Nanotechnology: an overview

Abstract

Nanotechnology has been an important scientific topic for future studies since 1959. ‘ Nano’ derives from the Greek word nanos meaning a dwarf, term strickly for size and not chemical composition. According to recent toxicological studies nanoparticles are any particle less than 100 nm in at least one dimension, classified as natural, anthropogenic or engineered in origin.

Nanomaterials are a major trend in medicine. These help deliver medications in a specific target, this is known as Nanomedicine. Another study of the impact of toxic nanoparticles is Nanotoxicity. This later one depends in the future understanding of the toxicity of nanomaterials depend on technological innovations and scientific results stemming from enhanced research and discovery in nanotechnologies. The communication between different areas in science to aid in the study of nanoparticles risk assessment, and toxicology. There are international efforts to study nanotoxicology. Therefore there is a high demand for research, on the effects of nanoparticles. The Amara Law is an advice to that as time pass when humans use the nanotechnology there increase in nanowaste. The interactions between nanoparticles and harmful environmental chemicals may lead to unique exposures and health risks. The research should focus in the merge between the nanoparticles and the environment. Therefore there are developing laws to be applied for better research the better risk assessment. Regulations for efficiently develop useful and well-planned studies, and future recommendations to manage nanowaste.

Nanotechnology is an applied science, growing by the creation of nanoconstructs and the presence of nanoparticles. This derived from nanoscience that is the science of the usage of materials in the nanometer scale. Nanoscience and nanotechnology developing areas of scientific interest in the entire world and have already become key for research and development (Piotrowska G et al. 2009). Nanotechnology has been an important scientific topic for future studies since 1959. According to Richard Feynman, “ There’s Plenty of Room at t the Bottom,” a presentation that is possible to manipulate matter at the atomic and molecular scales (Hardman R. 2006). Nanoparticles are nanotechnology products, these accumulate creating waste. Nanoparticles are necessary for new medical advances. Studies are currently being done as a result of their impact to the environment. Therefore another subsection of nanotechnology emerges nanotoxicology. There is high demand for studies in risk assessment have led to cross communication among physical science and biological science scientists, and recent laws and regulations regarding these small particles.

These nanomaterials have novel properties, and a great potential in becoming biologically active, that can lead to a environmental contamination (Friedrichs S, and Schulte J. 2007). Nanotechnology the enabling technology, that involves materials at the nanoscale. ‘ Nano’ derives from the Greek word nanos meaning a dwarf (Piotrowska G et al. 2009).

The term Nano is strickly to size and not chemical composition in terms of nanoparticles (Oberdoerster G et al. 2005). According to recent toxicological studies nanoparticles are any particle less than 100 nm in at least one dimension, classified as natural, anthropogenic or engineered in origin

(Moreira S et al. 2009) , (Kanno S et al. 2007), (Piotrowska G et al. 2009), (BéruBé K et al. 2007),(Oberdoerster G et al. 2005). Because of the small size these particles are toxic, as a result of their greater surface area. Their toxicity of remains widely unknown and still poses concerns, due to the peculiar characteristics of materials in the nano-size range (Kanno S et al. 2007), (Bregoli L et al. 2009). The most common nanoparticles present in the environment are combustion derived nanoparticles, from an anthropogenic source (Oberdoerster G et al. 2005), (Bregoli L et al. 2009). Nanoparticles are incorporated in many products from pharmaceuticals to catalysts. As an example, in 2002 an indium tin oxide nanopowder manufacturing facility was launched by Samsung, used in the production of flat panel displays based on liquid crystals. Therefore the silver nanoparticles and carbon nanotubes now have the widest range of applications (Piotrowska G et al. 2009), (Balbus J et al. 2007). The expansion of the nanotechnology, resulted in further classification of nanoparticles in size, shape, charge, chemistry, coating and solubility (Elliott KC. 2007). Some examples of nanoconstructs are carbon nanotubes, fullerene, carbon derivative, quantum dots, and manufactured nanoparticles.

Fullerene NanoCarbon60: Started since 1985 these are composed of 60 carbon atoms named Buckyballs o fullerenes, this discovery from Buckminster Fuller (Piotrowska G et al. 2009). This nanoparticle induces lipid peroxidation, this according to a study in fish. The investigation included that it also induces oxidative stress, and upregulate genes related to the inflammatory response and metabolism, and that nanoC60 releases oxyradicals in in vitro systems, or act as an oxyradical scavenger (Zhu S et al. 2006). These carbon materials including nanotubes are popular in consumer products since 2006 according to the Nanotechnology Consumer Products Inventory (Friedrichs S, and Schulte J. 2007).

Carbon Nanotubes and Asbestos: Started since 1991, these were synthesized, found to be 100 times stronger than steel. The unusual heat and conductivity characteristics of the nanotubes are important to further developing of new technology (Piotrowska G et al. 2009). Both asbestos and carbon nanotubes are consider to have major carcinogenic potential, they both act as needles to the cell membranes and cell walls (Moreira S et al. 2009). The asbestos fibers split lengthwise been in a size smaller than the nanosized particles.

Quantum Dots QD: These are the semiconductor nanocrystals with special properties applied in biomedical imaging and electronics industries. Because some these have fluorescent properties for biomedical imaging, also there are targets specific biologic events and cellular structures, such as peroxisomes, DNA and cell membrane receptors (Hardman R. 2006). This aids drug delivery and the advance in nanomedicine. For example, Nano selenium is one of the major components of Quantum Dots outer covering, there is a study in Makala Fish that studies the concentrations of micro and nano selenium in the Liver and Muscle. However the compound of selenium such as Sodiumselenite, Selenomethinine, and methylselenocysteine have greater toxicity impact than elemental nanoselenium(Li H et al. 2008). Then nanoparticles had a greater coverage.

Manufactured Nanoparticles -Titanium Dioxide and Silver Nanoparticles: Silver particles are use in fridges to avoid growth of saprophytic bacteria and fungi. These particles behave as copper nanoparticles, these nano-biocides can become even cheaper in the next few years. Another nano-biocide is titanium dioxide used to protect glazing. There are studies that focus in Titanium Dioxide. These nanomaterials have greater access to the micrometer size pores in plants since nanoparticles have a greater possibility of fitting through micropores, then this allows an accumulation in the xylem structure, eventually blocking the continuity and disturbing or destroying the function of the xylem (Seeger EM 2009). The willow tree study presented that before the nanoparticles get through the xylem pores, there is some sedimentation then blocking the passage through the micropores (Seeger EM 2009). Consequently, more studies are required this TiO2 is in contact with humans through the sunscreen, according to a british study done in 1997; contribute to the formation of free radicals in skin cells and in this way damage DNA. This can result in mutations further leading to modifications of the structure and function of proteins (Piotrowska G et al. 2009).

Combustion Derived Nanoparticles CDNP: Nanoparticles area a threat when inhaled, because of the large surface area they are linked to health effects and respiratory toxicity h. These combustion-derived nanoparticles are thought to be the most potent component of the air pollution cocktail (Oberdoerster G et al. 2005), (Bregoli L et al. 2009), (Elliott KC. 2007). Their toxicology is used to predict the health outcomes in humans following exposure to manufactured nanoparticles, there is necessary to understand the toxicity to reduce occupational and environmental exposure (BéruBé K et al. 2007). These emissions are considered to be carbon based aerosols nanoparticles as a result of incomplete combustion, as well as lead compounds. Because of these cars are equipped with catalysts, a couple of years ago platinum nanoparticles, with dimensions in the range 0. 8-10 nm, are released from car catalysts during their life-time. Then newer catalysts were introduced by pioneering company Mazda. Not long ago is found that additions to fuel of Aluminium or Aluminium Trioxide nanoparticles, aids to the fuel properties (Piotrowska G et al. 2009).

The detrimental health effects of inhaling fine aerosols were recognised as early as the 4th century BC (Oberdoerster G et al. 2005), (Friedrichs S, and Schulte J. 2007). Since this being acknowledge various attempts to minimize exposure have been done. These particle size of aerosols are known to influence the deposition region in the lungs and translocation potential to the organs, e. g. the inhalable fraction (which can enter the respiratory tract), the thoracic fraction (capable of penetration to the airways below the larynx, smaller than 10 lm) and the respirable fraction (particles smaller than 4 lm) penetratingbeyond the ciliated airways to the gas exchange region of the lung (Piotrowska G et al. 2009). Regular particles affect upper respiratory tract, fine particles affect lower respiratory tract, and ultrafine particles or nanoparticles affect distal respiratory tract. The nanoparticles get stuck to the alveoli and cause problems. ” Current and historical epidemiological and toxicological investigations with airborne nanoparticles are viewed as the pioneering nanoparticle for the expansion nanotoxicology, the major portal of entry into the human body for nanoparticles is via inhalation into the respiratory system” (BéruBé K, et al 2007).

Nanoparticles come in contact with the skin, then transported to the lymph nodes, then most are excreted via feces. Other ways for these tiny particles to get in are by blood circulation then these end up in the liver, and from there are distributed throughout every organ in the living organisms (Oberdoerster G et al. 2005), (Li C et al. 2009) . The skin is the great barrier against the nanoparticles for the new medicine the only way the particles enter the body effectively is through injection, for rapid release. The nanomaterials develop for medicinal purposes have been under development for many years.

Nanomaterials are a major trend in medicine, these help deliver medications in a specific target, this is known as Nanomedicine (Oberdoerster G et al. 2005), (Balbus J et al. 2007). Some of the nanomedicines have a combination of properties for example a useful combination of lipophilicity and hydrophilicity so that they have some solubility in an aqueous environment, but are sufficiently hydrophobic to partition through membranes. These properties mean that they distribute all over the body fairly rapidly via the circulation and by diffusion through tissues and cells (Garnett M, and Kallinteri P. 2006) , (Oberdoerster G et al. 2005). Nanomedicines must be well tested before they enter in the hands of consumers. These enter the environment and have ecotoxicological effects therefore a new subsection of Nanoscience have emerged Nanotoxicology. The study of the impact of toxic nanoparticles, or simply Nanotoxicity. This is more complicated than expected, therefore there is a great need for further investigation for fundamental research and practical applications of nanomaterials. Therefore, further supportive and extensive researches are warranted; the study of the interactions of nanostructures with biological systems with an emphasis on elucidating the relationship between the physical and chemical properties (e. g. size, shape, surface chemistry, composition, and aggregation) of nanostructures with induction of toxic biological responses (Moreira S et al. 2009), (Oberdoerster G et al. 2005), (Balbus J et al. 2007), (Hardman R. 2006).

Nanotoxicological research is in its infancy and the implementation of test standards and commercialisation of appropriate safety control systems can take several years (Friedrichs S, and Schulte J. 2007), (Marquis B et al. 2009) . The future understanding of the toxicity of nanomaterials depend on technological innovations and scientific results stemming from enhanced research and discovery in nanotechnologies, and conventional knowledge about exposure assessment, fate and transport, and current computer models is not necessarily applicable to nanoparticles"(Balbus J et al. 2007), (Elliott KC. 2007), (Friedrichs S, and Schulte J. 2007), (Marquis B et al. 2009), (Piotrowska G et al. 2009). The improved study methods for rapid testing and efficient nanotoxicity assessments. Because there is a need to study the potential of nanoparticles to carry toxic chemicals that are man made or those found in the environment. For example fullerenes or nanoCarbon60 is a major threat to marine or aquatic ecosystems, these particles are insoluble in water (Friedrichs S, and Schulte J. 2007) . This C60 is mixed with Tetrahydrofuran that is use as a vehicle solvent. The combination generates a yellowish adjacent C60. This is the main reason why there is potential that toxicity result from the presence of THF in between the adjacent nanoC60 and THF degradation products (Friedrichs S, and Schulte J. 2007).

There is a need for more research other than the traditional invitro using tissue samples but the actual use of in vivo organisms to study the life cycle of nanoparticles. The In vitro toxicity assessment faster, cheap, and minimum ethical concers. In another hand, in vivo life cycle is accurate in assessing nanotoxicity. This life cycle study is base in the different characterizations of the nanoparticles, and relation with the environment where exposed (Fisher HC, and Chang WC 2007), (Marquis B et al. 2009). The nanoparticles have an important role in driving cellular responses related to oxidative stress, so extracellular levels should also be considered (Elliott KC. 2007), (Balbus J et al. 2007), (Oberdoerster G et al. 2005). Therefore, new studies permit the mapping the effect of the toxicity of nanostructure, allowing for the development of predictive models of nanostructure toxicity. However, because of ethical regulations the transition animal to humans still far, as a result of ethical laws and regulations regarding human testing, if allowed nanotoxicology could greatly improve the degree of confidence on the safety of nanomaterials for diagnostic and/or therapeutic strategies in humans (Bregoli L et al. 2009) . Further studies lead to required information so responsible regulatory decisions could be made. Despite this increase in the prevalence of engineered nanomaterials, the field of nanotoxicology has formed in response to this lack of information to be applied when conducting research studies (Bregoli L et al. 2009), (Fisher HC, and Chang WC 2007), (Marquis B et al. 2009). Nanotoxicology is dependent of analytical methods for future classifications of nanomaterials as well as their effects on in vitro and in vivo studies (Marquis B et al. 2009). Moreover, there is currently a small amount of investigation dealing with the impact of toxicity of nanoparticles. There is a future focus on nanoparticles toxicity in the molecular level leading to cellular oxidative stress. The technology boom raises an important question: what is being done to address the environmental risks associated with nanotechnology (Piotrowska G et al. 2009), (Garnett M, and Kallinteri P. 2006).

So Nanotoxicologists could build a program to promote a safe and profitable nanotechnology (Elliott KC. 2007). The promotion of safe nanotoxicology started by a specific sub classification of nanoparticles, for example Quatum Dots. These are sub classified by inherent physical, and chemical properties, and environmental impact; the particle size, functional groups, and oxidative properties to establish the toxicity (Hardman R. 2006). The safe nanotechnology is achieve by following the main causes of nanoparticle toxicity (1) Due to chemical toxicity of materials from which they have been made. (2) Due to their small size: nanoparticles may stick to cellular membranes and enter the cells. (3) Due to their shape: e. g. carbon nanotubes can easily pierce cell membrane (Piotrowska G et al. 2009). According to Friedrichs S, and Schulte J. in 2007, acknowledge that by June 2005 the International Standard Organization launched a Nanotechnology Committee, that focus in the standardization of the nanotechnologies.

In the past there were early warnings against the effects of manufactured nanoparticles from commercial products and new-generation-waste. Therefore new studies are necessary for the recognition of biological effects of nanoparticles in the environment, and creation of the bases of nanobiomonitoring (Piotrowska G et al. 2009). This nanomonitoring must be started before the Nanowaste accumulation that will be present in the near future and reduce ecotoxicological problems.

There is a high demand for the appropriated risk assessment, this affecting global organizations in order to protect both their staff, clients, and customers. However, a cross disciplinary communication is required, this in the collaboration of researchers from different disciplines. For example communication between physical chemists that have knowledge in classification of materials, biologist with knowledge of the ecosystems and biological systems, and toxicologist to merge both skills to study the toxicity of these nanomaterials (Balbus J et al. 2007), (Friedrichs S, and Schulte J. 2007). For example analytical chemists in nanotoxicology, help in the classifications of future nanomaterials and particles. Some of their techniques are electron microscopy, this helps to study the accumulation of bioparticles(Marquis B et al. 2009). Then nanotoxicologist benefit from the intergration of both physical and biological sciences.

The toxicologists discover that analytical chemists can develop assays that are both sensitive and selective for any species or cell function affected by nanoparticles(Wittmaack K. 2007). There are many scientific disciplines working together to study nanoparticles and their toxicology. Efforts have been internationally for a better assessment with two main groups International Council on Nanotechnology, and the International Organization for Standardization (Marquis B et al. 2009), (Oberdoerster G et al. 2005). Therefore there is a high demand for research, on the effects of nanoparticles.

Since 1990, there is a high implementation of nanotechnologies (Piotrowska G et al. 2009) . The uses of nanotechnology products, these are used in electronics and cosmetics. As an comparative measurement, to consider is that in two grams of 100 nm nanoparticles contains enough to give every human a generous amount of these particles (Hardman R. 2006). There is a beneficial aspect by working with nanoscale technologies, expected to have heavy impact in diverse industries and areas of society like medicine, plastic, energy, electronics, aerospace, and emerging fields.

According to Piotrowska G et al. 2009, there is a law imposed by Roy Amara the president of the Institute for the Future, “ Nanoparticles benefits might be overestimated in the short run, and their effects in the long run such as the accumulation of nanowaste might be underestimated.” The short term effects are the benefits of the new technology, nanomaterials, and usages of Nanoparticles, no nanowaste present. The long term effects are those that prove to be detrimental to the environment and increase the nanomaterials toxicity. For example time of nanotechnology usage increase Nanowaste increases toxicity. The interactions between nanoparticles and the environmental leads to harmful exposures for the affected ecosystem and living organisms (Balbus J et al. 2007) . As a result of increase in nanowaste. According to the Amara Law, this materials will be around and living organisms exposure is ensure and likely to increase over time (Hardman R. 2006). We must study the physicochemical properties the research should focus on in vivo systems. Nanoconstructs interactions are important to take in consideration for future studies, there is the interactions of biological components such as proteins and cells organelles; that will give clues for the study of the nanocompounds biodistribution. This is important to understand because is the merge between the nanoparticles and the environment to then give specific laws (Marquis B et al. 2009), (Oberdoerster G et al. 2005), (Piotrowska G et al. 2009), (Friedrichs S, and Schulte J. 2007) . There is still a small amount of data regarding the handeling of discarded nanomaterials.

Since there is a high demand for research, there is the Organisation for Economic Co-operation and Development (OECD) which launched an initiative to test human health and environmental safety of those nanomaterials that are already in use and the nanomaterials that may be developed in the forthcoming years. Consequently the greater amount of research the better risk assessment, therefore is beneficial to study nanoparticles potential impacts on environmental health and safety (Marquis B et al. 2009), (Oberdoerster G et al. 2005), (Piotrowska G et al. 2009).

There is potential risk on environmental, health, and safety; with these new technology applied in commercialized products. As an example, in the usage of a glass and bathroom sealant spray Magic Nano, led to hospitalization of an aerosol industry (Friedrichs S, and Schulte J. 2007) . There is a high demand for nanotechnological research, these companies should focus in the appropriate toxicology and ecotoxicology for all nanoenabled products. The ecotoxicological hazard is that the nanoparticled accumulate in the soil, air, and surface water. There they last for a long time to be taken up by biological organisms, because they undergo biodegradation or bioaccumulate in the food chain (Piotrowska G et al. 2009), (Friedrichs S, and Schulte J. 2007). According to the United States Environmental Protection Agency there are nanoparticles contained in cosmetics, such as sunscreens can contaminate water and soil, contributing to their bioaccumulation in the food chain (Friedrichs S, and Schulte J. 2007),, (Oberdoerster G et al. 2005), (Elliott KC. 2007). In addition, this agency works closely with the Toxic Substances Control Act to study the toxicity of nanomaterials. The effects of carbon nanotubes are detrimental to humans and other living things, greater than any other nanoparticle (Oberdoerster G et al. 2005), (Piotrowska G et al. 2009), (Friedrichs S, and Schulte J. 2007).

Carbon Nanotubes cause necrosis, degeneration, and apoptosis in the animal and plant cells. These nanoparticles are less biodegradable, and they have a lipophilic property making them easy to cross the cell membrane. Such properties may be associated with a tendency of carbon nanotubes to bioaccumulate (Piotrowska G et al. 2009), (Oberdoerster G et al. 2005). .

Legal regulations are highly important issues, regarding nanowastes need to be regulated, following the life cycle of the remnants of the nanomaterials. This approach takes the stages of nanomaterials from production, through use, to disposal, which should avoid making the nanowaste problem a legacy of nanotechnology (Piotrowska G et al. 2009). This is an improvement after half a decade after the introduction of nanoparticles in manufacturing industries, known as the Life Cycle Assessment. Therefore, the companies working with nanotechnologies should keep up-to-date with information about the toxicological studies relevant to their area of R&D. (Friedrichs S, and Schulte J. 2007), (Piotrowska G et al. 2009). Currently many international institutions are collecting results regarding nanomaterials. Since all this collection of results proves beneficial since these toxicological and ecotoxicological studies on nanomaterials effect to the environment and health are expensive and have a great deal of length. This iniciative is known as ICON International Council of Nanotechnology. The University of California, has provided some surveys and research, to this international collection of nanomaterials research, this includes the Safety of Nano-Materials Interdisciplinary Research Centre, which conducts toxicological and epidemiological studies (Friedrichs S, and Schulte J. 2007). There is plenty room for further reaseach.

Conclusion and Recommendations

Nanotechnology an emerging science, from anthropogenic and natural sources for example ash from volcanoes. Other natural occurring nanoparticles biogenic magnetite, from bacteria to protozoa to animals; this associated with neurodegenerative diseases. As nanomaterials are used for manufacture industries, there is a need for accurate, and responsible nanotoxicological evaluation. Resources and funding for the study should be from government and pioneering industries. The studies will further help to sort and create regulations for risk evaluations, this information should be influenced from previous research studies (Marquis B et al. 2009), (Oberdoerster G et al. 2005), (Piotrowska G et al. 2009). The research on nanotechnology products is necessary to study adverse effects of the engineer nanomaterials to living organisms and the environment. Nanotoxicology is a challenge for research because of different exposure conditions, and biodistribution. This is the movements of materials through tissue, and organisms.

As of now, there should be more rules for standardized testing for the assessment of toxicity of the nanomaterials. According to National

Toxicology program of 2005 and the U. S. Environmental Protection Agency of 2003, these have harmful side effects that affect different biological systems and they have a novel properties and risk of exposures is inevitable becoming a concern for humans and the environment (Hardman R. 2006) , (Marquis B et al. 2009), (Oberdoerster G et al. 2005).

A major recommendation, other than more funding and advance research in ecotoxicology and nanotoxicology, is the recycling of nanowaste. This recycling proves beneficial in the reduction of nanowaste independently of the time increase and nanowaste increase direct relationship. This recycling needs segregation of used nanoproducts, making them available for future use, in new products. These products if not possible to be recycled bioutilization is need to be used. For example, some species of plants and fungi are hyperaccumulators of heavy metals. Bioaccumulation of heavy metals, radionuclides and other xenobiotics by plants, fungi and microorganisms (e. g. fitoand mycoextraction or biodegradation) is a convenient way of remediation of polluted soils, water and air (Piotrowska G et al. 2009). Finally, the emerging development of nanotechnology needs a better reaserch and knowledge in how to bioutilise or recycle the nanowaste.