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NANO-TECHNOLOGY
NANOTOXICOLOGY

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Abstract : With the rapid development of nanotechnology and its applications, a wide variety of Nano-structured materials are now used in commodities, pharmaceutics, cosmetics, biomedical products, and industries. While nano-scale materials possess more novel and unique physicochemical properties than bulk materials, they also have an unpredictable impact on human health. The entrance into and interaction of nano materials in the human body have generated intense scientific curiosity, attracting much attention as well as increasing concern from the public, nano material-based industries, academia, and governments worldwide. Nanotoxicology is the first textbook in this multidisciplinary area to address all those points and, thus, fill the knowledge gap concerning risks from nanotechnology, the impact of nano-materials on the human body, their interactions with biological systems, and their risk assessments.

Nanotoxicology is the study of nano-materials. Because of quantum size effects and large surface area, nano-materials have unique properties compared with their larger counterparts. Nano particles have proved toxic to human tissue and cell culture, resulting in increased oxidative stress, inflammatory cytokine production and cell death. Unlike large particles, nano materials may be taken up by cell mitochondria and cell nucleus. Studies demonstrate the potential for nano-materials to cause DNA mutations and induce major structural damage to mitochondria, even resulting in cell death. Size is therefore a key factor in determining the potential toxicity of a particle. However it is not the only important factor. Other properties of nano materials that influence toxicity include: chemical composition, shape, surface structure, surface charge, aggregation and solubility, and the presence or absence of functional groups of other chemicals. The extremely small size of nano-materials also means that they much more readily gain entry into the human body than larger sized particles. How these Nano-particles behave inside the body is still a major question that needs to be resolved. The behavior of Nano-particles is a function of their size, shape and surface reactivitywith the surrounding tissue, Immunogenicity to nano-particles. Very few attentions have been concentrated in the potential immunogenicity of nanostructures. Nanostructures can activate the immune system inducing inflammation, immune responses, allergy, or even affect to the immune cells in a deleterious or beneficial way (immunosuppression in autoimmunity diseases, improving immune responses in vaccines).

We are going to bring about new ideas and suggest new nanotech materials that could be used to potentially substitute the currently used nano-materials that can bring about a revolution.

Keywords: Nanotechnology, Nanotoxicology, boron nitride nano tubes, toxicity of carbon nano tubes.

INTRODUCTION

Nanotechnology is the ability to understand, control, and manipulate matter at the level of individual atoms, and molecules as well as the "supramolecular level" involving clusters of molecules, in order to create materials, devices and systems with fundamentally new properties and functions because of their small structure. The definition implies using the same principles and tools to establish a unifying platform for science and engineering at the nano-scale, and employing the atomic and molecular interactions to develop efficient manufacturing methods.

While many definitions for nanotechnology exist, the national nanotechnology initiative (NNI) calls it "NANOTECHNOLOGY" only if it involves all the following:

1. Research and technology development at the atomic, molecular or macro molecular levels, in the length scale of approximately 1-100 nano-meter range.

2. Creating and using structures, devices and systems that have novel properties and functions because of their small and or intermediate size.

3. Ability to control or manipulate on the atomic scale.

It has wide range of applications in various sectors such as:

1. Information Technology:
Smaller faster, more energy efficient and powerful computing and other IT based systems.

2. Medicine:
- Cancer treatment
- Bone treatment
- Drug delivery
- Appetite control
- Drug development
- Medical tools
- Diagnosis test
- Imaging

3. Energy:
More efficient and cost effective technologies for energy production
- Solar cells
- Fuel cells
- Batteries
- Bio fuels

4. Consumer goods:
- Foods and beverages
- Appliances and textiles
- Household and cosmetics

With the advent of nanotechnology, the prospects for using engineered nano materials with diameters of < 100 nm in various applications as mentioned above have progressed rapidly. The potential for nano-particles (NPs) in these areas is infinite, with novel new applications constantly being explored. The possible toxic health effects of these NPs associated with human exposure are many. Many fine particles generally considered "nuisance dusts" are likely to acquire unique surface properties when engineered to nano-size and may exhibit toxic biological effects. Consequently, the nuisance dust may be transported to distant sites and could induce adverse health effects. In addition the beneficial uses of NPs in drug delivery, cancer treatment, and gene therapy may cause unintentional human exposure. Because of our lack of knowledge about the health effects associated with NP exposure, we have an ethical duty to take precautionary measures regarding their use. In this paper we highlight the possible toxic human health effects that can result from exposure to ultra fine particles (UFPs).Therefore; it is prudent to elucidate their toxicology effect to minimize occupational and environmental exposure.

The advent of nanotechnology is considered to be the biggest engineering innovation since the Industrial Revolution. Proponents of this new technology promise to reengineer the man-made world, molecule by molecule, sparking a wave of novel revolutionary commercial products from machines to medicine This "industrial revolution" in molecular manufacturing will alter the relationship of materials so profoundly that this change may produce both positive and negative effects on health and the environment. The technologic progress during the Industrial Revolution enhanced quality of life but also resulted in a human health burden. As in the case of asbestos with its decades of long latency that still remain, there are many legitimate concerns about the unknown human health consequences of nano-materials. Nanotechnology, now at the leading edge of rapid development with many potential human health benefits, is perceived with apprehension for potential human health risks. Enhanced strength, durability, flexibility, performance, and inimitable physical properties associated with these materials has been exploited in a multitude of industries and treatment modalities including detection of tumours, targeted drug delivery, and prognostic visual monitoring of therapy. With these applications, unprecedented avenues of exposure to nano-particles (NPs) in humans are likely. Ambient and workplace exposures in combination with other toxic agents may cause unpredictable adverse health effects. Failure to address these imminent human health issues in a cohesive and concerted manner by industry, academia, government, environmentalists, and scientists may lead to detrimental health effects caused by exposure to NPs.

In addition to occupational exposure, direct human exposures through medicinal applications and ambient air pollution are a major concern. Inhaled NPs may evade phagocytosis, cross cell membranes, and redistribute to other sites of the body, causing systemic health effects. Therefore, the unbridled growth and use of nanotechnology in medical and human health evaluations opens society to the possibility that NPs could become the "asbestos" of the 21st century. And the study of adverse effects of these nano-particles on human health and environment is related to our topic known as NANOTOXICOLOGY.

In this paper we discuss briefly about some of the adverse effects of the currently used nano-materials on human health and also suggest some alternatives to the currently used nano materials. These alternatives could be less toxic and more beneficial to the humans.

NANOTOXICOLOGY

Nanotoxicology is the study of the toxicity of nano-materials. Because of quantum size effects and large surface area, nano-materials have unique properties compared with their larger counterparts.

Nanotoxicology is a branch of bionanoscience which deals with the study and application of toxicity of nano-materials. Nano-materials, even when made of inert elements like gold, become highly active at nanometer dimensions.

Nanotoxicology is a sub-specialty of particle toxicology. It addresses the toxicology of nano-particles (particles <100 nm diameter) which appear to have toxicity effects that are unusual and not seen with larger particles. Nano-particles can be divided into combustion-derived nano-particles (like diesel soot), manufactured nano-particles like carbon nano-tubes and naturally occurring nano-particles from volcanic eruptions, atmospheric chemistry etc. Typical nano-particles that have been studied are titanium dioxide, alumina, zinc oxide, carbon black, and carbon nano-tubes, and "nano-C60". Nano-particles seem to have some different properties from larger particles that are known to have pathogenic effects, like asbestos or quartz. These differences seem to be a result of their size. Nano-particles have much larger surface area to unit mass ratios which in some cases may lead to greater pro-inflammatory effects (in, for example, lung tissue). In addition, some nano-particles seem to be able to translocate from their site of deposition to distant sites such as the blood and the brain. This has resulted in a sea-change in how particle toxicology is viewed- instead of being confined to the lungs; nano-particle toxicologists study the brain, blood, liver, skin and gut. Nanotoxicology has revolutionized particle toxicology and rejuvenated it.

The smaller a particle is, the greater it's surface area to volume ratio and the higher its chemical reactivity and biological activity. The greater chemical reactivity of nano-materials results in increased production of reactive oxygen species (ROS), including free radicals ROS production has been found in a diverse range of nano-materials including carbon fullerenes, carbon nano-tubes and nano-particle metal oxides. ROS and free radical production is one of the primary mechanisms of nano-particle toxicity; it may result in oxidative stress, inflammation, and consequent damage to proteins, membranes and DNA.

The extremely small size of nano-materials also means that they much more readily gain entry into the human body than larger sized particles. How these nano-particles behave inside the body is still a major question that needs to be resolved. The behavior of nano-particles is a function of their size, shape and surface reactivity with the surrounding tissue. In principle, a large number of particles could overload the body's phagocytes, cells that ingest and destroy foreign matter, thereby triggering stress reactions that lead to inflammation and weaken the body's defense against other pathogens. In addition to questions about what happens if non-degradable or slowly degradable nano-particles accumulate in bodily organs, another concern is their potential interaction or interference with biological processes inside the body. Because of their large surface area, nano-particles will, on exposure to tissue and fluids, immediately adsorb onto their surface some of the macromolecules they encounter. This may, for instance, affect the regulatory mechanisms of enzymes and other proteins

Nano-materials are able to cross biological membranes and access cells, tissues and organs that larger-sized particles normally cannot. Nano-materials can gain access to the blood stream via inhalation or ingestion. At least some nano-materials can penetrate the skin; even larger micro-particles may penetrate skin when it is flexed. Broken skin is an ineffective particle barrier, suggesting that acne, eczema, shaving wounds or severe sunburn may accelerate skin uptake of nano-materials. Then, once in the blood stream, nano-materials can be transported around the body and be taken up by organs and tissues, including the brain, heart, liver, kidneys, spleen, bone marrow and nervous system. Nano-materials have proved toxic to human tissue and cell cultures, resulting in increased oxidative stress, inflammatory cytokine production and cell death. Unlike larger particles, nano-materials may be taken up by cell mitochondria and the cell nucleus. A study demonstrates the potential for nano-materials to cause DNA mutation and induce major structural damage to mitochondria, even resulting in cell death. Size is therefore a key factor in determining the potential toxicity of a particle. However it is not the only important factor.

Other properties of nano-materials that influence toxicity include: chemical composition, shape, surface structure, surface charge, aggregation and solubility, and the presence or absence of functional groups of other chemicals. The large number of variables influencing toxicity means that it is difficult to generalize about health risks associated with exposure to nano-materials – each new nano-material must be assessed individually and all material properties must be taken into account.

The extremely small size of fabricated nano-materials also means that they are much more readily taken up by living tissue than presently known toxins. Nano-particles can be inhaled, swallowed, absorbed through skin and deliberately or accidentally injected during medical procedures. They might be accidentally or inadvertently released from materials implanted into living tissue.

The nano particle currently used in various fields that also cause toxic effects is: Carbon nano tubes.

The application and limitation of this nano particle are briefly discussed in order to find new alternative.

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CARBON NANOTUBES

Carbon nano-tubes (CNTs; also known as buckytubes) are allotropes of carbon with a cylindrical nanostructure. These cylindrical carbon molecules have novel properties that make them potentially useful in many applications in nanotechnology, electronics, optics and other fields of materials science, as well as potential uses in architectural fields.

They exhibit extraordinary strength and unique electrical properties, and are efficient thermal conductors

The potential and current applications of nano-tubes are:

1. Space elevator: A space elevator is a proposed structure designed to transport material from a celestial body's surface into space.

2. Paper batteries: A paper battery is a battery engineered to use a paper-thin sheet of cellulose (which is the major constituent of regular paper, among other things) infused with aligned carbon nano-tubes. The nano-tubes act as electrodes, allowing the storage devices to conduct electricity. The battery, which functions as both a lithium-ion battery and a super capacitor, can provide a long, steady power output comparable to a conventional battery, as well as a super capacitor’s quick burst of high energy -- and while a conventional battery contains a number of separate components, the paper battery integrates all of the battery components in a single structure, making it more energy efficient.

3. Solar cell: Solar cells use a carbon nano-tube complex, formed by a mixture of carbon nano-tubes and carbon buckyballs (known as fullerenes) to form snake-like structures. Buckyballs trap electrons, although they can't make electrons flow. Add sunlight to excite the polymers, and the buckyballs will grab the electrons. Nano-tubes, behaving like copper wires, will then be able to make the electrons or current flow.

In spite of these applications their final usage, however, may be limited by their potential toxicity and controlling their property changes in response to chemical treatment.

For example taking the first application space elevator which uses carbon nano-tubes. Carbon nano-tubes under some conditions, can cross membrane barriers, which suggests that if raw materials reach the organs they can induce harmful effects such as inflammatory and fibrotic reactions. The needle-like fiber shape of CNTs, similar to asbestos fibers, raises fears that widespread use of carbon nano-tubes may lead to mesothelioma, cancer of the lining of the lungs often caused by exposure to asbestos.

This is of considerable importance, because research and business communities continue to invest heavily in carbon nano-tubes for a wide range of products under the assumption that they are no more hazardous than graphite. Our results suggest the need for further research and great caution before introducing such products into the market if long-term harm is to be avoided. So this creates an urge to find new alternatives for the carbon nano tubes. They are **BORON NITRIDE NANO-TUBES.**

Boron nitride is a binary chemical compound, consisting of equal proportions of boron and nitrogen, with composition BN. Boron nitride is stable at air to approx. 1000°C, under reduced conditions or inert gases it can be used up to 1800°C.

Carbon nano-tubes get a lot of press attention, but boron nitride (BN) nano-tubes might have superior properties. Recent calculations on BN nano-tubes in the presence of a transverse electric field and found that these systems exhibit dramatic decrease in band gap when subject to strong fields. This effect should be realizable experimentally for the 5 nm or more diameter BN nano-tubes, and it may be very important for tuning the band gap of BN nano-tubes for practical applications.

THE NECESSITY TO SHIFT FROM CARBON TO BORON NITRIDE NANOTUBES:

1. Boron nitride is far more resistant to oxidation than carbon and therefore suited for high temperature applications in which carbon nanostructures would burn.
2. BN nano-tubes electronic properties are independent of tube diameter and number of layers, unlike tubes made of carbon, making BN nano-tubes much more amenable: by doping these tubes, it is conceivable to have devices on single BN tubes which have diameters on the order of nanometers and lengths on the order of microns
3. The range of applications (e.g., in optoelectronic devices) of these boron nitride nano-tubes would be greatly extended if their band gap can be tuned to desired values in a controlled way.

CONCLUSION

Hence, from this paper it is evident that boron-nitride nano-tubes have superior properties when compared to carbon nano-tubes. The major differences between carbon and boron nitride nano-tubes are listed below.

CNT	BN Nano-tubes
Toxic and cause inflammatory reactions	Biocompatible and non cytotoxic
-less thermally and chemically stable	-much more thermally and chemically stable
-Comparatively less resistant to oxidation	-more resistant to oxidation
-at high temperature carbon nanostructures would burn	-suited for high temperature applications
properties depends on layers, rolling and diameter of tube	independent of tube diameter and number of layers
Preparation cost is high	Preparation cost is low

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