UNIT 44 – UPSC - Awareness in the fields of nano-technology

Nanotechnology is a technical notion. It is the study of manipulating matter on an atomic scale. The main uniting subject in nanotechnology is the control of matter on a scale below 100 nano meters, as well as the fabrication of devices on this same length scale. The word 'nano' is derived from the Greek word nannos which means very short man. Nanotechnology is a type of technology that consists of components smaller than 100 nanometers. Nanotechnology is described as the constructing and engineering of the functional systems at very micro level or we can say at atomic level. It is the art and science of manipulating matter at the nanoscale (down to 1/100,000 the width of a human hair) to create new and unique materials and products with enormous potential to change society. According to technical experts, Nanotechnology research and development includes management under control of the nanoscale structures and their integration into larger material components, systems and architectures. Within these larger scale assemblies, the control and construction of their structures and components remains at the nanometer scale. Group of researchers stated that Nanotechnology is the engineering of functional systems at the molecular scale. This includes both current work and concepts that are more advanced. Originally, nanotechnology denotes to the projected ability to construct items from the bottom up, using techniques and tools being developed today to make complete, high performance products. Nanotechnology is closely associated with Nanoscience,

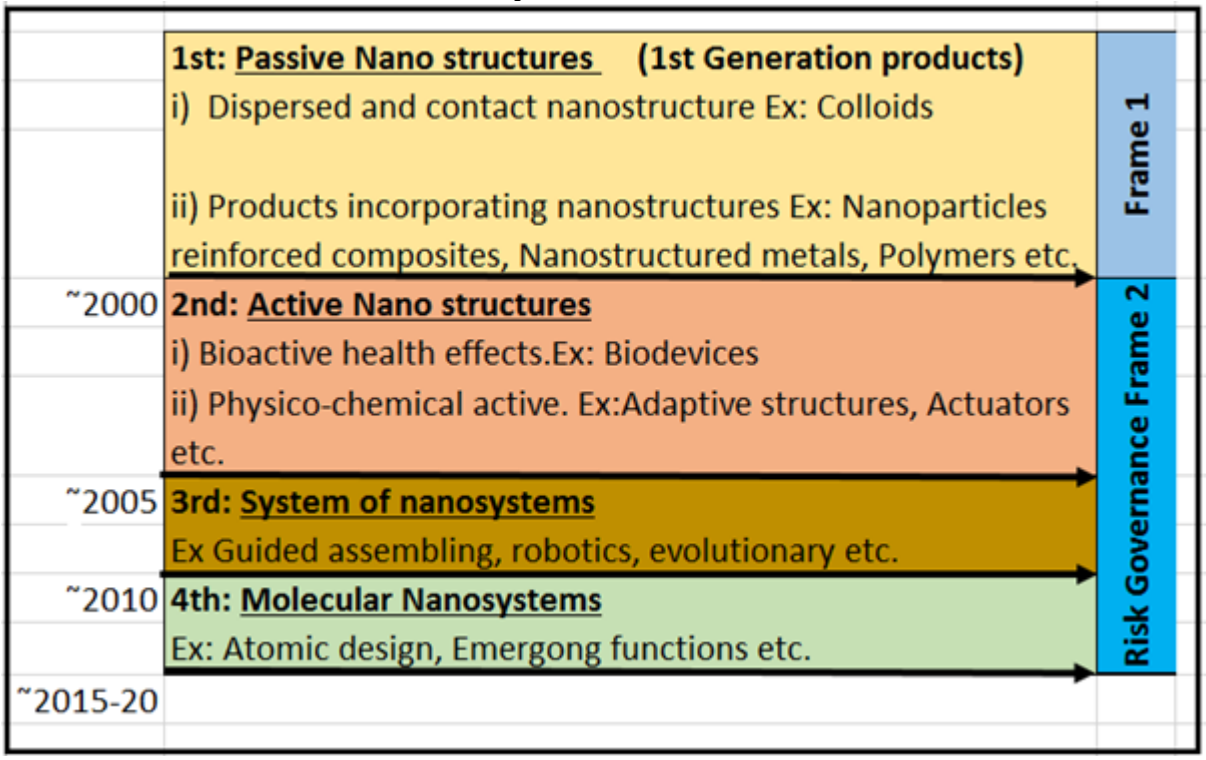
Origin of nanotechnology:

Nanotechnology was studied by many scientists. P.Feynman in 1959. Feynman talked about the principles of miniaturization and atomic-level precision and how these concepts do not violate any known law of physics. He proposed that it was possible to build a surgical nanoscale robot by developing quarter-scale manipulator hands that would build quarter-scale machine tools analogous to those found in machine shops, continuing until the nanoscale is reached, eight iterations later. The term 'nanotechnology' can be traced back to 1974. It was first used by Norio Taniguchi in a paper entitled "On the Basic Concept of Nano-Technology". Many invention like the scanning tunnelling microscope in 1981 and the discovery of fullerene (C60) in 1985 lead to

the development of nanotechnology. The phrase "Nano-technology" had been devised by Norio Taniguchi in 1974. Taniguchi labelled nanotechnology as the technology that engineers materials at the nanometre level. Taniguchi developed the concepts of Feynman in detail. Taniguchi specified, "Nano-technology is the production technology to get the extra high accuracy and ultrafine dimensions, i.e., the preciseness and fineness of the order of 1 nm (nanometre), 10−9 m in length. Taniguchi deliberated his concept of 'nanotechnology' in materials processing, basing this on the microscopic behaviour of materials. Taniguchi imagined that ion sputtering would be the most promising process for the technology. In 1987, K. Eric Drexler presented original work describing a novel type of technology based on molecular "assemblers," which would be able to "place atoms in almost any reasonable arrangement" and thereby allow the formation of "almost anything the laws of nature allow." In the beginning of 2000s there was commercial applications of nanotechnology, although these were limited to bulk application of nanomaterials such as Silver nano platform for using silver- nanoparticles as an antibacterial agent, nanoparticle-based transparent sunscreens, and carbon nanotubes for stain-resistant textiles.

The laws of physics that function on objects at the nanoscale combine classical (or Newtonian) mechanics, which governs operations of everyday objects, and quantum mechanics, which governs the interactions of very small things. Another feature of nanoscience is understanding the formation of nanoscale materials and devices. In looking at the nanoscale, traditional (non-nano) materials, structures, and devices are often denoted as "bulk technology." Using bulk technology, researchers can create exquisitely small devices and materials. However, this conception is still done by cutting, chipping, pounding, extruding, melting, and performing other such bulk procedures to materials to create the new device, structure, or material. Presently, Nanotechnology focuses on the development, understanding, and use of materials at the nanoscale, or nanomaterials. Materials are made up by an arrangement of particular atoms in a specific way which helps define the property of the material.

Timeline history of nanotechnology:



The field of nanotechnology concentrates on three main areas.

1. Identifying the chemical and physical changes that occurs at the nanoscale
2. Developing new tools to measure, and new chemistry to make, highly miniaturized structure.
3. Using the chemical and physical changes that occur at the nanoscale to develop new technologies.

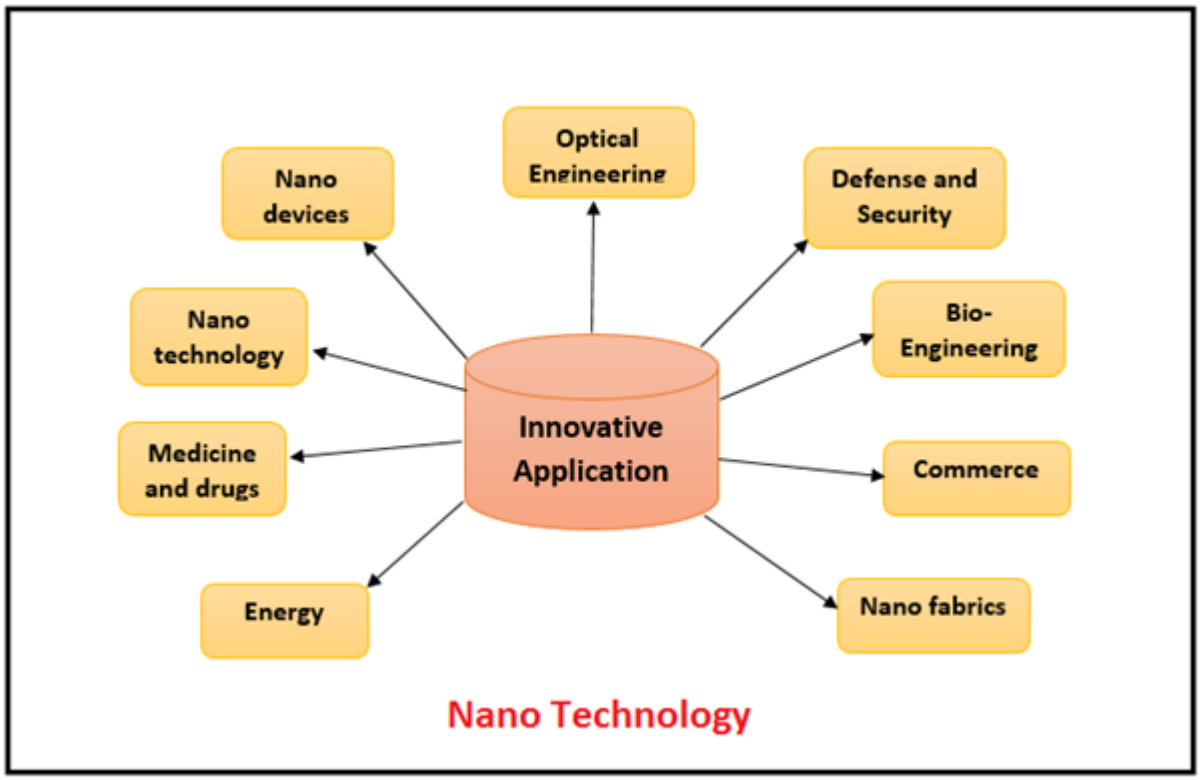
Nanoparticles are part of nature and numerous particles can be found in the air we take in at different times. Some people curious to know whether these nano particles are harmful for humans. According to the Northwe stern University (2005), "it depends upon the chemical composition, just like with all other chemicals, some will have its healthy side and some will have toxic properties".

Approaches of nanotechnology: Nanotechnology embrace number of technology fields especially in electronics.

1. Bottom up: In the bottom up approach, different materials and devices are built from molecular components of their own. They chemically assemble themselves by recognizing the molecules of their own breed. For examples molecular self-assembly are Watson crick base pairing, nanolithography.
2. Top down: In top down approach, nano objects and materials are formed by larger entities without bouncing its atomic reactions. Usually top down approach is practiced less as compared to the bottom up approach. Solid-state techniques can also be used to create devices known as nano electromechanical systems or NEMS, which are related to micro elctromechanical systems or MEMS. MEMS became practical once they could be fabricated using modified semiconductor device fabrication technologies, normally used to make electronics.

Application of Nanotechnology:

Nanotechnology has numerous applications:



1. Nanotechnology in medications: Nanotechnology provide new options for drug delivery and drug therapies such as in cancer. It enables drugs to be delivered to precisely the right location in the body and release drug doses on a predetermined schedule for optimal treatment and attach the drug to a nanosized carrier. They become localized at the disease site. Currently the treatment life threatening disease like cancer is done through radiotherapy or chemotherapy. Nano dentistry will assist in the maintenance of complete oral health by employing nanomaterials, biotechnology, including tissue engineering, and ultimately, dental nanorobotics. New probable treatment opportunities in dentistry may include, local anesthesia, dentition renaturalization, permanent hypersensitivity cure, complete orthodontic realignments during a single office visit, covalently bonded diamondised enamel, and continuous oral health maintenance using mechanical dentifrobots. In medical filed, scientists have developed a surgical nanorobot, programmed or guided by a human surgeon that can act as a semiautonomous on site surgeon inside the human body, when introduced into the body through vascular system or cavities. Such a device could perform numerous functions such as searching for pathology and then diagnosing and correcting lesions by nanomanipulation, coordinated by an on-board computer while maintaining contact with the supervising surgeon via coded ultrasound signals (Freitas. 2005).
2. Nanotechnology in Fabrics: Nanotechnology is also applicable in clothing. The properties of familiar materials are being changed by manufacturers who are adding nano-sized components to conventional materials to increase performance.
3. Nanotechnology in Mobile technology: Nanotechnology is beneficial in mobile communication process. Morph, a nanotechnology notion device developed by Nokia Research Center (NRC) which is super hydrophobic making it extremely dirt repellent. It is able to charge itself from available light sources using photovoltaic nanowire grass covering its surface. Nanoscale electronics also permit stretching. Nokia predict that a nanoscale mesh of fibres will allow mobile devices to be bent, stretched and folded into any number of plausible shapes.

4. Nanotechnology in Electronics field: Nanotechnology has modernized the electronics industry and allowed transistors to be scaled down to quantum dimensions. It enabled the further miniaturization of logic and memory devices (Tour,2003). Quantum mechanical confinement has been used to devise a high electron mobility transistor and a quantum well laser (Henry, 1993). Such a semiconductor device greatly improves reliability, efficiency, noise reduction and processing speed (Wilson, 2002). Organic molecules have been used to fabricate molecular wires and switches, and unimolecular rectifiers and molecular field effect transistors, which will hasten the development of quantum computers and nanodevices that have extraordinary computational speed (Takeuchi S, 2003). Other applications of nanoelectronics are spintronics, memory and storage devices, hard drives and tapes, optical switching and display technologies. Electrodes made from nanowires allow flat panel displays to be flexible as well as thinner than current flat panel displays. Nanolithography is used for fabrication of chips. The transistors are made of nanowires that are assembled on glass or thin films of flexible plastic.

5. Nanotechnology in computers: Nanotechnology has several applications in computers. The silicon transistors in computer may be replaced by transistors based on carbon nanotubes. A carbon nanotube is a molecule in form of a hollow cylinder with a diameter of around a nanometer which consists of pure carbon. Nanorods is a forthcoming technology in the displays techniques due to less consumption of electricity and less heat emission. Nano-computers would undertake the important task of activating, controlling, and deactivating such nano mechanical devices. Nano-computers would store and execute mission plans, receive and process external signals and stimuli, communicate with other nanocomputers or external control and monitoring devices, and possess contextual knowledge to ensure safe functioning of the nanomechanical devices. Such technology has massive medical and dental inferences.

6. Nanotechnology in food and agriculture safety: This technology is used to improve the quality of food. There are multiple application of nano particles in food and agriculture safety.

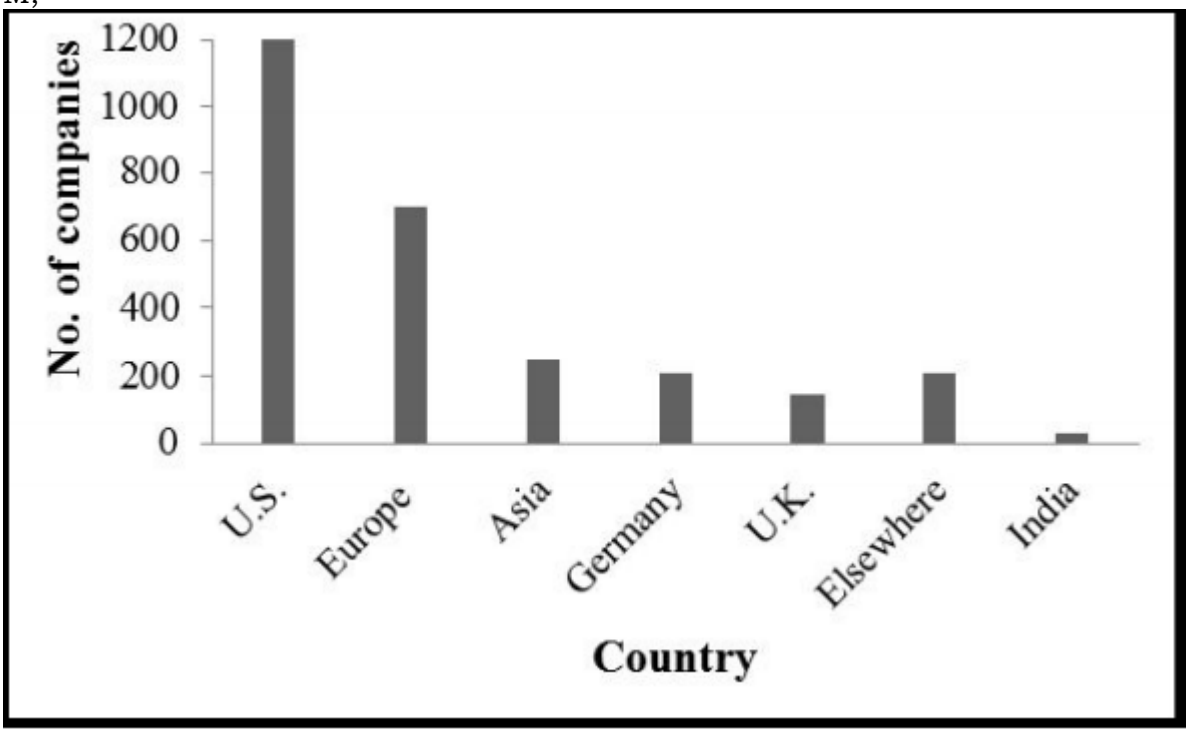
1 Nanotechnology from farm to fork (Batt, 1999)

Farm	Nanosensors for detection of pathogens in produce and meat. Nanosensors to detect level of nutrients or water in crops. Nanodispensors designed to release nutrients, fertilizers or water as needed.
Food processing and packaging	Nanosensors for detection of pathogens in produce and meat Detection of pathogens on the surface of equipment and machinery Plastic wraps coated with nanomaterials to protect food items from exposure to environmental conditions such as moisture and oxygen.
Consumers	Nanocapsules for flavour and taste enhancement Storage containers Refrigerators Cutting board, knives and counter tops Utensils.

Nanotechnology in cosmetic sector: The cosmetics industry also benefited with development of nanotechnologies. The applications of nanotechnology and nanomaterials are in numerous cosmetic products including moisturizers, hair care products, make up and sunscreen. Nanomaterials are being used in leading cosmetic products, most commonly as chemicals used to give the protection in sunscreens. In cosmetics field, there are mainly two uses for nanotechnology. The first is the use of nanoparticles as UV filters. Titanium dioxide (TiO2) and Zinc Oxide (ZnO) are the main compounds used in these applications and organic alternatives to these have also been developed. The second use is nanotechnology for delivery. Liposomes and Niosomes are used in the cosmetic industry as delivery vehicles. Newer structures such as Solid Lipid Nanoparticles (SLN) and Nanostructured Lipid Carriers (NLC) have been found to be better performers than liposomes. Nanocrystals, microemulsions, nanoemulsions and dendrimers are also being explored for cosmetic applications.

One assessment revealed that more than 2500 companies in over 48 countries that are involved in nanotechnology research, manufacturing or applications.

Figure: Number of companies involved in nanotechnology in different countries (Source: Berger M, 2010)



Nanotechnology in India:

Nanotechnology is widely used in India. IIT Mumbai is the leading organization in the field of nanotechnology. Researchers also involve in using nanotechnology in the arena of health, environment, and medicines. The Government of India launched the Nano Science and Technology Initiative (NSTI) in 2001. In 2007 the Nanoscience and Technology Mission 2007 was introduced with an allocation of Rupees 1000 crores for a period of five years. The main objectives of the Nano Mission include basic research promotion, infrastructure development to perform front-ranking research, development of nano technologies and their applications, human resource development and - international collaborations (Soni, 2014). Companies in India that are engaged in nanotechnology R&D include Cranes Software International Limited, Monad Nanotech, Velbionanotech, Innovations Unified Technologies, Qtech Nanosystems, and

Naga Nanotech India. Leading companies such as Reliance, Tata Group, and Mahindra and Mahindra have also made nanotechnology investments (The Energy and Resources Institute (TERI), (2009). There are around thirty new companies in India that are commercializing nanotechnology products.

Benefits of nanotechnology:

Nanotechnology is highly advantageous to perform activities and enhancing the living conditions of humans. Nanotechnology can actually transform a lot of electronic products, procedures, and applications. It can benefit in the sense that there is continued development of nanotechnology when it comes to electronic products such as nano transistors, nano diodes, OLED, plasma displays, quantum computers.

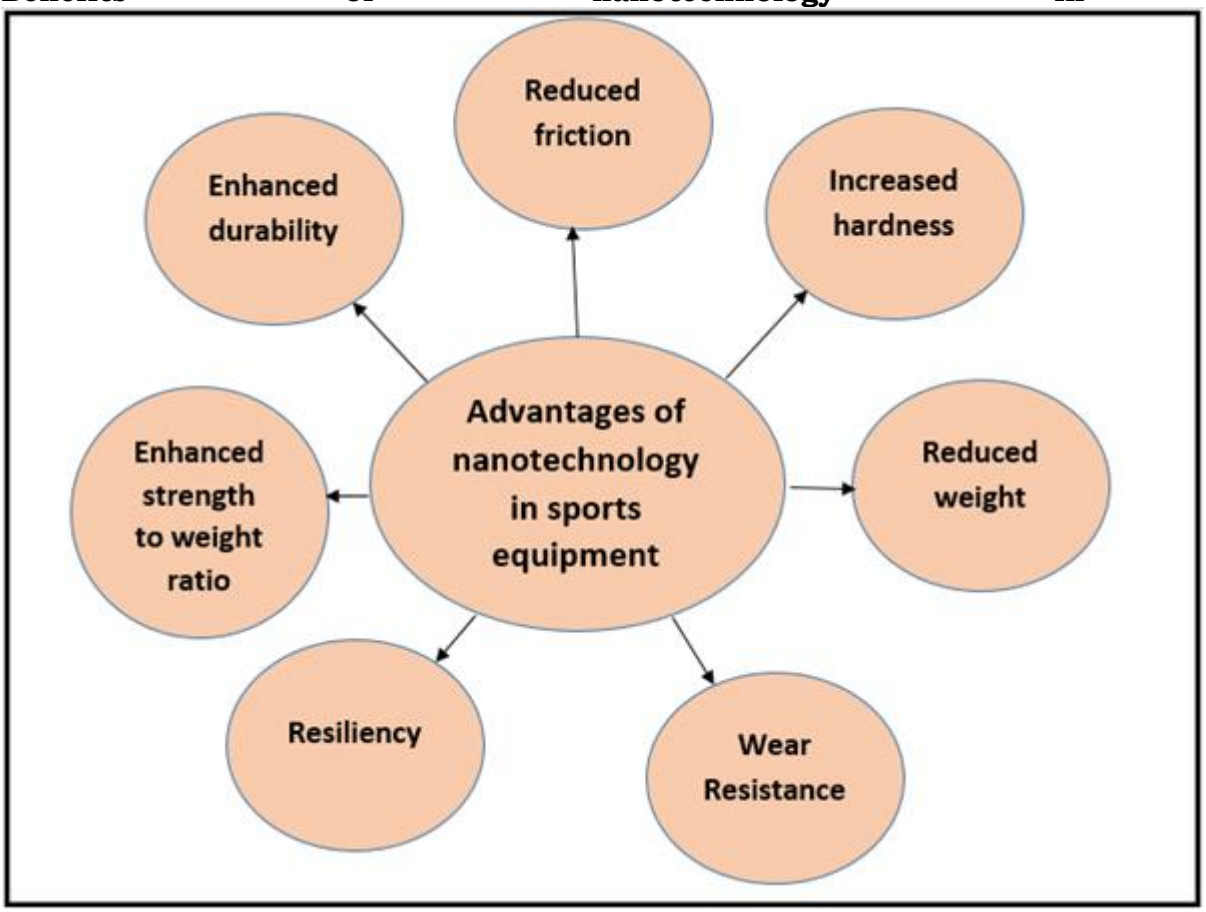
Nanotechnology can also have advantage in the field of the energy. The development of more effective energy-producing, energy-absorbing, and energy storage products in smaller and more efficient devices is possible with the development of nanotechnology. For example batteries, fuel cells, and solar cells can be built smaller but can be made to be more effective with this technology.

Nanotechnology is helpful in the manufacturing sector that will need materials like nanotubes, aerogels, nano particles, and other similar items to produce their products with. These materials are often stronger, more durable, and lighter than those that are not produced with the help of nanotechnology.

In the medical field, nanotechnology has significant role to treat many diseases. It helps cure people faster and without the side effects that other traditional drugs have. The research of nanotechnology in medicine is focusing on areas like tissue regeneration, bone repair, immunity and even cures for such ailments like cancer, diabetes, and other life threatening diseases (Soni, 2014).

In sports, nanotechnology has great contribution. This technology is used in every sports such as from bicycles to swimsuits to improve the performance of participants. Carbon nanotubes, are used to make bicycle frames and tennis rackets lighter and more durable and give golf clubs and hockey sticks a more powerful and accurate drive, while a coating of nanomaterials makes kayaks faster and more stable and keeps tennis balls bouncy for longer. Within the niche of sport equipment, nanotechnology offers a number of advantages and immense potential to improve sporting equipments making athletes safer, comfortable and more agile. Sporting equipment such as Baseball bats, tennis and badminton racquets, hockey sticks, racing bicycles, golf balls/clubs, skis, fly-fishing rods, archery arrows whose performance and durability are being improved with the help of nanotechnology. Nanomaterials such as carbon nanotubes (CNTs), silica nanoparticles (SNPs), nanoclays fullerenes, etc. are being incorporated into various sports equipment to improve the performance of athletes as well as equipment.

Benefits of nanotechnology in sports



Drawbacks of nanotechnology:

Although nanotechnology is more beneficial in diverse fields but it has some downsides. Development of Nanotechnology can increase risk to the health. Nano-particles can get into the body through the skin, lungs and digestive system, thus creating free radicals that can cause cell damage. Once nano-particles are in the bloodstream, they will be able to cross the blood-brain barrier.

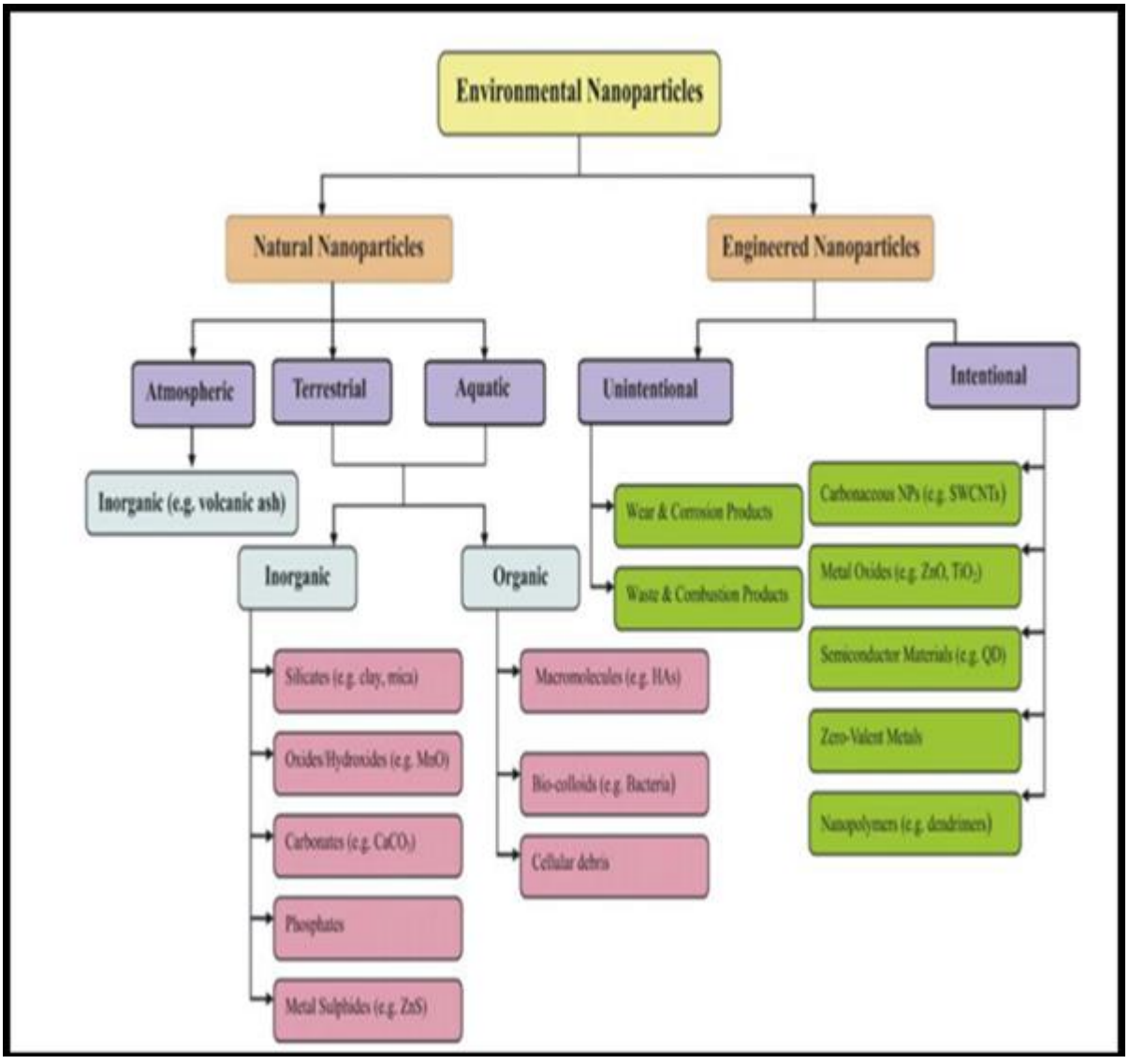
Another major drawback of nanotechnology is the lack of occupation in the fields of traditional farming and manufacturing and industrial sector because of the huge growth in the nanotechnology. Nanotechnology can cause a fierce risk in the field of terrorism. The terrorism and anti-groups exploit nanotechnology as a new form of torturing the societies as nanotechnology also has the ability to annihilate the human body at the molecular level.

With the initiation of nanotechnology, it is the easy availability of atomic weapons. Nanotechnology has made these weapons more powerful and more damaging. Unauthorized, criminal bodies can reach nuclear weapons easily, and its formulation could be stolen. The most perilous application of Nanotechnology for military purposes is the Nano-bomb that contain engineered self-multiplying lethal viruses that can continue to annihilate a community, country or even a society.

Environmental impact of nanotechnology:

It has been found in many researches that Nanotechnology increases the strengths of many materials and devices, as well as improves efficacies of monitoring devices, remediation of

environmental pollution, and renewable energy production. Though these processes have positive effect of nanotechnology, there are certain negative impacts of nanotechnology on environment in many ways, such as increased toxicological effluence on the environment due to the unclear shape, size, and chemical compositions of some of the nanotechnology products (or nanomaterials). Nanoparticles have higher surface areas than the bulk materials which can cause more destruction to the human body and environment compared to the bulk particles. Thus, scientist and researchers are more worried about these the potential risk to the society due to nanoparticles at global level. Nanoparticles are not only useful to modify the properties of polymeric composite materials and environment in air pollution monitoring, but also to support reduce material consumption and remediation.



There are few deliberations of potential risks need to be considered using nanoparticles:

1. The major problem of nanomaterials is the nanoparticle analysis method. As nanotechnology advances, new and novel nanomaterials are progressively developed. The materials vary by shape and size which are important factors in determining the toxicity. Lack of information and methods of characterizing nanomaterials make existing technology extremely problematic to identify the nanoparticles in air for environmental safeguard.

2. Information of the chemical structure is a critical factor to define how toxic a nanomaterial is, and minor changes of chemical function group could drastically change its properties.
3. Full risk assessment of the security on human health and environmental impact need to be appraised at all stages of nanotechnology. The risk assessment should include the exposure risk and its probability of exposure, toxicological analysis, transport risk, persistence risk, transformation risk and ability to recycle.
4. Life cycle risk assessment is also major factor that can be used to foresee the environmental impacts.
5. Good experimental design in advance of manufacturing a nanotechnology based product can decrease the material waste.

To summarize, nanotechnology is highly beneficial in today's technology driven society. It is the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering. Nanotechnology will continue to develop, advantageous to civilisation and improve the environment in numerous ways. Nanotechnology has provided an innovative and promising strategy to overcome the side effects of chemotherapy drugs (Soni, 2014). Nanoscale materials will make the products better in terms of functionality, weight savings, less energy consumption and a cleaner environment. Shortcomings always exist when new unproven technology is released. Nanomaterial may assist in cleaning certain environmental wastes, but also pollute environment in other ways. Experts posit that Engineering ethics must be defined before the marketable use of nanotechnology. Risk assessment on new nanomaterial based application is significant to assess possible risk to environment when the products are in use.