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NANOTECHNOLOGY: AN OVERVIEW OF THE PAST AND THE POTENTIAL OF THE FUTURE

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Abstract

Modern nanotechnology was the brain child of Richard Feynman, the 1965 Nobel Prize Laureate in physics. During the 1959 American Physical Society meeting at Caltech, he presented a lecture titled, ''There's Plenty of Room at the Bottom'', in which he introduced the concept of manipulating matter at the atomic level. This novel idea demonstrated new ways of thinking and Feynman's hypotheses have since been proven correct. It is for these reasons that he is considered the father of modern nanotechnology. In a timeframe of approximately half a century, nanotechnology has become the foundation for remarkable industrial applications and exponential growth. For example, in the pharmaceutical communities of practice, nanotechnology has had a profound impact on medical devices such as diagnostic biosensors, drug delivery systems, and imaging probes. In the food and cosmetics industries, use of nano-materials has increased dramatically for improvements in production, packaging, shelf life, and bioavailability. Zinc oxide quantum dot nanoparticles show antimicrobial activity against food-borne bacteria, and nanoparticles are now used as food sensors for detecting the food quality and safety. Unfortunately, there is no internationally accepted standard protocol for toxicity testing of nano-materials. Furthermore, there are few if any internationally accepted well-characterized–positive controls available at the present time for nano-material studies. The current practice is for investigators to use their own protocols and compare the results with the vehicle control. Under such circumstances, it is difficult to compare published nano-toxicity results. In this context, internationally approved models and methods are needed to enable regulatory agencies to evaluate the safety of nano-materials. This research paper is to be discussed about " **Nanotechnology: An Overview of the past and the potential of the future"**

Keywords:Antimicrobial activity, Development, Industrial Applications, Nanotechnology, Toxicity, Microsystems, Fussy, over production,geosystems

"Nanotechnology has been moving a little faster than I expected virtual reality a little slower"

Nick Bostrom

The development of nanotechnology across time

Human dreams and imagination often give rise to new science and technology. Nanotechnology, a 21st-century frontier, was born out of such dreams. Nanotechnology is defined as the understanding and control of matter at dimensions between 1 and 100 nm where unique phenomena enable novel applications. Although human exposure to nanoparticles has occurred throughout human history, it dramatically increased during the industrial revolution. The study of nanoparticles is not new. The concept of a ''nanometer'' was first proposed by Richard Zsigmondy, the 1925 Nobel Prize Laureate in chemistry. He coined the term nanometer explicitly for characterizing particle size and he was the first to measure the size of particles such as gold colloids using a microscope.

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that he is considered the father of modern nanotechnology. Almost 15 years after Feynman's lecture, a Japanese scientist, Norio Taniguchi, was the first to use ''nanotechnology'' to describe semiconductor processes that occurred on the order of a nanometer. He advocated that nanotechnology consisted of the processing, separation, consolidation, and deformation of materials by one atom or one molecule. The golden era of nanotechnology began in the 1980s when Kroto, Smalley, and Curl discovered fullerenes and Eric Drexler of Massachusetts Institute of Technology (MIT) used ideas from Feynman's ''There is Plenty of Room at the Bottom'' and Taniguchi's term nanotechnology in his 1986 book titled, ''Engines of Creation: The Coming Era of Nanotechnology.'' Drexler proposed the idea of a nanoscale ''assembler'' which would be able to build a copy of itself and of other items of arbitrary complexity. Drexler's vision of nanotechnology is often called ''molecular nanotechnology.'' The science of nanotechnology was advanced further when Iijima, another Japanese scientist, developed carbon nano-tubes.

The beginning of the 21st century saw an increased interest in the emerging fields of nano-science and nanotechnology. In the United States, Feynman's stature and his concept of manipulation of matter at the atomic level played an important role in shaping national science priorities. President Bill Clinton advocated for funding of research in this emerging technology during a speech at Caltech on January 21, 2000. Three years later, President George W. Bush signed into law the 21st Century Nanotechnology Research and Development Act. The legislation made nanotechnology research a national priority and created the National Technology Initiative (NNI).1 Today, the NNI is managed within a framework at the top of which is the President's Cabinet-level National Science and Technology Council (NSTC) and its Committee on Technology. The Committee's Subcommittee on Nanoscale Science, Engineering, and Technology (NSET) is responsible for planning, budgeting, implementation, and review of the NNI and is comprised of representatives from 20 US departments and independent agencies and commissions (Table 1).

Table-1: The table shows the US federal departments, independent agencies, and commissions that are participating in the National Nanotechnology Initiative (NNI)[a]

Departments, independent agencies, and commissions with budgets for nanotechnology research and development	Other federal departments, independent agencies, and commissions that are participating
Consumer Product Safety Commission	Department of Education
Department of Commerce	Department of Commerce
National Institute of Standards and Technology	Bureau of Industry and Security Economic Development Administration US Patent and Trademark Office
Department of Defense	Department of Interior US Geological Survey
Department of Energy	Department of Justice National Institute of Justice
Department of Health and Human Services	Intelligence Community

Food and Drug Administration National Institute for Occupational Safety and Health	Office of the Director of National Intelligence National Reconnaissance Office
National Institute for Occupational Safety and Health National Institutes of Health	Department of Labor
Department of Homeland Security	Department of Labor Occupational Safety and Health Administration
Department of Transportation Federal Highway Administration	Department of State
Environmental Protection Agency	Department of Treasury
National Aeronautics and Space Administration National Science Foundation	Nuclear Regulatory Commission
US Department of Agriculture Agriculture Research Service Forest Service National Institute for Food and Agriculture	US International Trade Commission

aTheir efforts are coordinated by the Subcommittee on Nanoscale Science, Engineering, and Technology, Committee on Technology, National Science and Technology Council. While the Consumer Product Safety Commission, Nuclear Regulatory Commission, and US International Trade Commission are represented on the Subcommittee, they are non-voting members.3

Future of nanotechnology:

In a timeframe of approximately half a century, nanotechnology has become the foundation for remarkable industrial applications and exponential growth. For example, in the pharmaceutical communities of practice, nanotechnology has had a profound impact on medical devices such as diagnostic biosensors, drug delivery systems, and imaging probes. In the food and cosmetics industries, use of nano-materials has increased dramatically for improvements in production, packaging, shelf life, and bioavailability. Zinc oxide quantum dot nanoparticles show antimicrobial activity against food-borne bacteria, and nanoparticles are now used as food sensors for detecting the food quality and safety. The most recent goals and accomplishments of each of the US federal entities listed on Table 1 are summarized in the NSTC's report titled, ''Supplement to the President's Budget for Fiscal Year 2015—The National Nanotechnology Initiative.''

Today, nanotechnology impacts human life every day. The potential benefits are many and diverse. However, because of extensive human exposure to nanoparticles, there is a significant concern about the potential health and environmental risks. These concerns led to the emergence of additional scientific disciplines including nano-toxicology and nano-medicine. Nano-toxicology is the study of potential adverse health effects of nanoparticles. Nano-medicine, which includes subsectors such as tissue engineering, biomaterials, biosensors, and bio-imaging, was developed to study the benefits and risks of nano-materials used in medicine and medical devices. Some of the potential benefits of medical nano-materials include improved drug delivery, antibacterial coatings of medical devices, reduced inflammation, better surgical tissue healing, and detection of circulating cancer cells. However, due to lack of reliable toxicity data, the potential to affect human health continues to be a major concern.

Safety evaluation of nano-materials:

Safety of consumer products containing nano-materials was an early societal concern.12 When US regulatory agencies adopted the NNI1 definition of the nano-materials, it was expected that the risk assessment techniques used for drugs and toxic chemicals would be used for the risk evaluation of nano-materials. However, reports of large data gaps indicated the need to augment conventional toxicity testing methods. Walker and Bucher summarized four reasons why nano-materials need to be assessed differently than through the conventional methods: (a) new routes of exposure emerge when a nano-material is small enough to enter new cellular portals; (b) Surface properties impact dissymmetry because they alter the toxic kinetics of materials of similar size and shape; (c) The new commercial applications might lead to new biological interactions and unforeseen toxicities; and (d) Assessment of relative risk using dose expressed in terms of mass may lead to false outcomes because some nano-materials' dose can scale with a size-dependent property such as surface area. Because physical properties of nano-materials are relevant to the first three steps in the US risk assessment/management paradigm, namely hazard identification, dose–response assessment, and exposure assessment, they are relevant to the fourth step, risk characterization. Since much of the needed physical characteristics information (e.g. shape, composition, surface area, surface properties, and agglomeration state) is unavailable, the need for reliable and reproducible exposure and toxicity data persists. Although significant progress in research in nano-toxicology and nano-medicine has been made in recent years, much more work remains to be done.

The challenges are not the India alone. Unfortunately, there is no internationally accepted standard protocol for toxicity testing of nano-materials. Furthermore, there are few if any internationally accepted well-characterized–positive controls available at the present time for nano-material studies. The current practice is for investigators to use their own protocols and compare the results with the vehicle control. Under such circumstances, it is difficult to compare published nano-toxicity results. In this context, internationally approved models and methods are needed to enable regulatory agencies to evaluate the safety of nano-materials. Efforts are ongoing and methods for safety evaluation of nano-materials have been developed. Standardized methods have also been suggested for this purpose. Availability of reference materials for nano-toxicity testing has been initiated by the UK Nanotechnology Research Coordination Group and the US National Nanotechnology Characterization Laboratory.

The International Alliance for Nano Environment, Human Health and Safety Harmonization has started developing test protocols for nano-toxicity testing. In the light of the toxicity testing in the 21st century proposed by the US National Research Council (NRC), high-throughput screening of nano-materials seems promising and may be possible in the not too distant future. Although the complex nature of the nano-materials makes the development of their safety assessment challenging, the future of the nanotechnology appears to be bright.

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