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Review Article

NANOTECHNOLOGY: A BOON OR BANE

Priyanka Singh[1], Raaz Maheshwari[2]*, A K Chauhan[2], Bina Rani[3]
[1]School of Pharmacy, Krishna Institute of Engineering &Technology, Ghaziabad, UP, India
[2]Department of Chemistry, SKGC, Sikar, Rajasthan, India
[3]Department of Engineering Chemistry & Environmental Engineering, PCE, Sitapura, Jaipur, Rajasthan, India

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*Email: binaraj_2005@rediffmail.com

ABSTRACT
Nanotechnology deals with the physical and chemical attributes of molecular scale structures, and they can be combined to form larger structures for human use. Because of this dimensional range, nanoparticles and structure get some unusual and novel properties. Nanotechnology deals with the study and analysis of these properties also. Indeed it is an emerging area of applied science and technology whose theme is the control of matter on the atomic and molecular scale generally 100nm or smaller. The impact of nanotechnology is expanding and nothing will remain untouched. Applications are enormous and limitless. Nanotechnology enables doing things better than in the conventional technology viz.

- Economic development
- Improving food security
- Health Diagnosis, Monitoring and Scanning
- Safe Drinking Water
- Environmental pollution
- Agriculture
- Energy Storage, Production and Conservation

As a coin has two sides, nanotechnology also has a flip side. No doubt, nanotechnology will be incorporated into every facet of our lives, making things easier, faster and longer lasting. Potential dangers of technology that are being discussed in various forms includes

- Possible increased inflammatory response in the body due to small size
- Potential terrorist use
- Social disruption from new products/ lifestyles
- Risks of a "Grey Goo" (hypothetical end of the world)

Now there is a critical need to fund researchers and engineers across disciplines and institutional boundaries in order to advance in the arena of nanotechnologies. There must be innovative partnerships that integrate research and education, accelerate applications and fully explore the implications of nanotechnology on our health, wealth and lives.

Keywords: Fullerenes; Nanopowders;Nanomembrane filtration; Quantum dots; Carbon nanotubes; Safety concerns; Environmental impacts; Nanointruders; Public awareness

INTRODUCTION

Many nanoforms of matter exist around us. One of the earliest nano-sized objects known to us was made of gold. Faraday prepared colloidal gold in 1856 and called it divided metals. The term nanotechnology was coined in 1974 which ultimately led to discovery of Fullerenes and carbon nanotubes. Nanotechnology is engineering at the molecular (group of atoms) level. It is the collective term for a range of technologies, techniques and processes that involve the manipulation of matter at the smallest scale (from 1 to 100nm). The classical laws of physics and chemistry do not readily apply at this very small scale for two reasons. Firstly, the electronic properties of very small particle can be very different from their larger cousins. Secondly, the ratio of the surface area to volume becomes much higher, and since the surface atoms are generally most reactive, the properties of the material change in unexpected ways. For example, when silver is turned into very small particles, it takes on anti-microbial properties while gold particles become of any colour we choose. Nature provides plenty of examples of materials with properties at the nanoscale – such as the dolphin skin or the 'nanofur' that allows geckos to walk up vertical surfaces. The geckos foot pad is covered with aggregates of hair formed from nanofibres which impart strong adhesive properties.Nanotechnologists use similar principles to deliberately engineer at the nanoscale to create products that make use of these unusual properties. Starting with nanostructures, researchers rearrange them and then assemble functional systems that can be incorporated into products with unique properties.

Nanotechnology Developments

- Overall investment in nanotechnology increased 10-fold during this decade, with similar growth in the number of patents filed in this field.
- Major public sector R&D initiatives on nanotechnology were announced over the past 5 years in the USA, Japan, European Union, China, Korea, Taiwan and UK.
- Lux Research (USA) projects that internationally; private sector spending will exceed that of governments after 2004. Some 1500 companies have announced nanaotechnology R&D plans, of which 80% were start-ups.
- Global sales of products derived from emerging nanotechnologies are estimated to escalate to over US$3 trillion per annum in the next ten years, with between 1 and 2 million new jobs generated.

Brief History Of Nanotechnology

Nanotechnology of gold and silver has been found in Ming dynasty pottery and stained glass windows in medieval churches. However, the origins of nanotechnology did not occur until 1959, when Richard Feynman, US physicist and Nobel Prize winner, presented a talk to the American Physical Society annual meeting entitled There's Plenty of Room at the bottom. In his talk, Feynman presented ideas for creating nanoscale machines to manipulate, control and image matter at the atomic scale. In 1974, Norio Taniguchi introduced the term 'nanotechnology' to represent extra-high precision and ultra-fine dimensions, and also predicted improvements in integrated circuits, optoelectronic devices, mechanical devices and computer memory devices. This is the so called 'top-down approach' of carving small things from large structures. In 1986, K Eric Drexler in his book Engines of Creation discussed the future of nanotechnology, particularly the creation of larger objects from their atomic and molecular components, the so called 'bottom-up approach'. He proposed ideas for 'molecular nanotechnology' which is the self assembly of molecules into an ordered and functional structure. The invention of the scanning tunnelling microscope by Gerd Binnig in 1981 (IBM Zurich Laboratories), provided the real breakthrough and the opportunity to manipulate and image structure at the nanoscale. Subsequently, the atomic force microscope was invented in 1986, allowing imaging of the structures at the atomic scale. Another major breakthrough in the field of nanotechnology occurred in 1985 when Harry Croto, Robert Curl and Richard Smalley invented a new form of carbon called fullerenes (buckyballs), a single molecule of 60 carbon atoms arranged in the shape of a soccer ball. This led to a Noble Prize in Chemistry in 1996. Since that time, nanotechnology has evolved into one of the most promising fields of science, with multi-billion dollar investments from the public and private sectors and the potential to create multi-trillion dollar industries in the coming decade.

Unifying Themes Of Nanotechnology

Because nanotechnology is classified by the size of the materials being developed and used, the products of this engineering can have little in common with each other – for example fuel cells , fabrics or drug delivery devices. What brings them together is the natural convergence of all basic sciences (biology, physics and chemistry) at the molecular level. At this level, these diverse fields are unified by the following common themes:

- **Characterization tools –** They are to be able to examine and see the nanostructures or the building blocks of nanomaterials, characterization tools such as X-ray diffraction, Electron Microscopy, Scanning Tunnelling, Atomic Force Microscopy are powerful tools across disciplines.
- **Nanoscale science –** Because the properties of the materials change in unexpected ways at the nanoscale, the science of understanding the behaviour of molecules at this scale is critical to the rational design and control of nanostructures for all product applications.
- **Molecular level computations –** These technologies such as quantum mechanical calculations, molecular simulations and statistical mechanics are essential to the understanding of all nanoscale phenomenon and molecular interactions.
- **Fabrication and processing technology –** Many nanoparticles, powders and suspensions can be directly applied in paints, cosmetics, and therapeutics. However, other nanomaterials must be assembled and fabricated into components and devices. In addition, processing techniques such as sol-gel, chemical vapour deposition, hydrothermal treatment, and milling are common techniques.

Applications Of Nano Technology

Nanopowders (building blocks of nanomaterials)

Nanopowders contain particle less than 100nm in size – 1/10,000th the thickness of human hair. The physical, chemical and biological properties of such small particles allow industry to incorporate enhanced functionalities into products. Some of the unique properties of interest to industry are enhanced transparency from particles being smaller than the wavelength of visible light, and high surface areas for enhanced performance in surface-area driven reactions such as catalysts and drug solubilisation. These unique properties give rise to a range of new and improved materials with a breadth of applications. For example, nanotechnology allows plastics to retain transparency while also taking on characteristics such as resistance to abrasion, conductivity or UV protection found in ceramics or metals. New medical nanomaterials are being developed, such as synthetic bone and bone cement, as well as drugs with improved solubility to allow lower dosing, more efficient delivery and fewer adverse side effects. The high surface areas of nanoparticle are being expoted by industry in catalyst thet inprove chemical reactions in application such as cleaning up car exhausts and potentially to remove toxins from the environment. For example, petroleum and chemical processing companies are usin nanostructured catalysts to remove pollutants - $30 billion industry in 1999 with the potential of $100 billion per year by 2015. Imported catalysts illustrate that improvements to existing technology can open up whole new markets – nanostructured catalysts look likely to be a critical component in finally making fuel cells a reality, which could transform our power generation and distribution industry.

Nanomembranes

Nanotechnolgy can address one of the most pressing issues of the 21st century – safe, clean and affordable water. There are 1.3 billion people without access to safe drinking water and indications are that global consumption of water will likely to double in the next 20 years. Fresh water supplies are already liming the growth of our cities – Australian cities such as Sydney and Perth are considering wastewater reuse schemes to augment their water supplies. London is investing £200 million in desalination and Singapore recycles recycle wastewater/ further technology development is require to make this cost effective and allow it to become a more main stream water supply option. Nanomembrane filtration devices that 'clean' polluted water, shifting out bacteria, viruses, heavy metals and organic material, are being explored by researches of US, Israel and Australia (at the UNESCO Centre for Membrane Science and Technology at the University of New South Wales and a Consortium of CSIRO Divisions). The key to lowering the energy demand and improving throughput for desalination is in understanding how to selectively separate small molecules, and package these technologies for the exploitation. Separation of molecules occurs efficiently in nature through membranes, such as the ion channels that remove salt from blood and the respiratory membranes that transport oxygen and carbon dioxide. In order to reduce the energy requirement for this process, nature provides large surface areas for the transport of the molecules. A parallel approach is being developed by nanotechnologists for the production of nanoarchitectures for cost-effective filtration systems in large-scale water purification. By bringing science, business and government together on this issue, it should be feasible to find nanotechnology solutions to a global problem and transform a US$400-billion-a-year water-management industry.

Carbon Nanotubes

The discovery that the graphite can be rolled into a cylinder with a diameter of about one nanometer already has far-reaching consequences. These strong but light 'carbon nanotubes' are being developed for a raft of uses, such as sensors, fuel cells, computers and televisions. The applications of nanotubes are set to expand even further now that researchers have found that other materials besides carbon can form nanorubes.

Carbon Nanotubes in Biotherapeutics: Nanotechnology is a term employed to define products, processes and properties at the nano scale. Recently, there have been rapid advances in this field. Specifically, nanotechnology has shown nearly limitless novel potential in biomedical (drug and gene delivery) applications, as our on biology is essentially a very complex system of nano-molecules. Thus emerges the field of nanomedicine defined as the manipulation and control of our own biological processes through materials constructed on a nano scale. In the nanotechnology arena, carbon nanotubes hold the key to nanomedicine. These nanotubes are formed from pure carbon bonds. It's well known that C-atoms easily construct basically two kinds of covalent bond – Sp^2 & Sp^3 – the former seen in graphite and the latter in diamond.

Two types of nanotubes exist in nature – single-wall nanotubes and multi-wall nanotubes. These nanotubes have been employed to deliver therapeutic molecules selectively to targeted cells and organs in a safe manner, with low immunogenic response and low toxicity. These nanotubes are structures made of thin sheets of C_6H_6

(benzene) ring carbon rolled up into the as the shape of a seamless cylinder and are often capped on at least one end by a spherical buckyball (fullerene) structures. As the single- and multi walled C-nanotubes are layers of **graphene sheets,** they possess interesting structural, mechanical and electrical properties. Owing to their unique electrical properties, unusual strength in heat conduction, these nanotubes are particularly promising nanomaterials for industrial use. These light and chemically stable C-nanotubes conduct heat better than diamond and are one of the strongest materials universally in existence. Also, characteristics of metal or a semiconductor and electrical properties are well exhibited by these nanotubes. All these amazing physical merits of nanotubes have astounded researchers from nearly every field of science providing them promising new material with many potential applications.

A group of American researchers has developed microcapsule – nanotube devices for various applications that can be employed to device function with a variety of molecules for specific purposes to deliver proteins, genes, NAs, drugs and other therapeutics into cells. Trials with administration of C-nanotubes to animal subjects has shown that these tubes could be rapidly cleared from systematic blood circulation through the renal excretion route without causing any side effect or mortality and weren't retained in any of the reticulorndothelial system organs. These results have proved the biocompatibility of C-nanotubes and cleared way for potential clinical uses without any fear of biohazards. Artificial cell microcapsuation is a technique wherein a polymer membrane protects the encapsulated materials from harsh external environments, while at the same time allows the metabolism of selected solutes capable of passing in and out of the microcapsule.

Several synthetic biopolymers are being used for encapsulation as long as they are chemically compatible. Therapeutic materials produced using biological means (biotherapeutics), in general possess relatively short-lives, which require appropriate controlled-release systems for improved release kinetics and better therapeutic results. Microencapulation facilitates controlled, sustained and prolonged release of the therapeutics to achieve optimum delivery of the bioactive molecules at the targeted sites. For many bioactive agents non-uniform release at target sites may offer advantages over continuous release in such cases programmed or triggered delivery microcapsule systems can be designed which allow the rapid and transient release of a therapeutic at the exact target site after a predetermined off-release period. Modifying the drug resistance time and drug release rates ensures increased amounts of the therapeutic reaching the diseased sites to achieve effective treatment. By means of APA membrane and single-wall C-nanotubes, design of novel polymeric membrane C-nanotube microcapsule devices for many targeted delivery applications has been achieved.

Carbon Nanotubes – Impregnated Fabric as Biosensor: Carbon nanotubes are molecular-scale tubes of graphitic carbon with outstanding merits and are among the stiffest and strongest fibres known, and possess remarkable electronic properties. Individual, well-formed carbon nanotubes are greatly conductive making them promising for applications such as battery electrodes and microprocessors. If molecules viz. Antibodies are anchored to their surface, they can also serve as very sensitive chemical detectors: when an antibody binds to its target, the nanotube's electrical properties are measurably altered. For these reasons they have attracted huge academic and industrial interest, although commercial applications have been rather slow to develop, primarily because of high production costs of the best quality nanotubes. One problem with C-nanotubes is that they tend to clump together preventing them from functioning individually, degrading electronic properties. In order to get around the problem of clumping, nanotubes are sprayed onto a flat surface in alternate layers with conductive polymer. Nicholas Kotov, a chemical engineer at the UM, in Ann Arbor, USA, found that this type o layer-by-layer assembly can be further simplified for a complex three-dimensional surface such as a cotton thread. It was observed that the tangle of fibres provides a structural template allowing simply dip the thread into a solution containing both the polymer and the nanotubes. Glued to the thread by the polymer, the nanotubes form a net with good electrical properties having well spaced and overlapped array. Number of possible applications viz. biosensors to safe textiles for mankind, are being explored. These fibres are cheap and sensitive enough for possible use in factories/stores, or even homes. Spot blood loss in soldiers on remote patrols or to detect airborne allergens or pathogens such as influenza. In order to make fabrics inexpensive, work is being done on reusable versions, changing the chemistry so that the antibodies release their targets after detection and remain in the fabric[1].

Quantum Dots & Artificial Atoms

These are small devices that contain a tiny droplet of free electrons. They are fabricated in semiconductor materials and have typical dimensions between nanometers to a few microns. A quantum dot can have anything from a single electron to a collection of several thousands. The physics of quantum dots show many parallels with the behaviour of naturally occurring atoms, but unlike their natural counterparts, quantum dots can be easily connected to electrodes and are therefore excellent tools to study atomic properties. The capability to make artificial atoms is revolutionary. The potential applications are enormous such as counterfeit-resistant inks, new biosensors, quantum electronics, photonics and the possibility of tamper-proof data transmission. The technology also highlights the important regulatory and safety issues that must be addressed before widespread application of such disruptive technologies.

Molecular electronics – cross bar latches to replace silicon chips

Hewlett-Packard – one of the world's biggest computers companies – declared on 1 February, 2005 that it is on the verge of a revolution in computer chip technology. They believe that silicon computer chips will have reached a technical dead end in about a decade, to be replaced by tiny nanotechnology devices described as 'cross bar latches'. These molecular-scale alternatives to the transistor should dramatically improve the performance of the computers because they are much smaller – only 2 or 3 nm in size compared with 90 nm for transistors – and they can store memory for much longer periods. The new device consists of a wire that is crossed by two other wires. The resulting junctions serve as switches that are only a few atoms across and can be programmed by a repeatable set of electrical pulses.

NEW TECHNOLOGIES FOR CLEAN AND EFFICIENT ENERGY GENERATION

The increased need for more energy will require enormous growth in energy generation capacity, more secure and diversified energy sources, and a successful strategy to take greenhouse gas emissions. All the elementary steps of energy conversion take place on the nanoscale. Thus, the development of new nanoscale materials, as well as methods to characterize, manipulate, and assemble them, create an entirely new paradigm for developing revolutionary energy technologies. A recent workshop led by the US Department of Energy identified the following areas in which nanoscience is expected to have the greatest impact:

- Scalable methods to split water with sunlight for hydrogen production
- Highly selective catalysts for clean and energy-efficient manufacturing
- Harvesting of solar energy with 20% power efficiency and 100x lower cost

- Solid-state lighting at 50% of the present power consumption
- Super-strong, light-weight materials to improve efficiency of cars, airplanes, etc
- Reversible hydrogen storage materials operating at ambient temperatures
- Power transmission lines capable of 1 gigawatt transmissions
- Low-cost fuel cells, batteries, and super capacitors built from nanostructured materials
- Materials synthesis and energy harvesting based on the efficient and selective mechanisms of biology

Social, Ethical And Safety Concerns

The introduction of ant new technology attracts debate about potential social, environmental and health impacts – nanotechnology no different. While some of the initial concerns raised about nanotechnology (such as US nanotechnology guru Eric Drexler's prediction of self-replicating nanomachines or 'nanorobots', or the 'grey goo taking over the world' scenario) can be seen as speculative futuristic hypothesises, it is valid to question whether existing regulatory frameworks are appropriate to protect humans and the environment from potential hazards. A relatively small number of groups such as Canada's ETC Group have campaigned consistently against the introduction of nanotechnology. Greenpeace, while recognizing the potential benefits of nanotechnology, has urged caution on environmental, occupation health and safety grounds. The working group considers that the development of a comprehensive impact and risk analysis framework must be seen as a high priority. This framework must adopt a science-based risk identification, assessment and management process.

Health And Environmental Impacts

A UK report released in 2004 by the royal Society and Royal Academy of Engineering concluded that many applications of nanotechnologies pose no new health or safety risks. However, some nanoparticles – those are freely mobile and not corporate into a material – may have the potential for negative health and environmental impacts by virtue of their size or particular chemical properties. The UK report therefore recommended that in the specific case of free nanoparticles and free nanotubes, existing regulatory frameworks need to be modified. Relatively little research has been published on the human or eco-toxicology of manmade nanoparticles. In contrast, nanoparticles from natural sources are everywhere in the environment and there are well-established studies on other manmade, small airborne particles, such as mineral dusts and carbon soot. It is reasonable to assume that at least some manufactured nanoparticles may be more toxic per unit of mass than the bulk material. The UK report recommended that until more is known about the environmental impacts of nanoparticles and nanotubes, release into the environment should be avoided. There may also be health risks from the medical application of nanoparticles, for examples to enhance drug delivery. The existing regulatory agencies such as the US Food and Drug Administration (FDA) and Australia's Therapeutic Goods Administration (TGA) and the National Industrial Chemicals Notification and Assessment Scheme (NICNAS) would be the appropriate vehicles to address and regulate such risks.

Nanointruders and toxicity: Women all over the world are doing a variety of things to combat aging. They want their faces to look like they did a few years ago, and try all kinds of new technologies to find the look of youth. One of these new technologies is being marketed by one largest manufactures of beauty products; the new technology is the use of nanoparticles in their cosmetics, particularly in anti-aging wrinkle creams. Nanocosmetics are so named because they utilize extremely tiny particles to penetrate the skin far more than traditional anti-aging treatments are able to do. Nanotechnology was originally introduced to be used in manmade fibres and medicinal drugs. Because of the ability of these particles to be absorbed into skin cells, questions have arisen concerning the long term effects of the chemicals being introduced into the body. This is particularly an issue if the particles leach into body cells or the bloodstream.

Both, the British Agency, the Royal Society (RS), and the American Agency, the Food and Drug Administration (FDA), have voiced concerns about the use of nanotechnology in cosmetic treatments. These governmental bodies are calling for some research into the long term effects of these cosmetics in the industry, which has been relatively unregulated since its conception. The FDA is also looking into the possibility of introducing a system which would require clinical trials and licensing within cosmetic industry. According to the FDA, urgent research is needed to assess safety concerns about nanoparticles used in cosmetics. The RS is also questioning whether the particles are taken into cells, whether they can enter the blood stream, and effect of these. The fears arising from the use of nanotechnology in cosmetics are due to questions about possible genetic mutation as a long term effect. Traditionally, anti-aging skin care products were designed to hold moisture in the skin by creating a barrier between the skin and outside world. Nanoparticles in the new generation of cosmetics do not work this way. They are designed to penetrate the upper layers of the skin and stimulate new cell production which gives skin a new, plump, and youthful appearance. Nanoparticles make it possible to get a multitude of chemicals into the deeper layers of skin because the chemicals can be covered by the particles. Many of these particles would cause irritation in other forms and may be stimulating the inner working by irritating from the inside. This is the nanotechnology secrete to anti-aging and anti-wrinkle skin care products. Basically, if we use these products, we will definitely see results, but we do not know what effects they may have on us in the long run.

Beware the next time you use a cosmetic product to protect the skin from the sun. According to a US study, nanoparticles of titania (Titanium dioxide; TiO_2) used in some sun screens can damage brain cells. Led by Bellina Veronesi of the National Health and Environmental Effects Research Laboratory (NHEER) of the Environmental Protection Agency (EPA), the study was published online on June 7 (2006) in Environmental Science & Technology. The researchers studied the effect of titania nanoparticles on culture of mouse microglia (specialised cells that protect the brain from invading microbes or foreign particles by engulfing them). The cells then release 'free radicals' known as reactive oxygen species (ROS) to burn up the invading substance. It was found that the titania particles provoke the cells to manufacture and release ROS in a prolonged manner. Though protective in the short term, ROS released in a sustained manner could subject in the brain to oxidative stress – thought to be the cause of diseases like Parkinson's and Alzheimer's.

Hundreds of nanoparticle containing products are released in the market every day and it is assumed that they will be safe because larger grains of those chemicals are safe. But this assumption cannot be granted, warn researchers. On the other hand, it should not be assumed that all nano-particles used in consumer products such as toothpastes and cosmetics are harmful. Titania is a white pigment used in paints, and is generally considered non-toxic. It has long been used in many face creams because of its ability to absorb ultraviolet light and appear transparent rather than white. Titania nanoparticles have also been used to speed up the degradation of environmental contaminants in the presence of light. Experts titania in sun creams may trigger similar reaction in the presence of sun light, which may harm the skin. But according to a German study, titania remains blocked in the upper layer of skin. Researchers, however, warn that nanoparticles may travel around natural environments, including the human body, in ways different than bigger particles do and may even enter the brain from the bloodstream. It is said that risk from such particles should be assessed as if they were new chemicals.

From sunscreens, antiseptics to medicines, artificially engineered nanoparticles are vital for numerous consumer and industrial products. Of a nanometre's size, these particles are of silver, gold, titanium dioxide and other elements and compounds. While nanotechnology has become the latest buzzword in science, a group of researchers has expressed concern that nanoparticles could be entering the food chain. Nanoparticles are released into the environment through the products they are used in. for instance, when someone washes face after having applied sunscreen, the cream gets washed down and so do the nanoparticles infused in such creams. These nanoparticles are taken up by species at lower levels of the food chain. From there, the pollutants move into organisms that feed on those species, according to a team of researchers led by Patrica Holden of Donald Bren School of Environmental Science and Management, University of California, Santa Barbara, in the US.

While exploring nanoparticle absorption in a microbial food chain, the researchers observed that nanoparticles of cadmium and selenium were entering bacteria Pseudomonas aeruginosa and accumulating in them. When the bacteria fall prey to a higher organism, protozoa called Tetrahymena thermophilia, nanoparticles moved too. Since each protozoan predator feeds on thousands of bacteria, the amount of nanoparticles was higher in Tetrahymena thermophilia. When quantified, the concentration was approximately five times higher in the predator than the prey. "This result, called biomagnifications, implies that the next organism in the food chain would have more nanoparticles," stated Holden

Commenting on the study, published in the January issue of Nature Nanotechnology, Nicholas S Fisher, professor at School of Marine and Atmospheric Sciences, State University of New York in the US stated. "This study is striking since it shows evidence of biomagnification in a simple, short food chain." Research done by other scientific groups has shown that metals like aluminium and even gold can be biomagnified across food chains as nanoparticles. For instance, in a study conducted by the University of Kentucky in the US lead researcher Paul M Bertsch and colleagues exposed tobacco plants to gold nanoparticles and then allowed herbivorous tobacco hornworms to feed on them. The predators accumulated the nanoparticles at concentrations six times than those measured in the plants, according to the study published in the December 2010 issue of Environmental Science and Technology Studies Research.

These experiments show that humans, the topmost consumers in the food chain, are likely to face a high degree of biomagnification implying a metal overload and subsequent toxicity. "As far as industrial products are concerned, it is important to control the random release of nanomaterials from manufacturing sites into the surrounding environment, and minimise manufacturing worker's exposure," stated Holden, she added, "The scientific should also decide on what dsign criteria would make engineered nanomaterials environmentally compatible. At present, nanoparticles are designed keeping in mind their functionality." David Buchwalter, coordinator of environmental toxicology concentration, department of environmental and molecular toxicology, North Carlina State University in the US, is not convinced with the paper's conclusion. He stated, "one cannot call things biomagnification just because one level of the food chain has higher concentrations than another." Most people agree that at least two successive steps in the chain with increasing concentration of biomagnifications are needed, he added[2].

Social And Ethical Issues Arising From Nanotechnology-Based Products

As with any new technology, control over its use and distribution of benefits, rather than the technology itself, will determine the social impact of nanotechnologies rather than the technology itself. Nanotechnology does not operate independently of other technological developments (ICT, medicine, materials, energy, etc.), so that incremental advances made in nanotechnology may have major influences in other areas. It is difficult to predict social and ethical implications of this convergence of various technologies, which are likely to hold a range of positive and possibly negative outcomes. It is also difficult to envisage the social impacts of what will be commercial decisions about the use of nanotechnology and business decisions about how products are marketed. The working group believes social issues need to focus on enabling community debate and choice, the economic impact of specific applications, inappropriate use of technology, equity and legal and regulatory frameworks. Some specific examples of potential social and ethical impacts are as follows:

	Potential Positives	Potential Negatives
Developing World Applications	Clean& Safe water, Environmental Remediation, Cheaper Medicines	A 'nanodivide' between rich and poor nations
Surveillance and Data Gathering	Improved business and Service Delivery	Compromised privacy
Defence	Better Early warning of Threats and Defence Capabilities	Personal and national security threats
Biotechnology	Improved drug delivery and Disease Treatment	Health risks, too invasive

These few examples illustrate the substantial social and economic benefit that nanotechnology should bring, but also the potential negative outcomes across society and to both developed and developing nations.

Although many of these concerns are still hypothetical, technical innovations tend to develop faster than all the stakeholders can keep up with. For these reasons, international policy formulation and public education on nanotechnology must be given high priority. For this reason, the US National Nanotechnology Initiative included funding for research on ethical, social and legal aspects of nanotechnology. To consider these and related issues, the USA held an international, mostly governmental, conference in 2004 on responsible research in nanotechnology, which agreed to set up a 'Preparatory Group', on which Australia is a member. The group is tasked to explore possible actions, mechanisms, timing, institutional frameworks and principles for an international dialogue and cooperation to occur on this in established international forums including the OECD's Global Science Forum. Australia also participates in other relevant forums such as the OECD Joint Meeting of the Chemicals Committee and the Working Party on Chemicals, Pesticides and Biotechnology; and the international Program on Chemical Safety.

Consideration of how to best build public awareness has already begun. In Europe in particular, there has been recognition of the need to avoid repetition of the past mistakes associated with public engagement on the issue of genetically-modified foods. A key point taken up by independent groups such as DEMOS in the UK and by government agencies such as the Irish Council for Science, Technology and Innovation, is the need to establish public forums. It is realistic however to expect the general public to keep abreast of the expanding wave of innovation in nanotechnology, and public views will rely heavily on information conveyed by the scientific community and the media. For their part, the scientific community needs to be mindful that the challenges they perceive may not match those perceived by the wider community and that narrow utilization approaches may not deliver an acceptable outcome to the public.

Presumptions On The Global Nanotechnology Scene

No one could have predicted that the invention of the scanning tunnelling microscope in 1981 would launch a revolutionary new technology that could be as significant as electricity or the microchip, transform whole industry sectors and generate product sales exceeding US$2 trillion by 2015. Like any other disruptive technology, nanotechnology offers both risks and rewards. The global developments in this field offer important lesions for Australia, notably:

- Global developments in nanotechnology will certainly impact on many of Australia's most important traditional industry sectors
- Nanotechnology has real potential to transform the way we live
- Collaboration on a global scale will be essential to realise the full potential of this multidisciplinary science
- In view of the massive global investment in nanotechnology, India will need to invest strategically to ensure we can maintain a competitive position

The challenge for India and indeed globally, over the next decade is to ensure that the full potential of this exciting technology can be harnessed, while ensuring that the social, ethical and safety issues are properly addressed.

PUBLIC AWARENESS

A survey of community perceptions commissioned by the Department of Industry, Tourism and Resources indicated that 46% of respondents had heard of nanotechnology (mostly from news stories or television, and in the context of miniaturisation) but only 28% could name possible applications (electronic, computers and environmental). Only one to two per cent of respondents saw benefits or had concerns about nanotechnology specifically. In contrast, in the, in the contrast of advances in science and technology in general, 58% per cent of respondents saw benefits from nanotechnology (improvements in health care and quality of life) compared to 18% who had concerns (mostly loss of privacy, adverse environmental impacts and unforeseen side effects). The survey also found that 49% of respondents wished to be consulted about nanotechnology developments, mostly in the context of general advances in science and technology. It was felt that adequate resources and infrastructure are required to engage the community in nanotechnology issues and that public education programs involving 'credible' advocates openly addressing public concerns and outlining key issues should be implemented. Such concerns include intrusions into privacy and loss of personal freedoms from security measures.

A model house (The Nanohouse) jointly developed by CSIRO and the University of Technology Sydney with seed funding from the Australian Government Department of Industry, Tourism and Resources, shows how new materials, products and processes emerging from nanotechnology research and development might be applied to our living system. The Nanohouse has an energy-efficient radiative cooling paint as the outer surface of some of the roofing material, which becomes a cooling element rather than a source of unwanted heat gain. Other features are sustainability, self-cleaning glass, cold lighting systems and dye-sensitised solar cells[3].

CONCLUSION

Nanoscience and nanotechnologies are starting to have an impact on our everyday lives with the potential to become important drivers for international competitiveness. It is possible nanotechnology will transform mainstream Indian industries as well as create whole new industries through disruptive technologies. India now has substantive research and an emerging SME nanotechnology sector. In addition some mainstream Indian businesses have developed comprehensive nanotechnology strategies. In is globally competitive in particular areas as evidenced by world-leading technologies being developed for diagnostic devices, nanomaterials, and quantum computing and energy storage. Our nanotechnology R&D is already making significant contributions to mainstream industry, and Indian industry will become increasingly reliant on nanotechnology solutions over the next 5-10 years. If India is to remain a global prayer in the development of nanotechnology-based industries we must understand that nanotechnology will become more expensive, complex, and multidisciplinary and dispersed. To capitalize on the opportunities offered by nanotechnology the challenge is to enhance the coordination of India's nanotechnology effort and the strategic concentration of resources. It is identified the need for government and non-government initiatives to catalyse the significant efforts in India. Long term support of India fundamental nanoscience research will be required as well as some consolidation and clustering of research effort.

Mechanisms are needed to support and strengthen India's fledging nanotechnology industry as well as enhance industry links with the public research sector. The competitiveness of Indian industry will also require a full complement of infrastructure – characterisation tools, nanoscale science, molecular level computations and fabrication and processing technology. a lack of prototyping facility is a particular impediment for industry development. It is crucial that we have in place the appropriate frameworks for coordination, regulation, training and education to ensure successful industry uptake and to address the issues at the research, industry and community levels. The development of a comprehensive impact and risk frameworks must be seen as a high priority.

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