in the soil, such as nitrogen fixing bacteria)[34].

Water

Nanoparticles can be toxic to aquatic life. For instance, silver nanoparticles widely used for their antimicrobial properties, can disrupt the growth and reproduction of aquatic organisms (e.g nematodes, zebra fish embryos). Some nanoparticles can accumulate in the tissues of organisms, potentially moving up the food chain and affecting higher tropic levels, including human. If not properly managed, it used in water treatment can remain in the treated water, posing indigestion risks.

Microorganisms

The antimicrobial activity of nanomaterials can be influenced by the pH and ionic strength of the environment, affecting nanoparticle stability and interaction with microorganisms. Many nanomaterials can attach to and penetrate microbial cell membranes, causing physical damage, leakage of cell contents and ultimately cell death. Oxidative Stress: Nanoparticles such as titanium dioxide (TiO_2) and silver can induce the production of ROS, leading to oxidative damage of proteins, lipids and DNA within microbial cells.

Plants

Some NMs can affect the photosynthetic apparatus, reducing chlorophyll content and impairing photosynthesis. For instance, cerium oxide nanoparticles can disrupt chloroplast structure and function. NMs such as carbon nanotubes, titanium dioxide and silver nanoparticles can inhibit seed germination, root elongation and overall plant growth.

ADVERSE EFFECTS IN FOOD TECHNOLOGY

There have been tremendous applications of nanomaterials in the occupational, environmental and consumer sectors. This has elevated the public concern with respect to adverse effects and health hazards. This concern is expressed as risk factor in consumers. Intense use of engineered nanomaterials in almost every aspects of human life has raised the concern in the minds of the consumers. The nanomaterials at the work place are effective and likely to cause adverse effects (poor working conditions or because of the negligence) either immediately or at a later stage of life. Worker may suffer from the derogative effects of these nanomaterials (either acute or chronic toxicity) depending on his/her general health. The worker may experience this impact either during the tenure of the job or latter part of the life[34]. While nanotechnology holds great promise for various applications, including food production and packaging, there are also potential disadvantages and concerns associated with its use in the food industry. Some of the disadvantages of using nanotechnology in food are:

The integration of nanotechnology into food production and packaging processes may increase production costs. The development and scale-up of nanomaterials, their incorporation into food products, and quality control measures can be expensive. This could potentially affect the affordability and accessibility of nano enhanced food products. Nanoparticles can interact with the gastrointestinal tract, affecting its normal function. These in turn undergo physiological changes. As a result, there is every possibility that these nanomaterials are likely to interact with the tissue, cellular organelles, and biomolecules. This interaction may be beneficial and/or adverse physiologically, biochemically, cytologically, histologically or genetically. Some of the nanomaterials like metallic and metallic oxides nanoparticles, quantum dots, fullerenes, and fibrous nanomaterials have been found to cause adverse effects that include fragmentation of chromosome, breakage of strands of DNA, changes in gene precision etc. There are reports on clinical toxicity but major studies indicate that nanomaterials are able to initiate adverse biological interactions leading to untimely physiological disruption and toxicological out come in due course of time[34]. Some inorganic nanoparticles produce toxicity by generating ions that interact with the normal functioning cellular components (such as proteins, nucleic acids, or lipids) required to maintain biochemical processes. These mechanisms of action are most likely to be important for inorganic nanoparticles that are absorbed by the intestinal cells, since most organic nanoparticles are digested before being absorbed. Consequently, any change in the gut micro biota due to the presence of food-grade nanoparticles could have adverse health effects. This is an important area that requires further research to determine the impact of specific nanoparticle characteristics on the gut microbiota and the resulting health implications. Today the most possible risks of nanomaterials we found that are generally affected the environment, human body and safety issue.

FUTURE RECOMMENDATIONS

The study of the potential toxic effects of food-grade nanoparticles has increased considerably in the past few years. Researchers from many disciplines have studied the potentially toxic effects of various kinds of organic and inorganic food nanoparticles. The results of these studies have led to considerable insights into the type of food nanoparticles that may cause adverse health effects, as well as into the possible physicochemical and physiological mechanisms involved[34]. Metallic nanomaterials are essential in the modern era for their crucial role in nanomedicine and other biological applications. These nanomaterials can be synthesized through various methods and are effectively applied in diverse nanomedical and biological fields. Nevertheless, there is a need to mass-produce these nanomaterials to drive down costs. The resources utilized for the production of these nanomaterials must be sustainable, affordable, environmentally friendly and devoid of toxic substances. The creation of mono disperse nanomaterials is imperative for future research initiatives.

Table No.1: Technique and their uses

S.No	Technique	Uses of the tecnique	Entity Characterized
1	TEM AND SEM (Transmission Electron Microscope and Scanning Electron Microscope)	Tem allows the researchers to visualize the structure morphology. Sem provides high resolution images of surface morphology and topography of nanomaterials.	Size (structure properties)
2	SMPS (Scanning Mobility Particle Sizer)	It is used to provide a fast and accurate measurements compared to other methods[24]	Size distribution
3	DMA (Differential Mobility analyser)	It is used for the charge determination of nanoparticles in gaseous phase[24]	Surface charge
4	NMR (Nuclear Magnetic Resonance Spectroscopy)	It is used to provide information about the local environment and interaction of atomic nuclei within a material.	Growth kinetics, surface area
5	XPS (X-ray Photoelectron Spectroscopy)	It is used to study surface modifications and functionalization of nanomaterials.	Composition (in solid)
6	CPC (Condensation Particle Counter)	This device is used to concentrate nanoparticles from a liquid suspension.	Concentration
7	BET (Brunauer – Emmett–Teller model)	It is used to measure the surface area of porous materials, including nanomaterials.	Surface area

Table No.2: Toxic effects of metals and metal oxides NMs

S.No	Types of Nanomaterial	Experimental models tested	Toxic effects
1	Silver NMS	Rats, Zebrafish embryos Human lung cancer cells	Memory Impairement (CNS Damage), foetus death
2	Zinc oxide NMS	Bacteria, Mammalian cells, Human mesothelioma cello, hepatocytes	Cytotoxicity**,** Inflammatory cell infiltration in mice
3	Titanium oxide NMS	Rat, Mice, Hamsters	Lesions observed in nasal cavity tissue
4	Carbon based NMS	Lung fibroblast cells	DNA damage, Halts G1 phase
5	Silica NMS	Rat, Mice, Human cells	Cytotoxicity, DNA damage
6	Graphene	Mice fibroblast cells	Genotoxic effects on lung cells and chromosomal alterations
7	Quantum dots	Rat adrenal medulla cells	Cell death by cell shrinkage due to Chromatin condensation and membrane blebbing

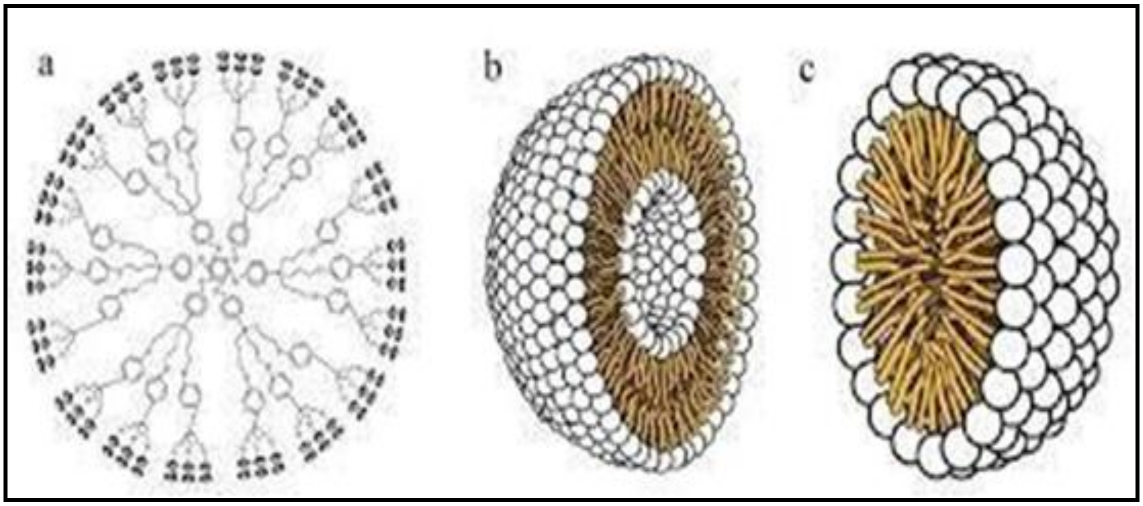

Figure No.1: Organic nanomaterials: A. Dendrimers B. Liposomes C. Micelles

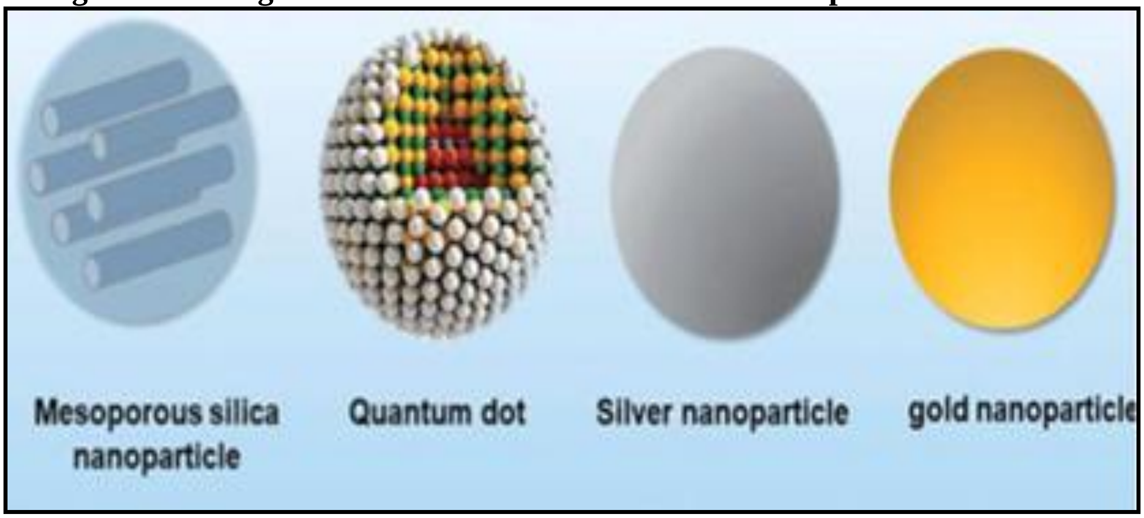

Figure No.2: Inorganic Nanoparticles

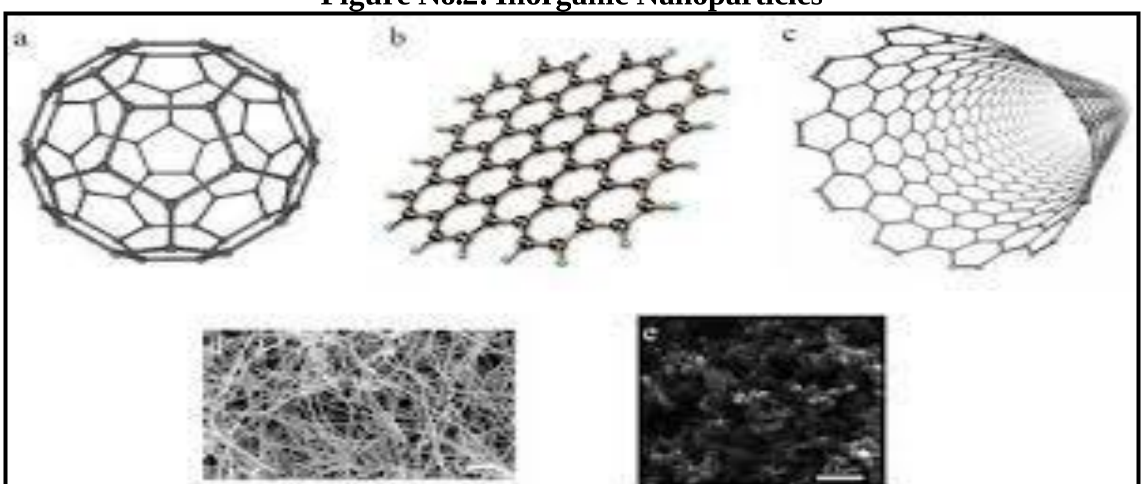

Figure No.3: Carbon based nanoparticles: a. fullerenes, b. graphene, c. carbon nanotubes, d. carbon nanoparticle and e. carbon black

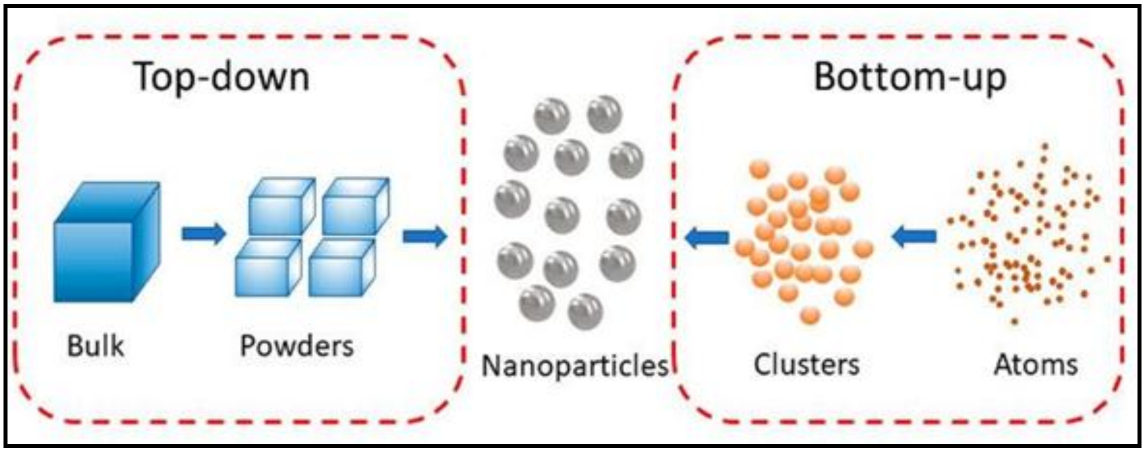

Figure No.4: Synthesis of Nanomaterials

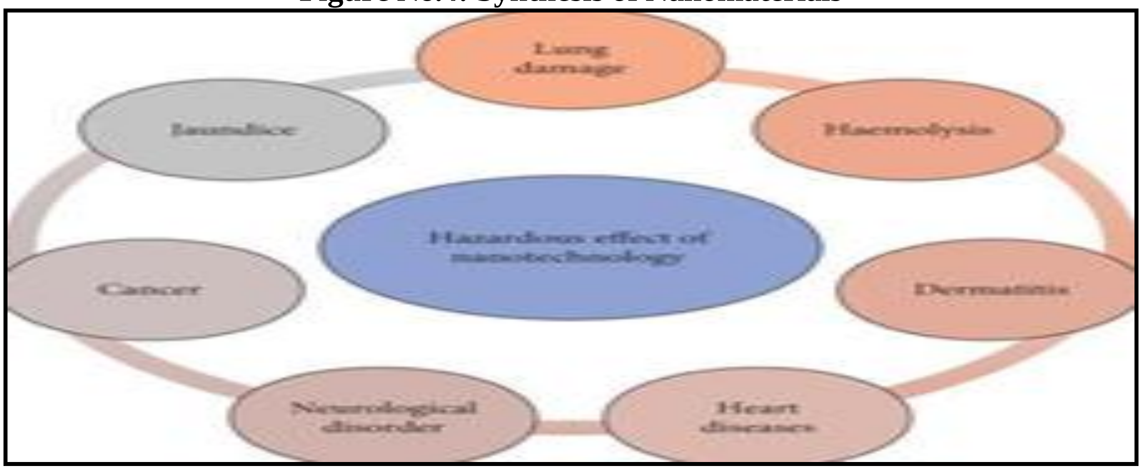

Figure No.5: Hazardous effect of nanomaterials

CONCLUSION

Nowadays, the use of nanotechnology became one of the most used and talked about subject due to its wide range of applications. Nanoparticles have been using in various fields such as medicine; food packaging and beverages, cosmetic, construction, agriculture, household furniture, electronics, textile, renewable energy, sports etc. But, as use of nanomaterials increases in different fields, their toxicity possesses some serious concerns. Nanomaterials can accumulate in different organs of human as well as animal body causing some critical health issues. They also pollute the air, water, soil increasing the environmental pollution. Nanomaterials are also hazardous for plants. They can reduce the photosynthesis and overall plant growth.

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CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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