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Nanotechnology: A Double Edged Sword

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Abstract : Nanoscience and Nanotechnology comprise one of the fastest-growing research and development areas in the world. Nanotechnology, which refers to a technology in which materials are designed and manipulated on a molecular scale, represents a technological leap on a scale analogous to the first industrial revolution. Nanotechnology has the potential to benefit environmental quality and sustainability through pollution prevention, treatment, and remediation. However, the development and use of nanomaterials also involves a great many environmental unknowns. There is a saying that "All good fruits will turn bad", with nanotechnology destructive objects such as atomic bomb grenades, nuclear weapons, robotic killers designed to kill humans etc., can be made which can dump humanity in danger.

Key words : Nanotechnology, Nanosciense, Molecular scale, Robotic killers

From time to time, revolutionary new technologies appear and cause dramatic changes in the course of human history. In the last decade or so, the sciences of biology, chemistry and physics have converged to create a new science and technology which will have enormous impacts on the course of history. Nanotechnology, which refers to a technology in which materials are designed and manipulated on a molecular scale, represents a technological leap on a scale analogous to the first industrial revolution.

Nanotechnology is a creation of functional material, devices and systems through control of matter on a nanometer scale. It is also termed as "Molecular Manufacturing". Nanotechnology or nanoscience is an emerging discipline which involves imaging, measuring, manipulating and manufacturing materials on a scale of 1-100 nanometers.

Manufacturing materials and systems with components thousands of times smaller than the width of a human hair promises vast and sometimes unimaginable advances in technology. For instance, when solids, liquids, and gases are confined to regions smaller than 100 nm, their behavior can be modified by the confinement because properties such as thermal conductivity, electrical conductivity, optical absorption and emission spectra, mechanical strength, and viscosity are size dependent (Roco, 2001). Atoms and molecules are the basic building blocks of all physical things. The emerging disciplines of nanoscience and nanoengineering are leading to a new and unprecedented understanding of, and control over, these fundamental building blocks. By offering the ability to work at the molecular level, atom by atom, nanotechnology allows scientists and engineers to create matter that has a fundamentally new molecular organization. This new organization results in materials and systems whose structures and components exhibit novel, and significantly changed, physical, chemical, and biological properties.

Nanotechnology includes integration of nanoscale structures into larger architectures that could be used in industry, medicine, and environmental protection. Nanotechnology is the amalgamation of knowledge from chemistry, physics, biology, materials science, and various engineering fields.

Nanotechnology began to emerge as a realistic scientific endeavour during the 1980's. The last decade has witnessed rapid technological advancements. Scientists have demonstrated their ability to "play" with molecules and atoms and nanostructures have already been incorporated into several commercial products (Roco, 2001). Nanotechnology could have a dramatic impact on society by significantly transforming industry. Research involving nanotubes, one area of nanotechnology, is likely to yield significant advances in electronics in the near future. Nanotechnology will also have an immediate effect on materials science, optical networking, and medicine (Atroley, 2001). In the longer run, the field is expected to have a profound influence on almost every industry.

It means nanotechnology has the potential to fundamentally restructure the technologies currently used for manufacturing, medicine, defense, energy production, environmental management, transportation, communication, computation, and education. However, the development and use of nanomaterials also involves a great many environmental unknowns. There is a saying that "All good fruits will turn bad", with nanotechnology destructive objects such as atomic bomb grenades, nuclear weapons, robotic killers designed to kill humans etc., can be made which can dump humanity in danger.

The Potential Advantages of Nanotechnology

Nano optimists, including many governments, see nanotechnology, delivering benefits such as: environmentally benign material abundance for all, by providing universal clean water supplies, atomically engineered food and crops resulting in greater agricultural productivity with less labor requirements, nutritionally enhanced interactive 'smart' foods, cheap and powerful energy generation, clean and highly efficient manufacturing, radically improved formulation of drugs, diagnostics and organ replacement, much greater information storage and communication capacities, interactive 'smart' appliances; and increased human performance through convergent technologies.

Nanoparticles

Nanoparticles considerably smaller than one micron in diameter have been used in revolutionary ways to deliver drugs and genes into cells. The particles can be combined with chemical compounds that are ordinarily insoluble and difficult for cells to internalize. The derivatized particles can then be introduced into the bloodstream with little possibility of clogging the capillaries and other small blood vessels, as in the case of insoluble powders. The efficacy and speed of drug action in the human body can thereby be dramatically enhanced. In similar ways, nanoparticles carrying DNA fragments can be used to incorporate specific genes into target cells (Roco *et al*., 2001).

A fullerene or "Bucky Ball" is a spherical structure consisting of 60 carbon atoms. The structure is hollow and can be used to carry and deliver other agents such as medications or catalysts. It can also accept specific coatings. Fullerene C_{60}

molecules are unique for their multi-functional uses in material science and optics, and are considered for a variety of biological applications such as imaging probes, antioxidants and drug carriers (Levi *et al*., 2006, Wang *et al*., 2002, Spanggard and Krebs, 2004). Nanoparticles and nanospheres have considerable utility as controlled drug delivery systems (Hanes *et al*., 1997). When suitably encapsulated, a pharmaceutical can be delivered to the appropriate site, its concentration can be maintained at proper levels for long periods of time, and it can be prevented from undergoing premature degradation.

Nanoparticles (as opposed to micron-sized particles) have the advantage that they are small enough that they can be injected into the circulatory system. Highly porous materials are also ideal candidates for controlled drug delivery (Schnur *et al*., 1994) and for tissue engineering (Hubbell and Langer, 1995).

Carbon nanotubes are one of the fundamental building blocks of nanotechnology. These are specialized forms or structures of engineered nanoparticles that have had increasing production and use (Donaldson *et al*., 2006). During synthesis, drugs can be entrained in the nanotubes, and the final product can be used as a controlled delivery system. Tubules prepared from phospholipid bilayers are ideal for such applications because they are biocompatible. Dendrimers can be prepared so they are of discrete size and contain specific functional groups (Karak and Maiti, 1997). They can be functionalized and used in biomedicine. Examples include gene transfer agents for gene therapy, made to carry and control the relaxivity of paramagnetic MRI (magnetic resonance imaging) contrast agents (Toth *et al*., 1996), and to deliver drugs on a controlled release basis.

Nanoscale Sensors

Integrated nanoscale sensors could monitor the condition of a living organism, the environment, or components of the nutrient supply, sampling a range of conditions with a high degree of sensitivity. With arrays of ultra miniaturized sensors that sample a range of chemicals or conditions, the confidence level and specificity of detection would be much greater than is now possible with separate macroscopic sensors.

As has been seen with electronic integrated circuits, as the level of device integration increases and the volume of production grows, the costs of highly complex units decreases.

Conforming to Technology : Health

In medicine, nanotechnology could produce an array of new products, from novel drugs and devices to nanorobots that travel through the body finding and diagnosing illness. Since disease is the result of physical disorder of misarranged molecules and cells. Medicines at the molecular or cellular level should be able to cure most diseases. Hence, nanotechnology has wide scope in medicine. Nanostructures such as particles and polymeric dendrimers could be designed as drug delivery systems. Assembler-based manufacturing will provide new tools for medicine, making possible molecular-scale surgery to repair and rearrange cells. Mutations in DNA could be repaired, and cancer cells, toxic chemicals, and viruses could be destroyed through use of medical nanomachines, including cell repair machines. Nanotechnology will improve health care, help extend the life span, improve its quality, and extend human physical capabilities.

A group of researchers created a class of biological polymers, known as peptide nanotubes that can effectively combat deadly bacteria (Ghadiri, 2001). Researchers are also developing a "nanogenerator" that can target cancer cells and destroy them (Scheinberg, 2001).

Medicinal fluids containing nanorobots programmed to attack and reconstruct the molecular structure of cancer cells and viruses to make them harmless. Nanorobots could also be programmed to perform delicate surgeries. CAT scans and MRIs are the products of nuclear physics. Nuclear medicine is used to detect abnormalities of blood flow, structure, or function. A thyroid scan uses small amounts of radioactive iodine or technetium and a device to produce a picture of the thyroid gland that will show any physical abnormalities. These medical devices have made it possible to decrease the rate of deaths per illness due to new cures and medicine.

Drug delivery

Nanomedical approaches to drug delivery center on developing nanoscale particles or molecules to improve the bioavailability of a drug. Bioavailability refers to the presence of drug molecules where they are needed in the body and where they will do the most good. Drug delivery focuses on maximizing bioavailability both at specific places in the body and over a period of time. This will be achieved by molecular targeting by nanoengineered devices (Shosaku, 2006; Andre, 2006). In vivo imaging is another area where tools and devices are being developed. Using nanoparticle contrast agents, images such as ultrasound and MRI have a favorable distribution and improved contrast. The new methods of nano-engineered materials that are being developed might be effective in treating illnesses and diseases such as cancer.

Drug delivery systems, lipid- or polymer-based nanoparticles, can be designed to improve the pharmacological and therapeutic properties of drugs (Michael, 2005). The strength of drug delivery systems is their ability to alter the pharmacokinetics and biodistribution of the drug. Nanoparticles have unusual properties that can be used to improve drug delivery. Where larger particles would have been cleared from the body, cells take up these nanoparticles because of their size. Complex drug delivery mechanisms are being developed, including the ability to get drugs through cell membranes and into cell cytoplasm.

Cancer

Nanoparticles of cadmium selenide (quantum dots) glow when exposed to ultraviolet light. When injected, they seep into cancer tumors. The surgeon can see the glowing tumor, and use it as a guide for more accurate tumor removal. Sensor test chips containing thousands of nanowires, able to detect proteins and other biomarkers left behind by cancer cells, could enable the detection and diagnosis of cancer in the early stages from a few drops of a patient's blood (Zheng *et al*., 2005). A schematic illustration showing how nanoparticles or other cancer drugs might be used to treat cancer.

Researchers at Rice University under Prof. Jennifer West have demonstrated the use of 120 nm diameter nanoshells coated with gold to kill cancer tumors in mice. The nanoshells can be targeted to bond to cancerous cells by conjugating antibodies or peptides to the nanoshell surface. By irradiating the area of the tumor with an infrared laser, which passes through flesh without heating it, the gold is heated sufficiently to cause death to the cancer cells (Loo *et al*., 2004).

Scientists, University of Michigan, discovered a highly efficient and successful way of delivering cancer-treatment drugs that is less harmful to the surrounding body. They developed a dendrimer that can be located and then eliminate cancerous cells. The dendrimers has over a hundred hooks on it that allow it to attach to cells in the body for a variety of purposes. Folic-acid is then attached to few of the hooks (folic-acid, being a vitamin, is received by cells in the body). Cancer cells have more vitamin receptors than normal cells. So, vitamin-laden dendrimer get absorbed by the cancer cell. To the rest of the hooks on the dendrimer, anti-cancer drugs are placed that is also absorbed with the dendrimer into the cancer cell, thereby delivering the cancer drug to the cancer cell and nowhere else (Shi *et al*., 2007).

Industrial Advantages

Even a primitive diamond-building nanofactory can create products vastly more powerful than today's versions. Assembler-based manufacturing will enable the construction of extremely small computers. The equivalent of a modern mainframe computer could fit into a cubic micron. Such nanocomputers will be inexpensive, enabling people to use many of them at once.

These new technologies can lead to more effective pollution reduction and prevention, new medical treatments and tools, more efficient energy production, electrical power can be converted to motion, and vice-versa, with one-tenth the power loss and about 108 (100,000,000) times more compactly, better access to clean water, and stronger, lighter materials for virtually any application. Nanotechnology holds tremendous potential for pollution prevention and sustainability, especially in the areas of clean water, energy and efficient sensors. Nanotechnology can be of benefit to environmental protection and sustainability by the development and use of many applications like; by treating waste streams effluents, minimizing or eliminating the generation of wastes, by remediation existing polluted sites, and by reducing the use of raw and manufactured materials (dematerialization).

The Environmental Protection Agency (EPA) is involved in research that is investigating different ways nanotechnology help make the environment cleaner. The focus of the research deals primarily with sensors, pollution prevention, and green technologies. Nanotechnology is not only getting attention by the EPA, but the Department of Defence (DoD) and other Federal agencies as well. A great deal of the DoD research involves increasing the protection and survivability of U.S. military personnel and enhancing battle system capabilities. Some of this research involves the development of nanotechnology-based protective lightweight uniforms and "smart" gear that, for example, can change colour on command for camouflage in changing environments, provide impact protection materials for bullets and shrapnel, provide chemical and biological protection materials and systems, or contain radio communications materials that have been woven directly into the fabric of the uniform.

Other DoD research involves nanotech applications in electronics, power, surfaces, coatings, and filters. Some of this research involves the development of systems that greatly improve the performance of military equipment that, in turn, reduce the costs. Nanotech materials and devices are very small and lightweight, offer high performance and functionality, and are resistant to the environment. All of these factors result in reduced material failure, longer life of materials, reduced maintenance, less downtime, and the use of less fuel. Other DoD environmental applications for nanotechnology include the development of nano-catalysts, scavengers, taggants, filters, and sensors. Energy-related applications include the development of high performance thermoelectric, thermionic, and photovoltaic nanoscale devices and systems, such as nanofuel cells and nanotube transmission lines for advanced solid state power generation, cooling, and thermal management.

Another highly desirable application for nanotechnology involves the development of "green" or environmentally benign technologies that eliminate or minimize harmful emissions and material waste from industrial processes. In the future, nanotechnology may be able to greatly enhance environmental protection by providing cost-effective ways to reduce toxic chemicals, such as Hazardous Air Pollutants (HAPs), Volatile Organic Compounds (VOCs), and Persistent Bioaccumulative Toxics (PBTs). The use of nanotechnology green chemistry may involve synthesizing new and improved catalysts at the atomic level for many industrial processes.

Revolutionizing the Future

The broader perspective of the qualitative changes nanotechnology will bring to society cannot be underestimated; some changes are unpredictable. There has been an explosion of discoveries in the last few years, and development is expected to accelerate in the next decade. Much scientific advancement exceeds the projections made just one year ago, in areas such as molecular electronics, guided self-assembly, medicine, and DNA processing. Nanoscale science and engineering promise to restructure almost all industries toward the next industrial revolution, and to assure the quality of life in an increasingly crowded planet with shrinking energy and materials resources and less environmental endurance. The blossom of two flag technologies, information and bio, would be severely hampered without the concepts, tools, materials, systems, and synergism provided by future nanotechnology growth. In the last several years, multibillion-dollar markets based on nanotechnology have been developed.

As nanotechnology has various potential to benefit environmental quality and sustainability through pollution prevention, treatment, and remediation but nanotechnology can also be disadvantageous as all things are. Researchers have demonstrated that small systems behave dramatically, differently from large systems, breaking the second law of thermodynamics and posing a major challenge for the developing nanotechnology. Advances in nanotechnology research, which involves investigating and manipulating matter at the atomic and molecular levels, may result in drastic changes in society. While nanotechnology has great potential to advance progress, it also has this mortal danger to life on earth. A commercial or academic laboratory accident, or even a bioweapon accident, could spread and wipe out the human race, and potentially a lot more life in our biosphere.

Disadvantages of Nanotechnology

Health and Pollution

Results of existing studies in animals or humans on exposure and response to ultrafine or other respirable particles provide a basis for preliminary estimates of the possible adverse health effects from exposures to similar engineered materials on a nano- scale. Experimental studies in rodents and cell cultures have shown that the toxicity of ultrafine or nanoparticles is greater than that of the same mass of larger particles of similar chemical composition (Oberdörster *et al*., 1992, 1994a,b; Lison *et al*., 1997; Tran *et al*., 1999, 2000; Brown *et al*., 2001; Duffin *et al*., 2002; Barlow *et al*., 2005). In addition to particle surface area, other particle characteristics may influence the toxicity, including solubility, shape, and surface chemistry (Duffin *et al*., 2002; Oberdörster *et al*., 2005; Maynard and Kuempel, 2005; Donaldson *et al*., 2006).

The smaller a particle, the greater its surface area to volume ratio and the higher its chemical reactivity and biological activity. The greater chemical reactivity of nanomaterials results in increased production of reactive oxygen species (ROS), including free radicals (Andre, 2006). **ROS production** has been found in a diverse range of nanomaterials including **carbon fullerenes, carbon nanotubes and nanoparticle metal oxides**. ROS and free radical production is one of the primary mechanisms of nanoparticle toxicity; it may result in oxidative stress, inflammation, and consequent damage to proteins, membranes and DNA (Andre, 2006). Nanomaterials are able to cross biological membranes and access cells, tissues and organs that larger-sized particles normally cannot (Holsapple *et al*., 2005). Nanomaterials can gain access to the blood stream following inhalation (Oberdörster *et al*., 2005) or ingestion (Hoet *et al*, 2004). At least some nanomaterials can penetrate the skin (Ryman-Rasmussen *et al*, 2006) even larger microparticles may penetrate skin when it is flexed (Tinkle *et al*., 2003). Broken skin is an ineffective particle barrier, suggesting that acne, eczema, shaving wounds or severe sunburn may enable skin uptake of nanomaterials more readily. Once in the blood stream, nanomaterials can be transported around the body and are taken up by organs and tissues including the brain, heart, liver, kidneys, spleen, bone marrow and nervous system. Nanomaterials have proved toxic to human tissue and cell cultures, resulting in increased oxidative stress, inflammatory cytokine production and cell death (Oberdörster *et al*., 2005). Unlike larger particles, nanomaterials may be taken up by cell mitochondria (Li *et al*., 2003) and the cell nucleus (Porter *et al*., 2007). Size is therefore a key factor in determining the potential toxicity of a particle. However, it is not the only important factor.

Some of the other possible adverse effects include the development of fibrosis and other pulmonary effects after short term exposure to carbon nanotubes (Lam *et al*., 2006; Oberdorster *et al*., 2005: Shvedova *et al*., 2005). Exposure to SiO2 nanoparticles results in a dose-dependent cytotoxicity in cultural human bronchoalveolar carcinoma-derived cells that is closely correlated to increased oxidative stress (Weisheng *et al*., 2006). Research is still ongoing to determine the physical factors that contribute to the agglomeration and de-agglomeration of nanoparticles, and the role of agglomerates in the toxicity of inhaled nanoparticles. Discrete nanoparticles are deposited in the lungs to a greater extent than larger respirable particles (ICRP, 1994). Based on animal studies, discrete nanoparticles may enter the bloodstream from the lungs and translocate to other organs (Takenaka *et al*., 2001; Nemmar *et al*., 2002; Oberdörster *et al*., 2002]. In an experimental study of healthy and asthmatic subjects inhaling ultrafine carbon particles, changes were observed in the expression of adhesion molecules by blood leukocyte, which may relate to possible cardiovascular effects of ultrafine particle exposure (Frampton *et al*., 2006).

Small receptor-enhancers designed to increase alertness and reduce the reaction times of humans could cause addiction and/ or subsequent Chronic Fatigue Syndrome, leading to weakness, neural damage and death.

Nano litterbugs as Potential Pollution Problems

Nanotechnology has the power to make the environment cleaner, but the manufacture and use of nanomaterials also offers up plenty of environmental unknowns as nanoparticles are not degradable. We are creating nanoplastic bags and nanoplastic chips that are littering the nanoenvironment and how these nanomatterials interact with environment has not been understood yet. For example, nanotubes and fullerenes are entirely new types of matter that are now being produced, yet little are known about their interaction with the environment.

Atmospheric aerosols in heavily polluted areas have the potential to accelerate ozone formation reactions. Furthermore, because they are respirable, they could represent a health hazard. Atmospheric aerosols generally contain two major components: one is composed of amorphous carbon that has fullerene-like particles dispersed in it; the second is inorganic and consists of oxides and sulfides supported on clay minerals. Iron oxide, manganese oxide, and iron sulfide nanoparticles have band-gaps that could enhance the photocatalytic adsorption of solar radiation. In addition, these materials are acidic and may be coated with water, which would enhance their catalytic ability to crack hydrocarbons and create free radicals (Chianelli, 1998). Epidemiological studies in workers exposed to aerosols including fine and ultrafine particles have reported lung function decrements, adverse respiratory symptoms, chronic obstructive pulmonary disease, and fibrosis (Kreiss *et al*., 1997; Gardiner *et al*., 2001; Antonini, 2003). In addition, some studies have found elevated lung cancer among workers exposed to certain ultrafine particles, e.g., diesel exhaust particulate (Steenland *et al*., 1998; Garshick *et al*., 2004) or welding fumes (Antonini, 2003).

A number of toxicological studies of CNT (Carbon Nano Tube) have been performed in recent years. These studies have shown that the toxicity of CNT may differ from that of other nanoparticles of similar chemical composition. The nanotubes and fullerenes are not inert. It is not yet known that what will they do when they get into the environment and what will they do when they get into people? One thing they're definitely going to do is absorb material.

If nanomaterials are thrown in a stream, they will be transported in some fashion. In addition, nanomaterials can insinuate themselves into cells, which is unusual for most inorganic materials. It is unknown what will they do at the cellular level. Although it's certain that nanomaterials will interact with biology in ways that larger materials cannot. In environmental science, the way contaminants concentrate in parts of the food chain is called **bioaccumulation**. For bioaccumulation to occur, substances must be long-lived, mobile, soluble in fats and biologically active. Many nanomaterials have the first three properties. The degree to which they affect the biological process is unknown, but being researched.

Societal Implications

Beyond the toxicity risks to human health and the environment which are associated with first-generation nanomaterials, nanotechnology has broader societal implications and poses broader social challenges. Social scientists have suggested that nanotechnology's social issues should be understood and assessed not simply as "downstream" risks or impacts. Rather, the challenges should be factored into "upstream" research and decision making in order to ensure technology development that meets social objectives (Kearnes *et al*., 2006).

Some observers suggest that nanotechnology will build incrementally, as did the 18-19th century industrial revolution, until it gathers pace to drive a nanotechnological revolution that will radically reshape the economies, labor markets, international trade, international relations, social structures, civil liberties, the relationship with the natural world and even what is understand to be human. Others suggest that it may be more accurate to describe change driven by nanotechnology as a "technological tsunami". Just like a tsunami, analysts warn that rapid nanotechnology-driven change will necessarily have profound disruptive impacts. If nanotechnology is going to revolutionize manufacturing, health care, energy supply, communications and probably defense, then it will transform labor and the workplace, the medical system, the transportation and power infrastructures and the military. None of these latter will be changed without significant social disruption.

Nano skeptics suggest that nanotechnology will simply exacerbate problems stemming from existing socio-economic inequity and unequal distributions of power, creating greater inequities between rich and poor through an inevitable nano-divide (the gap between those who control the new nanotechnologies and those whose products, services or labor are displaced by them). Skeptics suggest the possibility that nanotechnology has the potential to destabilize international relations through a nano arms race and the increased potential for bioweaponry; thus, providing the tools for ubiquitous surveillance with significant implications for civil liberties.

Nanoethicists posit that such a transformative technology could exacerbate the divisions of rich and poor - the so-called "nano divide." However nanotechnology makes the production of technology, e.g. computers, celular phones, health technology etcetera, cheaper and therefore accessible to the poor.

Possible military applications and Nanoweaponary

Societal risks from the use of nanotechnology have also been raised. On the instrumental level, these include the possibility of military applications of nanotechnology as well as enhanced surveillance capabilities through nano-sensors

(Torin and Wall, 2007). There is also the possibility of nanotechnology being used to develop chemical weapons and because they will be able to develop the chemicals from the atom scale up, critics fear that chemical weapons developed from nano particles will be more dangerous than present chemical weapons.

Nanoweaponary is the greatest threat to the envioronment economy and world peace. Criminals, terrorists and disturbed individuals, antisocial groups would be incredibly empowered by such technology. Nanoweapons could be made with incredibly accurate computerized system. Poison carrying nanorobots could be made. Such nanorobots, once inhaled might kill people with specific genetic signature. Large quantities of smart weapons, especially miniaturized, robotic weapons and intelligent, target-seeking ammunition without reliable remote off-switches could lead to unexpected injury to combatants and civilians, destruction to infrastructure, and environmental pollution.

Nanomaterials (e.g., nanotubes) in uniforms and equipment to make them stronger and lighter could lead to nanofiber-like materials that break off from uniforms and equipment and enter the body and environment. Nanoparticles as surface coverings to make it harder, smoother, and/or stealthier could erode and are inhaled by military staff and the general population.

No Nanomeasure

One "huge issue" is that what can be done to remove or sense nanomaterial as it is harmful to the environment? It is very difficult to find nanomaterials for regulating them. The problem is that there is **no nanomeasure**. In this new area, we're at a powerful point in the evolution of this technology, but this fact can not be denied that nanotechnique will also contribute in creating **environmental pollution**. Tests revealing accumulations of materials in the livers of laboratory animals demonstrate that nanoparticles will accumulate within organisms. Nanomaterials can be taken up by cells. If bacteria take them up, than there is an entry point for nanomaterial into the food chain. If we are making this material, there are bad reagents that if not handled properly are going to pose environmental problems.

It is important that scientists explore and investigate the possible negative aspects of nanotechnology because "**prevention is a lot better than cleanup**, for good environmental stewardship, the potentially harmful effects of nanotechnology applications need to be anticipated and then prevented or minimized. These effects may relate to the nature of nanoparticles themselves, the characteristics of the products made from them, or the aspects of the manufacturing process involved. Many scientist and environmentalists believe it is time to develop a regulatory framework for nanotechnology - a framework that encourages initiative and innovation, but also protects the public and the environment. Nanotechnology can only flourish if industry and government are committed environmental stewardship and sustainability and are willing to working together to identify and manage possible risks to workers, consumers, and the environment.

Green Nanotechnology

"Green nanotechnology is the small science which will develop products in environmentally safe way". U.S. regulators and experts who specialize in nanotechnology (science on the scale of single atoms and molecules) have launched an effort they say will help minimize environmental and health risks that could be associated with such processes and products. Key nanotechnology companies and researchers are taking responsibility to ensure that nanotech products are produced in environmentally safe ways.

The Green Nano series is designed to explore everything from new nanotechnology products claiming to be better for the environment - because of saved energy, reduced waste, or safer materials used - to smart engineering and business practices. The effort also will examine government policies that offer incentives for developing such low-risk practices, and highlight research in green nanotechnology applications, including an eight-session nanotechnology research and environment symposium at the American Chemical Society meeting March 26-30 in Atlanta.

Green Chemistry

Green chemistry means designing chemical products and processes in a way that reduces or eliminates hazardous substances from the beginning to end of a chemical product's life cycle. Reducing pollution at the source is fundamentally different and more desirable than managing waste and controlling pollution. Soon after the act became law, the EPA Office of Pollution Prevention and Toxics (OPPT) began to explore the idea of developing or improving chemical products and processes to make them less hazardous.

The problem is that making materials in an environmentally benign way is still an emerging science, and green chemistry is seeking to address that gap. A technology must meet **three criteria** to be considered green: it must be **environmentally benign**, and it must perform better than **conventional alternatives**, and it must be more **economical than conventional alternatives**.

Thus, nanotechnology represents not only wonderful benefits for humanity, but also grave risks. It is a revolutionary, transformative, powerful, and potentially very dangerous or beneficial technology.

References

Andre N. *et al*. (2006): "Toxic Potential of Materials at the Nanolevel". *Science*, **311 (5761)**, 622-627.

Antonini J.M. (2003): "Health effects of welding" *Crit. Rev. Toxicol*. **33**, 61-103.

Atroley A. (2001): As Small as IT Can Get, Computers Today, at http://www.india-today.com/ctoday/20010816/trends.html.

Barlow P.G., Clouter-Baker A.C., Donaldson K., MacCallum J. and Stone V. (2005): Carbon black nanoparticles induce type II epithelial cells to release chemotaxins for alveolar macrophages. *Particle and Fiber Toxicol* , **2**, 14 pp [open access].

Brown D.M., Wilson M.R., MacNee W., Stone V. and Donaldson K. (2001): "Size-dependent proinflammatory effects of ultrafine polystyrene particles: A role for surface area and oxidative stress in the enhanced activity of ultrafines". *Toxicol. Appl. Pharmacol*. **175**, 191-199.

Chianelli R.R. (1998): Synthesis, fundamental properties and applications of nanocrystals,sheets, and fullerenes based on layered transition metal chalcogenides. In R&D status and trends, ed. Siegel *et al*.

Donaldson K., Aitken R., Tran L., Stone V., Duffin R., Forrest G. and Alexander A. (2006): Carbon Nanotubes: a Review of Their Properties in Relation to Pulmonary Toxicology and Workplace Safety. **Toxicol Sci**. **92(1)**, 5-22.

Duffin R., Tran C.L., Clouter A., Brown D.M., MacNee W., Stone V. and Donaldson K.

(2002): "The importance of surface area and specific reactivity in the acute pulmonary inflammatory response to particles" Ann. Occup. Hyg., 46: 242-245.

Frampton, M.W., Stewart, J.C., Oberdorster, G., Morrow, P.E., Chalupa, D., Pietropaoli, Frasier, L.M., Speers, D.M., Cox, C., Huang, L.S., Utell, M.J. (2006): Inhalation of ultrafine particles alters blood leukocyte expression of adhesion molecules in humans. *Environ. Health Perspect*., **114(1)**, 51-8.

Gardiner K., Tongeren M. and Harrington M. (2001): "Respiratory health effects from exposure to carbon black: Results of the phase 2 and 3 cross sectional studies in the European carbon black manufacturing industry". *Occup. Environ. Med*., **58**, 496-503.

Garshick E., Laden F., Hart J.E., Rosner R., Smith T.J., Dockery D.W. and Speizer F.E. (2004): "Lung cancer in railroad workers exposed to diesel exhaust" *Environ. Health Perspect*., **112**, 1539-1543.

Ghadiri M. R. et. al. (2001): Antibacterial Agents Based on the Cyclic D, Lpeptide Architecture. *Nature*, **451**, 452-455.

Hanes J., Cleland J.L. and Langer R. (1997): New advances in microsphere-based single dose vaccines. *Advanced Drug Delivery Reviews*, **28**, 97-119.

Hoet P.H.M., Bruske-Hohlfeld I. and Salata O.V. (2004): Nanoparticles-known and unknown health risks. *J Nanobiotechnology*, **2(12)**, 1-15.

Holsapple Michael P. *et al*. (2005): "Research Strategies for Safety Evaluation of Nanomaterials, Part II: Toxicological and Safety Evaluation of Nanomaterials, Current Challenges and Data Needs". *Toxicological Sciences*, **88 (1)**, 12-17.

Hubbell J.A. and Langer R. (1995): Tissue engineering. *Chem. Eng. News*, **(March 13)**, 42-54.

ICRP (1994): International Commission on Radiological Protection Publication 66** Human Respiratory Tract Model for Radiological Protection, Elsevier Science Ltd, Oxford, Pergamon.

Karak N. and Maiti S. (1997): Dendritic polymers: A class of novel material. *J. Polym. Mater*., **14**, 105.

Kearnes Matthew, Grove-White, Robin & Macnaghten Phil *et al*. (2006) : From Bio to Nano: Learning Lessons from the UK Agricultural Biotechnology Controversy. **15**, Science as Culture, Routledge, pp. 291 - 307.

Kreiss K., Mroz M.M., Zhen B., Wiedemann H. and Barna B. (1997): Risks of beryllium disease related to work processes at a metal, alloy, and oxide production plant. *Occup. Environ. Medicine*, **54(8)**, 605-612.

Lam C.W., James J.T., McCluskey R., Arepalli S. and Hunter R.L. (2006): A review of carbon nanotube toxicity and assessment of potential occupational and environmental health risks. *Crit. Rev. Toxicol*. **36**, 189-217.

Levi N., Roy R., Hantgan, Lively M. O., Carroll D. L. and Prasad G.L. (2006): C60-Fullerenes: detection of intracellular photoluminescence and lack of cytotoxic effects. *J Nanobiotechnology*, **4**, 14.

Li N., Sioutas C., Cho A., Schmitz D., Misra C., Sempf J., Wang M.Y., Oberley T., Froines J. and Nel A. (2003) : "Ultrafine particulate pollutants induce oxidative stress and mitochondrial damage" *Environ. Health Perspect*., **111**, 455-460.

Lison D., Lardot C., Huaux F., Zanetti G. and Fubini B. (1997): "Influence of particle surface area on the toxicity of insoluble manganese dioxide dusts". *Arch. Toxicol*. **71**, 725-729.

Loo C., Lin A., Hirsch L., Lee M.H., Barton J., Halas N., West J. and Drezek R. (2004): "Nanoshell-enabled photonics-based imaging and therapy of cancer". *Technol Cancer Res Treat*. **3 (1)**, 33-40.

Maynard A.M. and Kuempel E.D. (2005): Airborne nanostructured particles and occupational health. *J. Nanoparticle Research*, **7(6)**, 587-614.

Nemmar A., Hoet P.H.M., Vanquickenborne B., Dinsdale D., Thomeer M., Hoylaerts M.F., Vanbilloen H., Mortelmans L. and Nemery B. (2002): "Passage of inhaled particles into the blood circulation in humans." *Circulation*, **105**, 411-414.

Oberdörster G., Oberdörster E. and Oberdörster J. (2005): Nanotoxicology: an emerging discipline evolving from studies of ultrafine particles. *Environ. Health Perspect*. **113(7)**, 823-839.

Oberdörster G., Ferin J. and Lehnert B.E. (1994a): "Correlation between particle-size, in-vivo particle persistence, and lung injury." *Environ. Health Perspect*., **102**, 173-179.

Oberdörster G., Ferin J., Soderholm S., Gelein R., Cox C., Baggs R. and Morrow P.E. (1994b): "Increased pulmonary toxicity of inhaled ultrafine particles: Due to lung overload alone?" *Ann. Occup. Hyg*., **38**, 295-302.

Oberdörster G., Ferin R., Gelein J., Soderholm S.C. and Finkelstein J. (1992): "Role of the alveolar macrophage in lung injury - studies with ultrafine particles." *Environ. Health Perspect*., **97**, 193-199.

Oberdörster G., Sharp Z., Atudorei V., Elder A., Gelein R., Lunts A., Kreyling W. and Cox C. (2002): "Extrapulmonary translocation of ultrafine carbon particles following whole-body inhalation exposure of rats." *J. Toxicol. Environ. Health Pt A*, **65**, 1531-1543.

Porter A. E. *et al*. (2007): "Visualizing the Uptake of C60 to the Cytoplasm and Nucleus of Human Monocyte-Derived Macrophage Cells Using Energy-Filtered Transmission Electron Microscopy and Electron Tomography". *Environmental Science and Technology*, **41 (8)**, 3012-3017.

Roco M. (2001): A Frontier For Engineering: The Aim of Nanotechnology is To Build the Future, Molecule By Molecule, *Mechanical Engineering*, **52**, 54.

Roco M.C., Bainbridge W. *et al*., (2001): Societal implications of nanoscience and nanotechnology. Arlington, VA: National Science Foundation.

Ryman-Rasmussen, Jessica P. *et al*. (2006): "Penetration of Intact Skin by Quantum Dots with Diverse Physicochemical Properties". *Toxicological Sciences*, **91 (1)**, 159-165.

Scheinberg D. A. et. al. (2001): Tumor Therapy With Targeted Atomic Nanogenerators, *Sci*., **294**, 1537.

Schnur J.M., Price R. and Rudolph A.S. (1994): Biologically engineered microstructures-Controlled release applications. *J. Controlled Release*, **28**, 3-13.

Shi X., Wang S., Meshinchi S., Van Antwerp M.E., Bi X., Lee I. and Baker J.R. Jr. (2007): "Dendrimer-entrapped gold nanoparticles as a platform for cancer-cell targeting and imaging". *Small*, **3 (7)**, 1245-1252.

Shosaku K. (2006): "Distribution of Nanoparticles in the See-through Medaka (Oryzias latipes)." *Environmental Health Perspectives*. **114** , 1697-1702.

Shvedova A.A., Kisin E.R., Mercer R., Murray A.R., Johnson V.J., Potapovich A.I., Tyurina Y.Y., Gorelik O., Arepalli S. and Schwegler-Berry D. (2005): Unusual inflammatory and fibrogenic pulmonary responses to single walled carbon nanotubes in mice. *Am. J. Physiol. Lung Cell. Mol. Physiol*., **289**, L698-L708.

Spanggaard H. and Krebs F.C.(2004): A brief history of the development of organic and polymeric photovoltaics. *Solar Energy Materials and Solar Cells*, **83**, 125-146.

Steenland K., Deddens J. and Stayner L. (1998): Diesel exhaust and lung cancer in the trucking industry: exposure-response analyses and risk assessment. *Am. J. Ind. Med*. **34(3)**, 220-228.

Takenaka S., Karg D., Roth C., Schulz H., Ziesenis A., Heinzmann U., Chramel P.and Heyder J. (2001): Pulmonary and systemic distribution of inhaled ultrafine silver particles in rats. *Environ. Health Perspect*. **109(4)**, 547-551.

Tinkle S.S., Antonini J.M., Rich B.A., Robert J.R., Salmen R., DePree K. and Adkins E. J. (2003) "Skin as a route of exposure and sensitization in chronic beryllium disease." *Environ. Health Perspect*., **111**, 1202-1208.

Torin M. and Wall T. (2007): Somatic Surveillance: Corporeal Control through Information Networks. *Surveillance & Society*, **4 (3)**, 154-173.

Toth E., Pubanz D., Vauthey S., Helm L. and Merbach A.E. (1996): The role of water exchange in attaining maximum relaxivities for dendrimeric mri contrast agents. *Chemistry-A European Journal*, **2**, 1607-1615.

Tran C.L., Cullen R.T., Buchanan D., Jones A.D., Miller B.G., Searl A., Davis J.M.G. and Donaldson K. (1999): Investigation and prediction of pulmonary responses to dust. Part II. In: Investigations into the Pulmonary Effects of Low Toxicity Dusts. Parts I and II. Contract Research Report 216/1999. Suffolk, UK, Health and Safety Executive, UK.

Tran C.L., Buchanan D., Cullen R.T., Searl A., Jones A.D. and Donaldson K. (2000) "Inhalation of poorly soluble particles. II. Influence of particle surface area on inflammation and clearance." *Inhal. Toxicol*., **12**, 1113-1126.

Wang S., Yang J.L., Li Y.L., Lin H.Z., Guo Z.X., Xiao S.X., Shi Z.Q., Zhu D.B., Woo H.S., Carroll D.L., Kee I.S. and Lee J.H.(2002): Composites of C-60 based poly(phenylene vinylene) dyad and conjugated polymer for polymer light-emitting devices. *Applied Physics Letters*. **80**, 3847-3849.

Weisheng L., Huang Y., Zhou X. and Ma Y. (2006): In Vitro toxicity of silica nanoparticles in human lung cancer cells. *Toxicology and Applied Pharmacology*, **217**, 252-259.

Zheng G., Patolsky F., Cui Y., Wang W.U. and Lieber C.M. (2005): "Multiplexed electrical detection of cancer markers with nanowire sensor arrays". *Nat Biotechnol*., **23 (10)**, 1294-1301.