Environmental Challenges in the context of Nanomaterials

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Abstract: Nanotechnology has gained a great deal of public interest due to the needs and applications of nanomaterials in many areas of human endeavors including industry, agriculture, business, medicine and public health. Environmental exposure to nanomaterials is inevitable as nanomaterials become part of our daily life and as a result, nanotoxicity research is gaining attention. A critical evaluation of challenges and future needs for the safe environmental nanotechnology has been discussed.

Keywords: Nano-materials, toxicity, environmental impact.

INTRODUCTION:

Many scientists consider nanotechnology as the next logical step in science, integrating engineering with biology, chemistry, medicine, and physics[1-3]. When the dimensions of a material become very small, its physical and chemical properties can become very different from those of the same material in bulk form. Current nanotechnology is building devices of microscopic or even molecular size, which will potentially he benefiting medicine, environmental protection, energy, and space exploration[3]. With our increasing knowledge of nanoscience and the ability to engineer new products and services, it would not be far before the entire history can be compressed inside .our pockets or the system extended by specially designed molecules that mimic the living systems. In the last couple of years, the term "Nanotechnology" has been inflated and has almost become synonymous for things that are innovative and highly promising. Nanotechnology enables us to create functional materials, devices, and systems by controlling matters at the atomic and molecular scales, and to exploit novel properties and phenomena4. The fabrication of smaller and faster transistors has long been a driving force for the computer industry. As transistor sizes decrease to nanometre regime, we are approaching the point where nano-lithography will achieve the required resolution for creating these nanometre-sized devices. An obvious route when thinking about the very small is to shrinic the size and cost of computers, and speed their operation phenomenally. Today's technology relies on etching patterns on silicon so that tiny electronic switches can be turned on and off the basis for the binary code that represents everything the computer understands. Tomorrow's nano-computers will have molecular switches, or logic rods, to place today's nanomaterial-based microbes injected into an organism to combat disease-causing bacteria and viruses, remove cancerous cells or dispense medicines. Microscopic robots may repair, or even assemble complex devices or remove harmful substances from the environment. There is no doubt that nanoscience and nanotechnology is one of the fastest growing research and technology areas. Nanotechnology has gained a great deal of public interest due to the needs and applications of nanornaterials in many areas of human endeavours including industry, agriculture[5], business, medicine and public health[6].

Engineered nanomaterials are rapidly becoming a part of our daily life in the form of cosmetics, food packaging, drug delivery systems, therapeutics, biosensors, and others[7-9]. Since their size scale is similar to that of biological macromolecules and due to their antibacterial and odour-fighting properties, nanomaterials are extensively used for a number of commercial products such as wound dressing, detergents or antimicrobial coatings. According to the National Nanotechnology Initiative (USA) , thousands of tons of silica, alumina and ceria, in the form of ultrafine abrasive particle mixtures including nanoparticles, are used each year in slurries for precision polishing of silicon wafers.

Thus, the exposed population to nanomaterials continues to increase as their application expands. Despite obvious benefits of the power of small materials, there are open questions about how the nanoparticles used for day-to-day life may affect the environment. One of the crucial issues that have to be addressed in the near future, before massive fabrication of nanomaterials, is their toxicity to humans and impact on the environment. There are considerable debates regarding how the novel properties of nanomaterials could lead to adverse biological effects, with the potential to cause toxicity. One needs to understand when hanoparfb1es undergo biodegradation in the cellular environment, what will the cellular responses be? For example, biodegraded nanoparticles may accumulate within cells and lead to intracellular changes such as disruption of organelle integrity or gene alternations. Some of the crucial questions are: 1) Are nanomaterials more toxic than their non-nano counterparts? 2) toxic forms? Before nanomaterials are allowed to be used in daily life activities, it is important for Nan toxicology research to uncover and understand how nanomaterials influence the environment so that their undesirable properties can be avoided. To address issues concerning potential effects of emerging nanotechnologies on environment, this review discusses recent progresses on toxicity and environmental impact of nanomaterials.

TOXICITY OF NANO-MATERIALS:-

Any toxic effects of nanomaterials will be specific to the type of base material, size, shape and coatings. However, to determine and understand the toxic effects of nanornaterials, strategies and interpretation of the data must be done correctly and assumptions taken into consideration. In toxicity studies of nanoparticles, different research groups used different cell lines, culturing conditions, and incubation times. With our understanding about the nature of nanoparticles during toxicity test, it is difficult to compare results from different research groups and determine whether the cyto-toxicity observed is physiologically relevant. Many biological models, including cells in culture, aquatic organisms including embryonic zebrafish (*Danio rerio*), and whole-animal tests such as rodents, currently are used to determine potential toxicological effects of chemicals. In urban atmospheres, diesel- and gasoline-fuelled vehicles and stationary combustion sources have for many years contributed particulate materials throughout a wide size range including nanomaterials The toxic effects of such particles are still being investigated with regulatory concerns moving from the traditional particles less than 10 μm in aerodynamic diameter and below. Experimental results indicate that increased toxicity of finer-sized particles. However, to determine and understand the toxic effects of nanomaterials, strategies and interpretation of the data must be done correctly and assumptions taken into consideration. The range of nanotechnology products is very extensive and they can be broken down into a number of different compound classes, including metals, metal oxides, carbon, and semiconductor nanomaterials. The following discussions will be based on nanomaterial classes.

CARBON NANOMATERIALS:-

Carbon nanotubes (CNTs), with their unique one-dimensional hollow nanostructure and unusual properties, are emerging as an important new class of multifunctional building blocks for the development of nanotechnology. Recent rapid development in nanotechnology has renewed the pressing demand for large scale production of CNTs for applications in commercial products. The number of industrial scale facilities for the relatively low-cost production of multi-walled carbon nanotubes (MWCNTs) continues to grow, and therefore, professional and public exposure to MWCNTs is expected to increase significantly in the coming years. Several research groups have examined the uptake and potential hazards of CNI's, particularly MWCNTs, to humans and other biological systems. For instance, it has been demonstrated that CNTs can induce inflammatory and apoptosis responses in human T-cells[10-12]. Gene expression analysis by Ding et al. [10]indicated that MWCNTs activated genes involved in cellular transport, metabolism, cell cycle regulation, and stress response in human skin fibroblasts. Magrez et al.[13]found evidence of cytotoxicity for carbon-based nanomaterials, although MWCNTs were the least toxic among the carbon nanotubes, carbon nanofibers, and carbon nanoparticles tested. In a somewhat related publication, Dumortier et al.[14]demonstrated that water-soluble CNTs functionalized with polyethylene glycol chains did not have toxic effects when tested in a wide variety of immune system cells.Silvia et al.[15]demonstrated that ultrafine carbon particles show greater lung penetration than larger particles and are able to cross the blood-brain barrier and impact on the central nervous system. Their results indicate that toxic effects appear quickly after exposure and suggest that carbon nanoparticles travel from the lungs to the bloodstream rather than release clotting agents from the lungs. Since inhalation of asbestos fibre is known to induce asbestosis, lung cancer, and malignant mesothelioma of the pleura, there would seem to be a high probability that CNTs are also likely to have significant toxic effects on human health due to their structural resemblance to asbestos. Several studies have indicated that CNTs exhibit substantial cytotoxicity in vitro, including induction of oxidative stress, inhibition of cellular proliferation, and induction of apoptosis/necrosis. Jia et al. [16]reported cytotoxicity results for SWCNTs, MWCNTs and fullerenes (C60) in vitro. Their results show that cytotoxicity increases by as much as 35% when the dosage of SWCNTs increases by 11.30 $\mu g/cm^2$. No significant toxicity was observed for C60 up to a dose of 226.00 $\mu g/cm^2$. The cytotoxicity'[17] apparently follows a sequence on a mass basis: SWCNTs > MWCNTs > quartz > C60.

OUTLOOK AND FUTURE NEEDS:-

Much more studies are needed to evaluate the stability of these matrices in a variety of test systems to fully determine the potential for human exposure to the nanoscale components of commercially available products, as well as future products. Toxicity studies of nanoparticles using different cell lines and incubation times are increasingly being published, but due to the wi4e range of nanoparticle concentrations, variety of cell lines as well as culturing conditions, and lack of understanding of mechanism, it is very difficult to determine whether the toxicity observed is physiologically relevant. Importantly, analytical techniques are needed that permit real-time, in situ monitoring to optimize production processes, thus minimizing waste and energy costs as well as providing mechanistic information.

Further research is necessary to develop these methods. There are encouraging results that suggest that the green nanoscience framework can guide design, production, and application of greener nanomaterials across the range of compositions, sizes, shapes, and functionality. Further development and application of this framework will provide research opportunities and challenges for this community for the foreseeable future.

CONCLUSION:-

To assess the safety of complex multi-component and multi-functional nanomaterials, scientists will need to develop validated models capable of predicting the release, transport, transformation accumulation, and uptake of engineered nanornaterials in the environment. These models should relate physical and chemical characteristics of nanomaterials to their behaviour, allow an integrated approach to predict potential impact of engineeered nanomaterials and nanoproducts, and estimate impacts within susceptible populations. Developing structure-activity relationships is needed to predict biological impacts, ecological impacts, and degradation at end-of-life. Each of these models in necessary to design nanoparticles that will have the desired human health and environmental performance to complement their physical properties.

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