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General Evaluations of Nanoparticles

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Abstract: Nanoparticles have actually been in our lives for many years and begun to possess inevitable place in the life cycle with the gradual development of nanotechnology. Recent studies and improvement indicate that the use of nanoparticles will be expected to increase in many areas such as biology, medicine, engineering and optics in the future. In this review, nanoparticles, their applications, damage and damage prevention methods are discussed.

Keywords: Nanoparticles, Developments, Applications, Damage, Prevention

Nanotaneciklerin Genel Değerlendirilmesi

Özet: Nanotanecikler aslında uzun yıllardır hayatımızda yeralan nanoteknolojinin giderek gelişmesiyle yaşam döngüsünde büyük bir yer edinmeye başlamıştır. Teknolojideki son dönem çalışma ve gelişmeler kullanımlarının gelecekte daha da artacağını göstermektedir. Biyoloji, tıp, mühendislik, optik gibi birçok alandaki geniş kullanımlarının yanı sıra insanlara ve ekosisteme verdiği zararlarda büyük tartışma konusu olmuştur. Bu derleme yazısında nanotanecikler, kullanım alanları, zararları ve zararlarını önleyici yöntemler ele alınmaktadır.

Anahtar kelimeler: Nanotanecik, Gelişim, Uygulama, Zarar, Önleme

1. Introduction

Nanoparticles are amongst the most important materials of our Era. There are numerous studies on this subject. Nowadays, nanoparticles are used in different fields such as electronics industry, medical applications, drugs, cosmetics and environmental processes. Investments in nano–technological applications are increasing all around the world [1]. Available information about the current usage and the production rate of nanoparticles is insufficient. However, according to the estimation on the production rates of nanoparticles, approx. 2,000 tons were produced in 2004 and the production rate is expected to rise to 58,000 tons by 2020. Environmental and human health concerns will also rise up because of increased production and usage level of nanoparticles [2]. Nanoscale particles are not new in nature or in science. However, recent breakthroughs in areas such as microscopy have given scientists new tools to understand and exploit naturally occurring phenomena when organisms are organized in the nanoscale. In essence, this phenomenon is based on other simple physical effects such as "quantum effects" and large surface area. In addition, the vast majority of biological processes taking place at the nanoscale give models and templates to imagine and establish new processes that will augment scientists' work in medicine, imaging, computing, printing, chemical catalysis, material synthesis and many other fields. Nanotechnology is not working in smaller dimensions; More often, working at the nanoscale allows scientists to take an advantage of the unique physical, chemical, mechanical and optical properties that naturally

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occur at that scale [3]. When particles are created at about 1–100 nanometres (particles can only be "seen" with strongly customized microscopes), the properties of the materials properties such as melting point, fluorescence, electrical conductivity, magnetic permeability and chemical reactivity change significantly from the larger scales [4].
Nanoscale gold shows unique properties. At the nanoscale, the movement of the electrons of gold is limited. Therefore, gold nanoparticles react differently with light than with larger–sized gold particles. Dimensions and optical properties can be used in practice: Nano–scale gold particles selectively accumulate in tumours, where they do not damage healthy cells, providing both targeted imaging and laser imaging of the tumour.

Figure 1. Computer simulation of electron motions within a nanowire that has a diameter in the nanoscale range (Image: NSF multimedia/Eric Heller Gallery) [3].

That is, by changing the size of the particle, a scientist can precisely adjust a material property (for example, changing the fluorescent colour; In this case, a particle can be used to define a fluorescent colour particle, and various materials can be "labelled" with fluorescent markers for various purposes). Another strong quantum effect of the nanometre scale is known as "tunnelling"; this is a phenomenon that provides scanning tunnel microscope and flash memory for processing [5]. The purpose of nature has perfected the art of biology in the field of nanology for thousands of years. Many of the inner processes of cells naturally occur in the nanoscale. For example, haemoglobin, the protein that transfers oxygen to the body, is 5.5 nanometres in diameter. A deoxyribonucleic acid (DNA) sequence, one of the cornerstones of human life, is only about 2 nanometres in diameter. Many medical researchers are trying to design more sensitive and personalized instruments, treatments and therapies than traditional ones by drawing on the natural biological scale, which can be applied at the onset of a disease and cause less adverse side effects. A medical example of nanotechnology is bio–barcode analysis; it is a relatively low–cost method to detect specific biomarkers for the underlying disease, even if very few in this sample. The basic process of linking fragments and DNA "amplifiers" to "gold nanoparticles" was originally shown for a prostate cancer biomarker that followed prostatectomy at North Western University [6].

The growing understanding of nano–scale bio molecular structures also affects other areas, according to the tibia. Some scientists are exploring ways to use molecular biology, self–organization and quantum mechanics to build new computing platforms. Other researchers have discovered that, in photosynthesis, the energy harvested by plants from sunlight is transferred almost instantaneously to plant "reaction centres" at about 100 % efficiency (wasted as little heat energy) by quantum mechanical processes. They are investigating photosynthesis as a model for "green energy" nano systems for cheap production and storage of non–glowing solar energy [6–7]. Nanoscale materials have much larger surface areas than similar large–scale materials. As the surface area per mass of a material increases, a larger portion of the material may contact the surrounding material, thereby affecting reactivity. A simple thought experiment indicates why nanoparticles have phenomenally high surface areas. A solid cube of a material 1 cm on a side has 6 cm^2 of surface area, about equal to one side of half a stick of gum. But if that volume of 1 cubic centimetre were filled with cubes 1 mm on a side, that would be 1,000 mm–sized cubes (10 x 10 x 10), each one of which has a surface area of 6 mm^2, for a total surface area of 60 cm^2 about the same as one side of two–thirds of a 3” x 5” note card. When the 1 cubic cm is filled with micrometre–sized cubes a trillion (10^{12}) of them, each with a surface area of 6 μm^2 the total surface area amounts to 6 m^2, or about the area of the main bathroom in an average house. And when that single cubic centimetre of volume is filled with 1 nanometre–sized cubes 10^{21} of them, each with an area of 6 nm^2 their total surface area comes to 6,000 m^2. In other words, a single cubic centimetre of cubic nanoparticles has a total surface area one–third larger than a football field [8]!

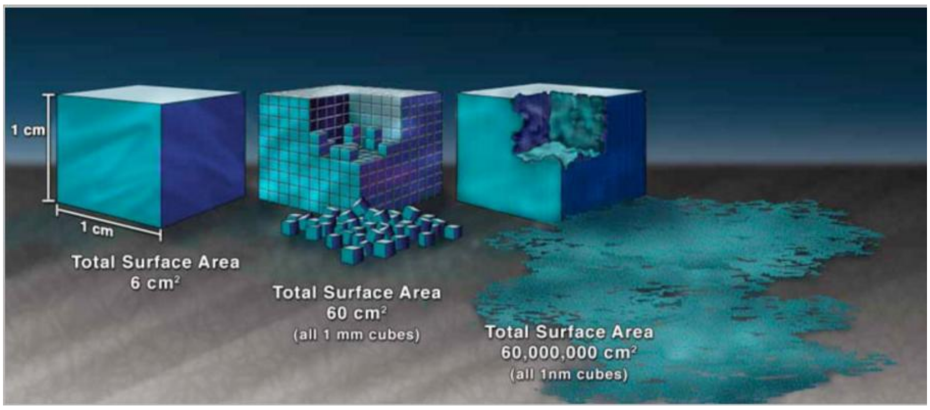

Figure 2. Illustration demonstrating the effect of the increased surface area provided by nanostructured materials [3].

One feature of larger surface area (and improved reactivity) is that they help to form better catalysts. As a result, the catalysis produced by engineered nanostructured materials affects about one third of the huge US and global catalyst markets affecting billions of dollars in oil and chemical industries. A daily example of catalysis is a car that reduces the toxicity of engine smoke. Nano engineered batteries, fuel cells and catalysts can potentially use advanced reactivity at the nanoscale to produce cleaner, safer and more economical modes for generating and storing energy. The large surface area also makes nanostructured membranes and materials ideal candidates for water treatment and desalination [e.g., "Self–assembled nano–structured carbon for energy storage and water treatment", National Nanotechnology Initiative (NNI) achievement archive] in addition to other uses. For applications ranging from drug delivery to clothing isolation, nanoscale also helps to "functionalize" the material surfaces (by adding particles for specific purposes) [9].

2. Definition, Classification and Application of Nanoparticles

Nanoparticles which may be spherical, tubular or irregular in shape are divided into two groups as natural and synthetic that are also divided into organic and inorganic (mineral) subgroups based on the chemical composition of the nanoparticles. Fullerenes and carbon nanotubes (CNTs) are among the natural nanoparticles of geogenic or pyrogenic origin. Synthetic nanoparticles can be produced unnecessarily (either by combustion or as a byproduct) or consciously. Intentionally produced nanoparticles using certain processes are engineered or produced nanoparticles, such as fullerenes and CNTs. Regarding environmental issues, current research on nanotechnology focuses heavily on engineered nanoparticles [10].

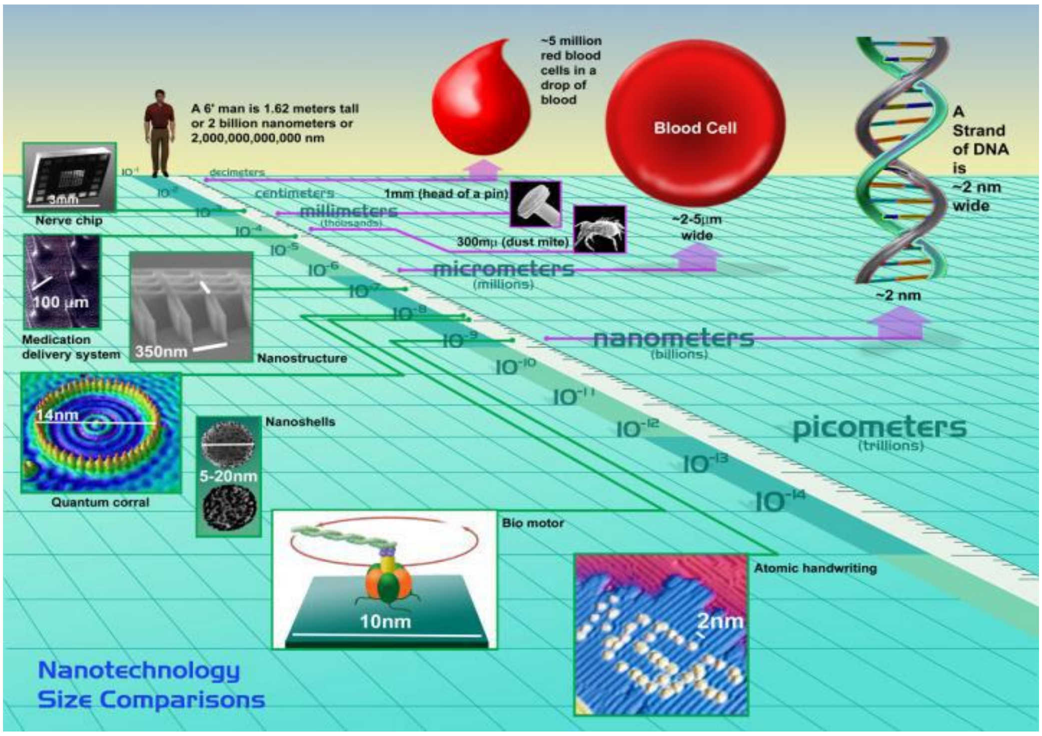

Figure 3. Scales illustration [11].

3. Types of Nanoparticles
3.1. Organic Colloids

Colloidal materials in natural waters contain particles and macromolecules ranging from 1 nm to 1 µm. For this reason, some of these particles are nanoparticles. Although human knowledge about the structure and environmental effects of natural colloids has increased significantly in recent years, their exact composition and function remains uncertain [12].

3.2. Soot

Processes of natural and artefacts that occur in mobile or stationary sources emit particles in various dimensions. Only very small particles, such as "ultra–fine" ones are small enough to be classified as nanoparticles. Due to the incomplete combustion of fossil fuels and renewable fuels, soot is released into the atmosphere and is mixed with water and soil by steam. The rainfall comes to the water. Carbon black, which is the industrial grade of the cement, has various uses, for example in rubber compositions, especially as a filler in tires. Carbon black particles are in the nanometre size range and mean sizes in different materials range from 20 to 300 nm [13].

3.3. Natural and Unintentionally–Produced Fullerenes and Carbon Nanotubes

Although fullerenes and carbon nanotubes are designed as nanoparticles, natural fullerenes and carbon nanotubes are also found in the environment. Some of these fullerenes are of interstellar origin and brought to Earth by comets and meteors [14].

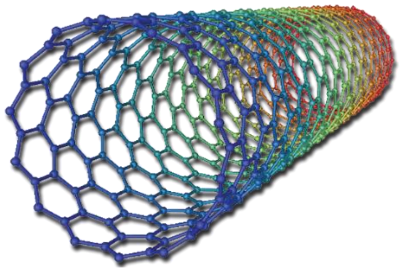

Figure 4. Single–walled “zig–zig” carbon nanotube [15].

3.4. Natural and Unintentionally–Produced Inorganic Nanoparticles

Natural mineral or inorganic nanoparticles may have atmospheric, geological or biological origin. Mineral nanoparticles are found everywhere in the Earth and in geological systems. Aerosols in the atmosphere are also considered nanoparticles and are precursors to larger particles that strongly affect the global climate, the atmosphere chemistry, the visual field, and the global emissions of pollutants. Some of the randomly and undesirably produced nano–particles are platinum and radium particles that are produced in catalytic converters of vehicles. Although most of these platinum and radium particles adhere to larger particles, about 17 % of them are found in thin aerosols (less than 0.43 μm in diameter) [16].

3.5. Engineered Fullerenes and CNTs

Among the fullerenes, buckminsterfullerene (C_{60}) has been extensively studied since it is the oldest known member of the fullerene family. Most fullerenes are used in polymeric composites such as thin membranes, in electro–optical devices and in biological applications. Because of the poor aqueous solubility of fullerenes, lots of research have been conducted to increase its usefulness and numerous compounds have been made from C_{60}, each with its own characteristics and properties. Carbon nanotubes have become an ongoing and controversial topic in physics [17]. Several types of carbon nanotubes with different properties have been obtained, depending on the synthesis method and techniques for isolating and removing unconventional by products [15].

3.6. Engineered Polymeric Nanoparticles

Synthetic nanoparticles derived from organic polymers are used as drug delivery devices in many applications. Different types of nanoparticles have been studied in relation to their ability to cross brain blood vessels. Many polymeric nanoparticles have also been produced to cure soil and groundwater [18].

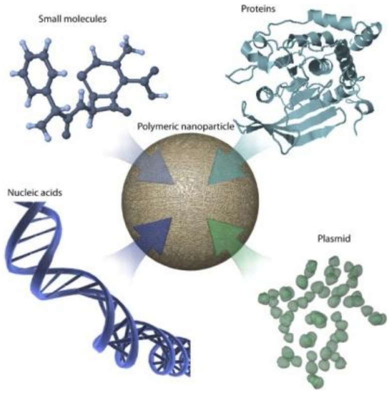

Figure 5. Polymeric nanoparticles [19].

3.7. Engineered Inorganic Nanoparticles

Processed inorganic nanoparticles have a wide range of materials such as elemental metals, metal oxides and metal salts. Elemental silver is used as a bactericide in many products. Elemental gold is employed in various applications due to its catalytic properties. Numerous studies have been conducted on the application of nanotechnology in the environmental context with regard to the use of nano–scale zero–valence iron (nZVI) to replace and improve ground water [20].

The advantages of using nanoparticles as a drug delivery system include the following:
1. Particle size and surface characteristics of nanoparticles can be easily manipulated to achieve both passive and active drug targeting after parenteral administration.
2. They control and sustain release of the drug during the transportation and at the site of localization, altering organ distribution of the drug and subsequent clearance of the drug so as to achieve increase in drug therapeutic efficacy and reduction in side effects.
3. Controlled release and particle degradation characteristics can be readily modulated by the choice of matrix constituents. Drug loading is relatively high and drugs can be incorporated into the systems without any chemical reaction; this is an important factor for preserving the drug activity.
4. Site–specific targeting can be achieved by attaching targeting ligands to surface of particles or use of magnetic guidance.
5. The system can be used for various routes of administration including oral, nasal, parenteral, intra–ocular etc.

The applications of nanomaterials to biology or medicine cover: Bio detection of pathogens, drug and gene delivery, detection of proteins fluorescent biological labels, magnetic resonance imaging (MRI) contrast enhancement, phagokinetic studies, probing of DNA structure, separation and purification of biological molecules and cells, tissue engineering, tumour destruction via heating (hyperthermia).

Table 1. Definitions of nanoparticles and nanomaterials by various organizations: International Organization for Standardization (ISO), American Society of Testing and Materials (ASTM), National Institute of Occupational Safety and Health (NIOSH), Scientific Committee on Consumer Products (SCCP), British Standards Institution (BSI), and Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BAuA) [21]

	Nanoparticle	**Nanomaterial**
ISO	A particle spinnig 1-100 nm (diameter)	
ASTM	An ultrafine particle whose length in 2 or 3 places is 1-100nm	
NIOSH	A particle withe diameter between 1 and 100 nm,or a fiber spanning the range 1-100nm	
SCCP	Ar least one side is in the nanoscale range	Materials for which at least one side or internal structure is in the nanoscale
BSI	All the fields or diameters are in the nanoscale range	Materials for which at least one side or internal structure is in the nanoscale
BAuA	All the fields or diameters are in the nanoscale range	Materials consisting of a nanostructure or a nanosubstance

Table 2. Nanoparticles and nanomaterials clinically approved, in clinical trials or in proof–of–concept research stages [22]

Nanomaterial/Nanoparticle	Applications
Metallic:	
Iron oxide	Magnetic resonance imaging/cancer therapy
Gold	In vitro diagnostics/cancer therapy
Gold (nanorods,nanoshells,nanocages)	Cancer therapy, diagnosis
Carbon Structures	
Fullerenes	Cancer therapy (photodynamic therapy)
Carbon nanotubes	Fluorescence and photoacousting imaging, antioxidant
Ceramic nanoparticles	
Silica	Cancer therapy, diagnosis
Alumina	Cancer therapy, diagnosis, computed tomography
Semiconductor	
Quantum dots	Fluorescent contrast, in vitro diagnostics
Organic	
Protein based nanoparticles	Cancer therapy
DNA based nanoparticles	Cancer therapy
Liposomes	Cancer therapy
Polymer nanoparticles	Cancer therapy
Polymer drug conjugates	Cancer therapy
Polymeric micelles	Cancer therapy
Dendrimers	Microbiocides, cancer therapy
Nanogels	Gene and drug delivery
Bicelles	Topical delivery
Hybrid	
Magnetoliposomes	Magnetic resonance imaging/cancer therapy

4. Several Examples of Most Widely Used Nanoparticles

Despite the use of many nanoparticles today, some special ones have a wide range of applications, and these have been widely used due to their superior properties.

4.1. Titanium Dioxide

The nano–crystalline titanium dioxide produced for specific applications is about 100 % thinner than titanium dioxide (TiO_2) pigments and has other physical properties. The production volume of nanoscale TiO_2 corresponds to less than 1 % of the TiO_2 pigments [23]. Unlike TiO_2 pigments, nano–scale titanium dioxide is not used as a food additive. Today, they are predominantly found in high–impact sun protection creams, textile fibres or wooden protectors. For a long time, sun creams were produced by adding titanium oxide micro particles, which give pasty, sticky consistency to the products. By leaving a visible film, these sun creams were not easy to apply and the skin did not feel good. Transparent nanoscale sunscreen containing titanium dioxide can be applied much easier. In addition, the protective effect against harmful ultraviolet (UV) rays is much better. Today, high sun protection factors can only be achieved using nanoparticles of titanium dioxide [24].

Table 3. Energy balance for the production of one ton titania [25]

Process	Energy[GJ/t]	TiO_2 manufacturing	Follow up treatment	Acid concenteration and filter salt decomposition	Total
Sulfate	Electric Energy	1.5-2.3	0.6-1.4	0.1-1.3	2.2-5
	Steam	3.7-7.7	6.7-10.4	0-5	10.4-23.1
	Gas	7.3-11.8	2.3-4.2	0-0.01	9.6-16.1
	Coal	-	-	5-8	5-8
	Total Energy	12-20	9-14	5-15	32-40
Chloride	Electric Energy	1.5	0.8	-	2.3
	Steam	1.7	7.6	-	9.3
	Gas	2.8	4.2	-	7
	Coal	-	-	-	-
	Total Energy		12.6	-	19

This TiO_2 is also coated with other materials in order to achieve better dispersibility and provide photo stability [26]. Another characteristic of TiO_2, photocatalytic activity, is significantly enhanced by the high surface/volume ratio of nanoparticles compared to that of micro particles. However, each of the above modifications cannot be used for photocatalytic purposes. As shown above, while rutile TiO_2 is mainly applied in sun creams, paints and dyes, anatase modifications are well suited for photo catalysis. In the presence of UV radiation, anatase TiO_2 may form radicals from air or water that can degrade oxidative organic contaminants. Because of the hydrophilic nature of titanium dioxide, water forms a closed film that can easily transport contaminants and degradation products. For this reason, house paints or tiles containing TiO_2 particles are self–cleaning and pollutant–degrading. In addition, so–called anti–cis coatings utilize the hydrophilic properties of nanocluster titanium dioxide. Ultra–thin water film on a glass plate coated with a transparent nano–scale TiO_2 layer prevents water droplets from forming and thus prevents fogging. Nano–scale titanium dioxide is also suitable for the use in dye–sensitized solar cells (Graetzel cells). Titanium dioxide is not as self–igniting as the nanometre–sized powder. It is also not combustible as a mixture of air (dust) under the influence of an ignition source, so there is no possibility of dust explosion.

4.2. Zinc Oxide

Nanostructures of zinc oxide (ZnO) can be synthesized into a variety of morphologies including nanowires, nano–rods, tetrapod, nano–belts, nano–flowers, nano–particles etc. [27]. Nano structures can be obtained with most above–mentioned techniques, at certain conditions, and also with the vapour–liquid–solid method [28]. The synthesis is typically carried out at temperatures of about 90 °C, in an equimolar aqueous solution of zinc nitrate and hexamine, the latter providing the basic environment. Certain additives, such as polyethylene glycol or polyethylenimine, can improve the aspect ratio of the ZnO nanowires. Doping of the ZnO nanowires has been achieved by adding other metal nitrates to the growth solution. The morphology of the resulting nanostructures can be tuned by changing the parameters relating to the precursor composition (such as the zinc concentration and pH) or to the thermal treatment (such as the temperature and heating rate).

Aligned ZnO nanowires on pre–seeded silicon, glass, and gallium nitride substrates have been grown using aqueous zinc salts such as zinc nitrate and zinc acetate in basic environments. Pre–seeding substrates with ZnO creates sites for homogeneous nucleation of ZnO crystal during the synthesis. Common pre–seeding methods include in–situ thermal decomposition of zinc acetate crystallites, spin coating of ZnO nanoparticles and the use of physical vapour deposition methods to deposit ZnO thin films. Pre–seeding can be performed in conjunction with top down patterning methods such as electron beam lithography and nano sphere lithography to designate nucleation sites prior to growth. Aligned ZnO nanowires can be employed in dye–sensitized solar cells and field emission devices [29].

Figure 6. Synthetic ZnO crystals (Red and green colour are associated with different concentrations of oxygen vacancies) [30].

4.3. Iron Oxide

Iron oxide nanoparticles are iron oxide particles having diameters of about 1 to 100 nanometres. The two main forms are magnetite (Fe_3O_4) and its oxidized form maghemite (γ–Fe_2O_3). Their superparamagnetic properties and their many potential applications in the field have been of great interest (Co and Ni are toxic and readily oxidized, although they are highly magnetic materials). Applications of diatomite nanoparticles include terabit magnetic storage devices, catalysis, sensors and bio molecular magnets for medical diagnostics and therapeutics resonance imaging (TRI). These applications require nanoparticles to be coated with agents such as long chain fatty acids, alkyl–substituted amines and diols [31].

In the paramagnetic state, the individual atomic magnetic moments are randomly oriented, and the substance has a zero net magnetic moment if there is no magnetic field. These materials have a relative magnetic permeability greater than one and are attracted to magnetic fields. The magnetic moment drops to zero when the applied field is removed. But in a ferromagnetic material, all the atomic moments are aligned even without an external field. A ferrimagnetic material is similar to a ferromagnet but has two different types of atoms with opposing magnetic moments. The material has a magnetic moment because the opposing moments have different strengths. If they have the same magnitude, the crystal is antiferromagnetic and possesses no net magnetic moment [32].

The superparamagnetic behaviour of iron oxide nanoparticles can be attributed to their size. When the size gets small enough (<10 nm), thermal fluctuations can change the direction of magnetization of the entire crystal. A material with many such crystals behaves like a paramagnet, except that the moments of entire crystals are fluctuating instead of individual atoms [33].

The preparation method has a large effect on shape, size distribution, and surface chemistry of the particles. It also determines to a great extent the distribution and type of structural defects or impurities in the particles. All these factors affect magnetic behaviour. Recently, many attempts have been made to develop processes and techniques that would yield "monodisperse colloids" consisting of nanoparticles uniform in size and shape [34].

5. Properties of Nanoparticles

The dimension of matter important in nanoscience and nanotechnology is typically on the 0.2 to 100 nm scale (nanoscale). The properties of materials change as their size approaches the nanoscale.

Further, the percentage of atoms at the surface of a material becomes more significant [35]. Bulk materials possess relatively constant physical properties regardless of their size, but at the nanoscale this is often not the case. As the material becomes smaller the percentage of atoms at the surface increases relative to the total number of atoms of the material bulk. This can lead to unexpected properties of nanoparticles which are partly due to the surface of the material dominating over the bulk properties. At this scale, the surface to volume ratios of materials become large and their electronic energy states become discrete, leading to unique electronic, optical, magnetic, and mechanical properties of the nanomaterials. In general, as the size of inorganic and organic materials decreases towards the nanoscale, their optical and electronic properties largely vary from the bulk material at the atomic/molecular levels becoming size and shape dependent. Their crystallographic surface structure and the large surface to volume ratio make the nanoparticles exhibit remarkable properties. Moreover, the increased catalytic activity due to morphologies with highly active facets and the tailoring of its synthesis as per the requirement makes the nanoparticles an attractive tool to solve various technological problems [36]. In the field of medicine, nanoparticles are being explored extensively because of their size dependent chemical and physical properties. The size of nanoparticles is similar to that of most biological molecules and structures. This makes them an interesting candidate for application in both in vivo and in vitro biomedical research. The result of their integration in the field of medicine has led to their application mainly in targeted drug delivery, imaging, sensing, and artificial implants. Another interesting avenue for their exploration in medicine is their use as antimicrobials to target highly pathogenic and drug resistant microbes. But, for the application of nanoparticles in biology, biocompatibility is a highly desired trait. Biocompatibility is the materials ability to perform medically without exertion of undesired local or systemic effects [37].

6. Applications and Uses

The properties of many conventional materials change when formed from nanoparticles. This is typically because nanoparticles have a greater surface area per weight than larger particles which causes them to be more reactive to some other molecules.

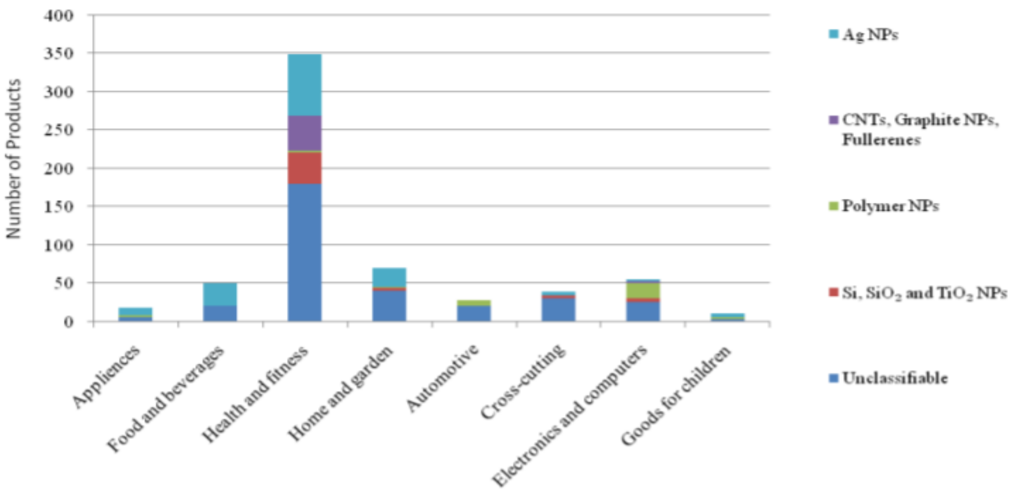

Figure 7. Materials vs. product category [38].

Nanoparticles are used, or being evaluated for the use, in many fields. The list below introduces several of the usage under development.

Figure 8. Innovative applications of nanoparticles [39].

6.1. Nanoparticle and Energy

Some interesting ways to exploit nanotechnology to produce more efficient and cost–effective energy are:

Researchers show that sunlight condensing on nanoparticles can produce steam with high energy efficiency. The "solar–powered steamer" is designed for the use in electrically non–developing countries for the applications such as cleaning water or disinfecting dentistry. Another group of researchers is the development of nanoparticles in which light is not used to produce steam to be employed in the operation of plants.

In a high efficiency bulb, a nano–engineered polymer matrix is used. New bulbs have the advantage of not being shattered and double the efficiency of compact fluorescent bulbs. Other researchers produce high–efficiency light-emitting diode (LEDs) using nano–sized arrays of structures called plasmonic cavities. Another developing idea is the incandescent bulbs, wrapping conventional yarn with crystalline material that turns some of the waste infrared radiation into visible light. An epoxy containing carbon nanotubes is used to make windmill blades. Stronger and lower weight blades become possible using nanotube–filled epoxy. The resulting longer blades increase the electricity generated by each wind mill. The researchers used nanotube leaves to create electricity–generating thermos cells at different temperatures at the edges of the cell. These nanotube plates can be wrapped around hot pipes like car's exhaust pipe to generate electricity, which is usually wasted heat. The scientists prepared graphite layers to increase the energy of bonding to the graphene surface with hydrogen gas in a fuel tank, resulting in a higher amount of hydrogen storage and thus a lighter fuel tank. Other researchers have exhibited that sodium borohydride nanoparticles can efficiently store hydrogen [40].

Researchers have developed piezoelectric nanofibers that are flexible enough to be touched by clothing. Fibres can convert electricity into normal motion to power your mobile phone and other mobile electronic devices [41].

Companies have developed nanotechnology cells that can be produced at a lower cost than traditional solar batteries. They are already developing batteries using nanomaterials. Such a battery will be a good new battery after sitting on the raft for decades. Another battery can be charged much faster than normal batteries [41–42].

Nanotechnology is used to reduce the cost of catalysts evaluated in fuel cells. These catalysts produce hydrogen ions from fuels such as methanol. This technology is also used to increase the efficiency of membranes employed in fuel cells to separate hydrogen ions, such as oxygen, from other gases. To produce more fuel efficient raw material, nanotechnology can make fossil fuels such as diesel and gasoline open by providing economical production of fuels from low grade raw materials. It can also be used to increase the mileage performance of engines and make the production of fuels from normal raw materials more efficient [42].

Nanotechnology, a relatively new change in the capture, transmission and storage of energy, will have and continue to have many positive economic impacts on society. An important problem in current energy production is the loss of heat production and productivity, a side product of the process. A common example of this is the heat generated by the internal combustion engine which loses approximately 64 % of the energy of the fuel as heat, and this alone can have a significant economic impact. However, its improvement in this respect has proven to be extremely difficult without sacrificing performance. Using nanotechnology to improve the efficiency of fuel cells seems more reasonable using molecular customized catalysts, polymer membranes and improved fuel storage. The fuel cells already designed for transport need a quick start–up period for the practicality of consumer use. This process places too much pressure on conventional polymer electrolyte membranes and shortens the life of the membrane that needs to be changed frequently. Engineers using nanotechnology have the ability to form a more durable polymer membrane that addresses this problem. Nanometre polymer membranes are also more effective in ionic conductivity. This increases the efficiency of the system and reduces the renewal times, which decreases costs [43].

Another problem with modern fuel cells is the storage of fuel. In the case of hydrogen fuel cells, hydrogen storage from gas form increases the efficiency by 5 %. However, the materials provided at this time significantly limit fuel storage capacity due to low stress tolerance and costs. Scientists have found this answer by using a nano porous styrene material (a relatively inexpensive material) that naturally retains hydrogen atoms when cooled to –196 °C and releases hydrogen to reuse when heated. Today's best solar cells have various layers of semiconductors combined to absorb the energy of different energies, yet they are only able to use 40 % of the solar energy. Commercially available solar cells have lower efficiencies (15–20 %). Nano structuring has been used, for example, to enhance the efficiency of photovoltaic cells developed through the development of current collection in amorphous silicon devices, plasmonic enrichment in dye–sensitized solar cells and improved light trapping in crystalline silicon. In addition, nanotechnology can help to increase the efficiency of light conversion by using nanostructures with a continuous band of mass, or by directing photovoltaic devices and controlling the probability of photon escape [44–45]. The efficiency level of the internal combustion engine is now about 30–40 %. Nanotechnology can develop combustion by designing specific catalysts with a maximum surface area. In 2005, scientists at the University of Toronto developed a nanoparticle material that, when applied to a surface, instantly transformed it into a solar collector [46].

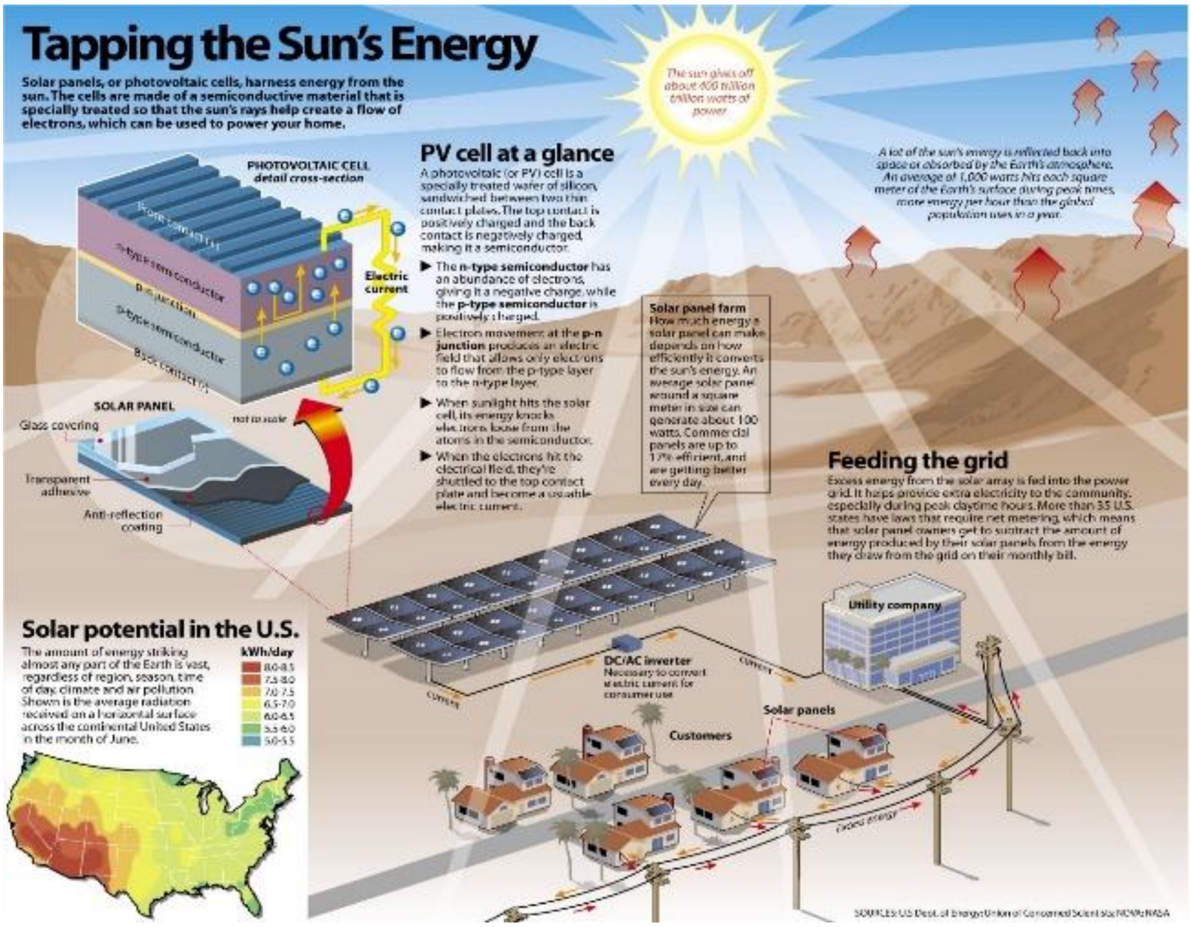

Figure 9. Nanoparticles in the solar system [47].

6.2. Nanoparticle Applications in Medicine

The use of polymer coated iron oxide nanoparticles to break up bacterial clusters allows the treatment of possibly more effective chronic bacterial infections [48].

Surface modification of protein–impregnated nanoparticles has been shown to influence the ability of nanoparticles to stimulate immune responses. Researchers believe in that these nanoparticles can be used for inhalable vaccines [48–49].

Researchers at Rice University have inhibited that cerium oxide nanoparticles serve as an antioxidant to remove oxygen–free radicals in the bloodstream of a patient following a traumatic injury. Nanoparticles absorb oxygen–free radicals and then release nanoparticles by releasing oxygen in less hazardous conditions to absorb less free radicals. Researchers are developing ways to use carbon nanoparticles called nano–diamonds in medical applications. For example, protein molecules bound nanotubes can be used to enhance bone growth around the teeth or joint implants. Researchers are testing the usage of chemotherapy drugs linked to nano–diamonds to treat tumours in the brain. Other scientists are testing the use of chemotherapy drugs linked to nano–diamonds in the treatment of leukaemia [49–50].

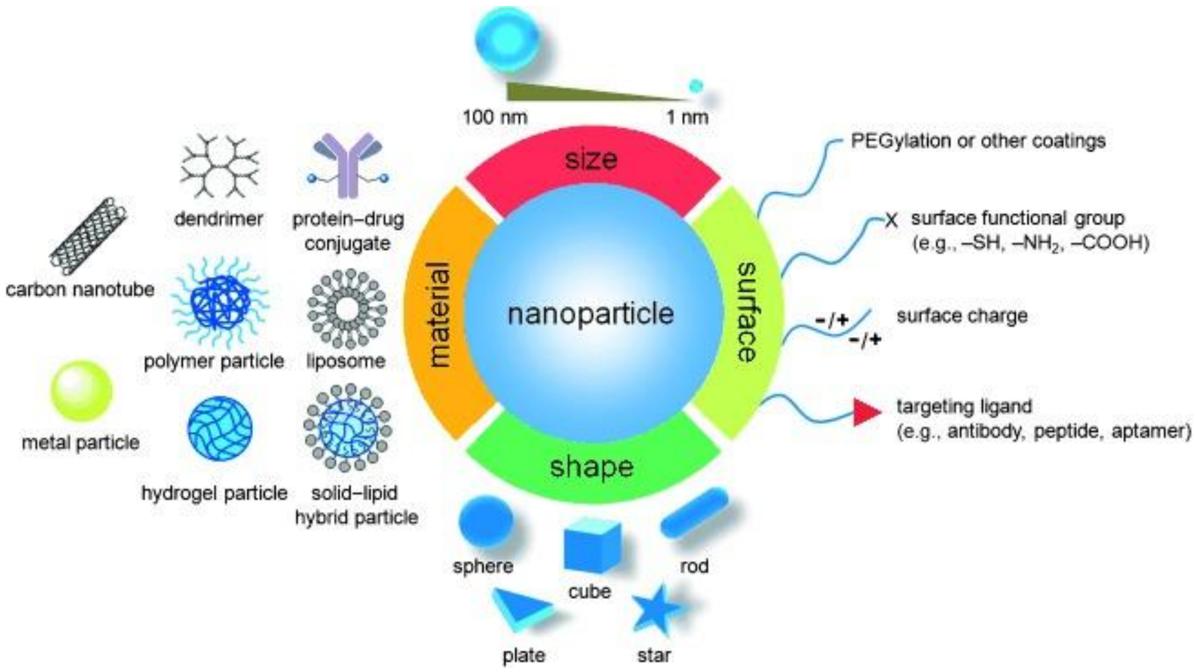

Figure 10. A summary of nanoparticles that have been explored as carriers for drug delivery in cancer therapy, together with illustrations of bio physicochemical properties [51].

6.3. Medical Applications

Nano medicine is the medical application of nanotechnology. Nano medicine approaches range from medical use of nanomaterials to nano–electronic biosensors, and even future applications of molecular nanotechnology. Nano medicine aims to offer a range of valuable research tools and clinically useful devices in the near future. The National Nanotechnology Initiative expects new commercial applications in the pharmaceutical industry to include advanced drug delivery systems, new therapies and in vivo imaging. Neuro–electronic interfaces and other nano–electronics based sensors are another active target of the research. The speculative field of molecular nanotechnology believes in that cell repair machines can revolutionize medicine and cadavers. Nano toxicology is the area that investigates the potential health risks of nanomaterials. The extremely small size of nanomaterials means that they are much more easily taken by the human body than larger sized particles. These nanoparticles are at the forefront of important issues that need to be addressed how they behave in the organism. The behaviour of nanoparticles is a function of the surface, the texture, shape and surrounding tissue. Another potential concern is the potential for interaction with the biological processes in the body, as well as the occurrence of nanoparticles that accumulate in the organs, where they are not broken down or slowly disintegrated. Nanoparticles immediately adsorb on their surfaces upon tissue and fluid exposure due to their large surface. This can affect, for example, the regulatory mechanisms of enzymes and other proteins. Numerous variables affecting toxicity mean that it is difficult to generalize about health risks associated with exposure to nanomaterials; Each of new nanomaterials must be evaluated separately and all material properties must be considered. Health and environmental problems combine at the workplace of companies that produce or use nanomaterials and laboratories researching nanoscience and nanotechnology. It is safe to say that existing exposure standards for dusts cannot be applied directly to nanoparticle powders [52]. The extremely small size of nanomaterials means that the human body is much easier to handle than larger sized particles. How these nanoparticles are treated in the body is one of the issues to be solved. Phagocytes can overburden cells that ingest and destroy foreign matter, thereby triggering stress reactions that cause inflammation and weakening the body's defence against other pathogens. Another concern is the potential for interactions with the biological processes in the body, as well as the occurrence of nanoparticles that accumulate in the organs when they are broken down or slowly disintegrated [44]. In the National Personal Protective Technology Laboratory (NIOSH), studies and certified dust masks are conducted to investigate the filter penetration of nanoparticles in NIOSH–certified and European Commission (EU)–labelled respiratory devices. These studies have found that the most penetrating particle size range is between 30 and 100 nanometres, and that the size of the leak is the largest factor in nanoparticles found in respiratory devices of test puppies [52–53].

Other properties of nanomaterials affecting toxicity include: chemical composition, shape, surface structure, surface charge, aggregation, solubility and the presence or absence of functional groups of other chemicals. Numerous variables affecting toxicity mean that it is difficult to generalize about health risks associated with exposure to nanomaterials; Each new nanomaterial must be evaluated separately and all material properties must be considered.

Literary studies show that the release of engineered nanoparticles and personal exposure can occur during different work activities. The situation directs regulatory bodies to enforce prevention strategies and regulations in nanotechnology workplaces [54].

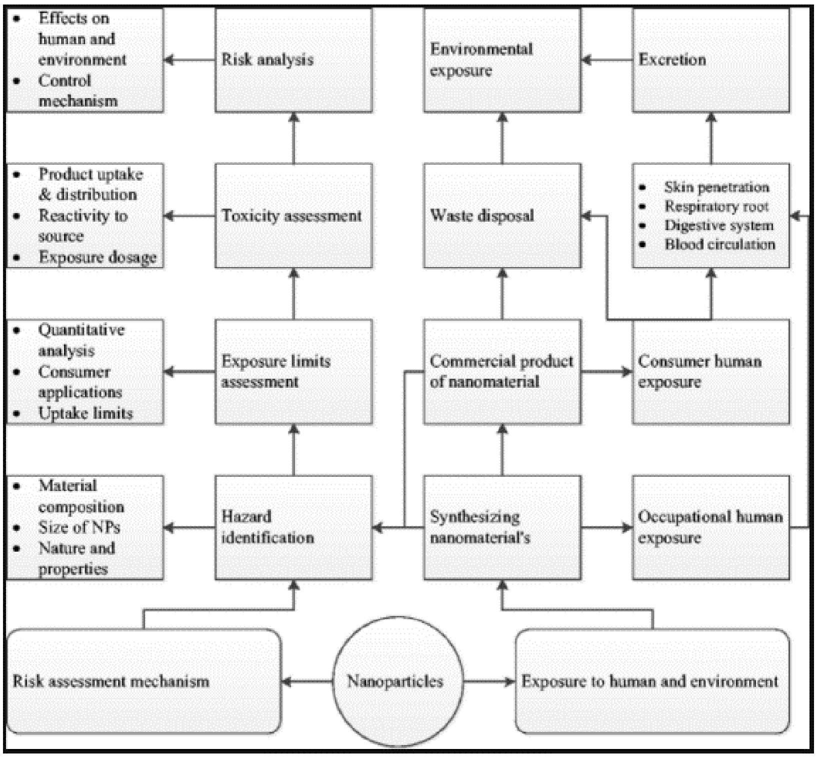

Figure 11. Mechanism of human exposure and risk assessment of engineered nanoparticles [55].

6.4. Nano Biotechnology

Biotechnology and nano–biotechnology serve as a general term for a variety of related technologies. This discipline points to the convergence of biological research with various fields of biotechnology. Concepts developed by nano–biology include: nano–devices (such as biological machines), nanotubes, and nanometre events that occur within the discipline of nanotechnology. This technical approach to biology allows scientists to imagine and create systems which can be used for biological research. Nanotechnology, a biologically inspired source, employs biological systems as a source of inspiration for technologies that have not yet been created. However, like nanotechnology and biotechnology, bio nanotechnology has many potential ethical issues connected with it. One of the most important goals in nano–biology is to apply and refine nano–tools to related medical/biological problems. The development of new tools such as peptoid nano–sheets for medical and biological purposes is the primary goal of nanotechnology. The imaging of natural biomolecules, biological membranes and tissues is also an important issue for nano–biology researchers. Other topics related to nano–biology include the use of ganged array sensors and the application of nano–photonics to manipulate molecular processes in living cells [56].

Recently, the use of microorganisms to synthesize functional nanoparticles has been of great interest. Microorganisms can change the oxidation state of metals. These microbial processes have created new opportunities to discover new applications such as biosynthesis of metal nanomaterials. In contrast to chemical and physical methods, microbial processes for synthesizing nanomaterials can be achieved in aqueous phase under gentle and environmentally benign conditions. This approach has become an attractive focus for current green biotechnology research for sustainable development [55–56].

6.5. Nano Devices

Nano devices are critical enablers that will allow mankind to exploit the ultimate technological capabilities of electronic, magnetic, mechanical, and biological systems. While the best examples of nano–devices at present are clearly associated with the semiconductor industry, the potential for such devices is much broader. Nano devices will ultimately have an enormous impact on our ability to enhance energy conversion, control pollution, produce food, and improve human health and longevity.

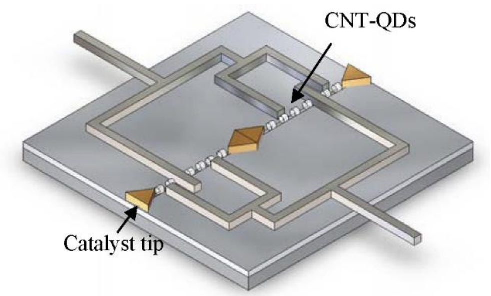

Figure 12. Example of device [57].

At the The City University of New York (CUNY) and Arctic Slope Regional Corporation (ASRC), several faculty conduct research in nano devices. These efforts are based in the basic and applied sciences as well as technology aspects of electronics, photonics and biomedical devices. Much of this research focuses on the understanding of various physical phenomena arising from novel material systems or novel device structures fabricated in our in–house nanofabrication facility.

6.6. Nanophotonics

Nano photonics or nano–optics is the study of the behaviour of light on the nanometre scale, and of the interaction of nm–scale objects with light. It is a branch of optics, optical engineering, electrical engineering, and nanotechnology. It often (but not exclusively) involves metallic components, which can transport and focus light via surface plasmon polaritons.

The term "nano–optics", just like the term "optics", usually refers to the situations involving ultraviolet, visible, and near–infrared light (free–space wavelengths from 300 to 1200 nm) [58].

Normal optical components, like lenses and microscopes, generally cannot normally focus light to nanometre (deep subwavelength) scales, because of the diffraction limit (Rayleigh criterion). Nevertheless, it is possible to squeeze light into a nanometre scale using other techniques like, for example, surface plasmons, localized surface plasmons around nanoscale metal objects, and the nanoscale apertures and nanoscale sharp tips used in near–field scanning optical microscopy (NSOM) and photo assisted scanning tunnelling microscopy.

Nano photonic researchers pursue targets in a wide range of fields, from biochemistry to electrical engineering. A few of these goals are summarized below: If the light can trap a small volume, it can be absorbed and detected by a small detector. Small photodetectors tend to have desirable characteristics such as low noise, high speed and low voltage and power.

The small lasers have various desirable characteristics for optical communication, including low threshold current (helping power efficiency) and fast modulation (meaning more data transmission). Very small lasers require optical gaps under the wavelength. An example of this is spas with laser surface plasmon versions. The integrated circuits are made using photolithography, in other words by exposure to light. To make very small transistors, the light must focus on extremely sharp images. Using a variety of techniques, such as immersion lithography and phase shift photo masking, it is possible to obtain images that are thinner than the wavelength, indeed by drawing 30 nm lines using 193 nm light. Plasma techniques have also been proposed for this application. Heat assisted magnetic recording is a nano–photonic approach to increase the amount of data a magnetic disk drive can store. Before writing data, a laser is required to heat under surface area of the magnetic material. The magnetic writing head would have metal optical components to concentrate the light in the right place. Miniaturization in optoelectronics, for example, has improved the speed and cost of miniaturization of transistors in integrated circuits. However, optoelectronic circuits can be miniaturized only when optical components are reduced with electronic components. This is true for optical communication on the chip (i.e., transferring information from one part of a microchip to another by sending light through optical waveguides instead of changing the voltage on a wire). When the light is absorbed near the surface, the solar energy cells often get the best result, because the electrons near the surface have a better chance of collecting and the device is more incarnated and reduces the cost. Researchers have explored a variety of nano–photonic techniques to concentrate the light in the most convenient locations within a solar cell. Using nano–photonics to create high peak intensities: When a certain amount of light energy is compressed into a smaller volume ("hot–spot"), the density at the hot spot increases and grows. This is particularly useful for non–linear optics; One example is surface enhanced Raman scattering. At the same time, averaging over millions or billions of molecules allows sensitive spectroscopy measurements even for single molecules at the hot spot, unlike conventional spectroscopy methods [59].

One aim of nano–photonic processing is to construct metamorphic or use other techniques to create images being more pronounced than the diffraction limit (deep wavelength), which is called the "super–sensor". A near–scan optical microscope (NSOM or SNOM) is a totally different nano–photonic technique that achieves the same goal of taking images with a much smaller resolution than the wavelength. It involves raster-scanning a very sharp tip or very small aperture over the surface to be imaged. Near field microscopy refers to any technique that uses the near field to obtain nanometre, sub–wavelength resolution. For example, the dual polarization interferometer has a vertical resolution of the picometer above the waveguide surface [60].

6.7. Nanotechnology in Defence: Developing Practices

The Institute for Soldier Nanotechnology (ISN) is in the business of exploiting and developing nanotechnology to help survive soldiers in battle conditions. A nanobaltit tool that can be as slim as Spandex and includes health monitors and communication equipment is being developed. Nanomaterials make bullet proofing much more effective by providing far more excellent protection than current materials. Even these overalls can react and stop the biological and chemical attack. This protection and these devices are made into a tool that will be more efficient and lightweight than the existing packages. US Army Natick Soldier Systems Centre published a white paper discussing how nanotechnology could be used in the "Future Soldier Initiative".

Figure 13. Military armour made of nanotechnology [61].

The researchers worked on planes that fly their wings on high–speed flights on aircraft and extend their wings to provide more elevators for take–off and landing. Unfortunately, the hinges that allow wings to lose weight, so researchers are developing materials that only require one electrical voltage to change the shape of aircraft wings and other structures. National Aeronautics and Space Administration (NASA) has developed a carbon nanotube polymer composite that bends when a voltage is applied [62].

The Mission Adaptive Rotor program is focused on improving the performance of helicopter rotors. Transformed rotors last longer and offer better performance. These improvements are partly due to the reduction in rotor vibration. Improved performance includes increasing the weight the helicopter can carry and extending its range. Deformation is not limited to the sky. The Transformer tool, developed by Defence Advanced Research Project Agency (DARPA), can travel on the roads, but it can take off and land vertically. The body of the vehicle may show a flicker to enlarge the wings or to retract them looking at the land or on the ground. Military personnel were able to use their ability to fly while traveling in Combat Aircraft (TX), jumping on obstacles, overcoming rough terrain, avoiding land mines, or ambushing, while maintaining their ability to drive on the roads [61–62].

6.8. Nanotechnology and Bioengineering

Nanotechnology and bioengineering transform basic science into novel materials, devices and processes for improved sustainability and health. They play a vital role in current and emerging technologies, and contribute to all areas of engineering through materials expertise including developing new materials and improving existing ones [62]. “Nano–bio” applications are as diverse as sustainable energy, regenerative medicine, biomedical imaging, drug and vaccine delivery, and personalised medicine. The impact of these new technologies will be felt across a wide range of endeavours, from therapeutic and tissue regeneration products, to bio derived consumer products and environmental applications. Of particular interest at The University of Queensland (UQ) is nanotechnology research at the biological interface, including nanoparticles developed to detect early cancer markers in the blood; 'smart surfaces' mimicking conditions in the body and encouraging high rates of stem cell production; and the engineering of cells to produce the building blocks for plastics. UQ has particular expertise in the areas of: Functional nanomaterials, biomedical engineering and industrial biotechnology [63].

6.9. Nanotechnology in Cosmetics

The applications of nanotechnology and nanomaterials can be found in many cosmetic products including moisturisers, hair care products, make up and sunscreen. A report from Observatory Nano (this report looks into some of the nanotechnologies used in the cosmetic industry and provides an overview of activity in this area) describes two main uses for nanotechnology in cosmetics: The first of these is the use of nanoparticles as ultraviolet (UV) filters. Titanium dioxide and zinc oxide are the main compounds used in these applications. Organic alternatives to these have also been developed.

Figure 14. Examples of additives for sunscreen formulations and additives for coloured cosmetics creams [64].

The second use is nanotechnology for delivery. Liposomes and niosomes are employed in the cosmetic industry as delivery vehicles. Newer structures such as solid lipid nanoparticles and nanostructured lipid carriers have been found to be better performers than liposomes. In particular, nanostructured lipid carriers have been identified as a potential next generation cosmetic delivery agent that can provide enhanced skin hydration, bioavailability, stability of the agent and controlled occlusion. Encapsulation techniques have been proposed for carrying cosmetic actives. Nanocrystals and nano–emulsions are also being investigated for cosmetic applications. Patents have been filed for the application of dendrimers in the cosmetics industry [64].
Key points include:

The legal requirements for cosmetics manufactured using nanomaterials are the same as those for any other cosmetics. While cosmetics are not subjected to premarket approval, companies and individuals who market cosmetics are legally responsible for the safety of their products and they must be properly labelled. To conduct safety assessments for cosmetic products containing nanomaterials, standard safety tests may need to be modified or new methods developed. Penetration enhancer–encapsulating or suspending key ingredients in so–called nano–spheres or nano–emulsions, increases their penetration into the skin: Hair products–using nano–emulsions to encapsulate active ingredients and carry them deeper into hair shafts [65].

6.10. Nanoparticle Applications in Manufacturing and Materials

Ceramic silicon carbide nanoparticles dispersed in magnesium produce strong, lightweight materials. A synthetic skin that can be used on the prosthesis is shown by its ability to heal itself and its ability to sense the pressure. The material is a combination of nickel nanoparticles and a polymer. If the material is brought together after cutting, it will give the ability to self–heal with each other in about 30 minutes. In addition, the electrical resistance of the material changes according to the press and gives the feeling of touch [65–66].

Silicate nanoparticles can be used to provide a barrier (e.g., oxygen) for gases or to provide nip in a plastic film used for packaging. This may slow down the food or the drying process. Zinc oxide nanoparticles are distributed to industrial coatings in order not to expose wood, plastic and textile products to UV radiation. Silicon dioxide crystal nanoparticles can be used to fill gaps between carbon fibres; So, the tennis racquets become stronger. Silver nanoparticles in the fabric are used to kill bacteria by softening the food [66].

7. Potential Hazards of Nanoparticles

Science and technology have described the unique properties of nanomaterials. These features can provide a wide range of social benefits, but at the same time they can create hazards and risks. The nanotechnology industry is still in its infancy, but when more nanotechnological applications are commercialized, the potential for human exposure to nanoparticles and raw nanomaterials will continue to increase. One of the areas of greatest concern about hazards is the exploration, use, disposal or recycling of a research laboratory, new company, manufacturing facility or engineering nanomaterials. To determine if the unique chemical and physical properties of new nanoparticles have resulted in specific toxicological properties, the nanotechnology community needs new ways to evaluate the hazards and ultimately to assess the risk factor, and therefore an attempt must be made to concentrate exclusively on potential health hazards. A potential danger that seems so until nowadays is the possibility of an explosion. Exploring the physical and chemical properties of nanoparticles, toxicity, the use of nanoparticles in the industry, and potential hazards have been literally reviewed [67].

Table 4. Possible risks of nanomaterials [68]

Nanomaterials	Possible Risks
Carbon nanomaterials, silica nanoparticles	Pulmonary inflammation, granulomas and fibrosis
Carbon, silver and gold nanomaterials	Distribution into other organs including the nervous system
Quantum dots, carbon and TiO_2 nanoparticles	Skin penetration
MnO_2, TiO_2 and carbon nanoparticles	May enter brain through nasal epithelium olfactory neurons
TiO_2, Al_2O_3, carbon black Co and Ni nanoparticles	May be more toxic than micron sized particles

7.1. Nanotoxicology: Health Effects of Nanotechnology

The environmental impact of nanotechnology has become an increasingly active research area. Until recently, the potential negative effects of nanomaterials on human health and the environment have not been highly speculative and proven [69]. Nevertheless, in the past few years several studies have been conducted on specific nanomaterials, e.g. nanoparticles may have a side effect in humans and animals. This gives great importance to parallels the negative experiences of some people with small particles.

Some types of nanoparticles are expected to be benign and are Us Food and Drug Administration (FDA) approved and used for making paints and sunscreen lotion etc. However, there are also dangerous nano sized particles and chemicals that accumulate in the food chain and have been known for many years: Asbestos, diesel particulate matter, ultra fine particles, dichloro diphenyl trichloroethane (DDT) and lead. The problem is that extrapolation of the experience of bulk materials to nanoparticles is difficult because the chemical properties can be quite different. For example, anti–bacterial silver nanoparticles dissolve in bulk silver–free acids with increased reactivity [70].

Table 5. An overview of some exposure cases for humans and the environment [71]

Product	**Examples**	**Potential release and exposure**
Cosmetics	IV absorbing TiO_2 or ZnO_2 in sunsreen	Directly applied to skin and late washed off. Disposal of containers
Full additives	Cerium oxide additives in the EU	Exhaust emissions
Paints and Coatings	Antibacterial silver nanoparticles coatings and hdrophobic nanocoatings	wear and washing releases the particles or componnets such as Ag
Clothing	Antibacterial silver nanoparticles coatings and hdrophobic nanocoatings	skin absorption; wear and washing releases the particles or componnets such as Ag
Electronics	Carbon nanotubes proposed for future use in commercial electronics	disposal can lead to emission
Toys and utensils	Sports gear such as golf clubs are beginning to be made from eg. carbon nanotubes	disposal can lead to emission
Combustion processes	Ultrafine particle are the result of diesel combustion and may other processes can create nanoscale particles in large quantities.	Emission with the exhaust
Soil regeneration	Nanoparticles being considered for soil regeneration	High local emission and exposure where it is used
Nanoparticle production	Production often produces by product that cannot be used (eg.not all all nanotubes are singlewall)	If the production is not suitably planned, large quantities of nanoparticles could be emitted locally in wastewater and exhaust gasses.

7.2. Nanoecotoxicology

In response to the above concerns, a new area of research called "nano (eco–) toxicology" is defined as "the knowledge of nanostructures and nanostructures dealing with the effects of living organisms." Below it will be briefly explained why people are exposed to nanoparticles, and in particular it will be tried to explain the concerns of nanoparticles. This will lead to a general knowledge of the dangerous properties of nanoparticles in the environment and nanocomotoxicology and includes a discussion of the main areas of uncertainty and information gaps [72].

7.3. Human or Ecotoxicology

This section will focus on human toxicology on the focal point, the ecotoxicological and environmental effects of nanomaterials, but on the assumption that such analogies are warranted or that their work provides new information on the field of nanocomotoxicology. As further investigations are made, it will be learned more about nanoparticles human toxicology. Today, it is difficult to predict the global production of nanomaterials for three fundamental reasons:

First of all, it is not clear what "nanotechnology" is. Second, nanomaterials are used in a wide variety of products and industries, and there is a general lack of knowledge about what is produced in third place, what and in what amount.

The annual production of carbon–based nanomaterials is guessed to be several hundred tons in 2001, but it is estimated that in 2003, nanotubes alone would be around 900 tons distributed worldwide among 16 manufacturers [73].

Although there is little information on the production of carbon–based nanomaterials, for example, the annual production volumes of materials with quantum dots, nano–metals and nanostructured surfaces are not known at all. The development of nanotechnology is still in its infancy and the current production and the use of nanomaterials probably does not represent future use and production [5].

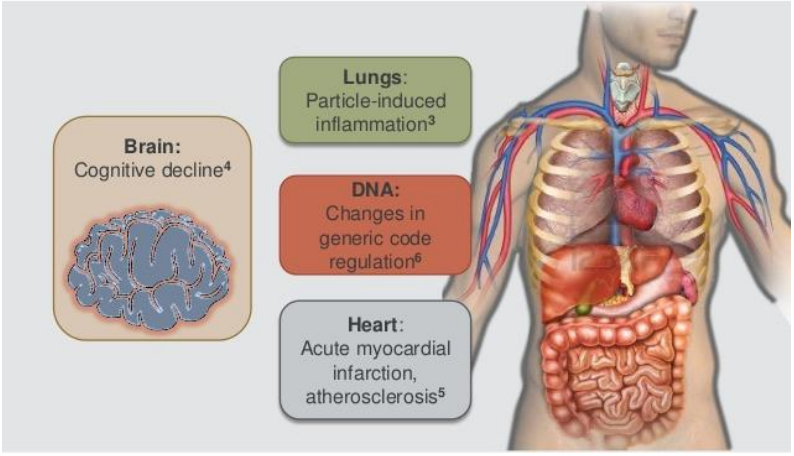

Figure 15. Illustration indicating how nanoscale particles can damage the body [74].

7.4. Exposure of Environment and Humans

Exposure of nanomaterials to workers, consumers and the environment is inevitable with increasing numbers of commercially available products containing increased production volumes and nanomaterials or based on nanotechnology. Exposure is an important element in the risk assessment of nanomaterials as it is a prerequisite for the potential toxicological and eco toxicological effects to take place. If there is no exposure–there is no risk. Nanoparticles are already used in a variety of products and exposure can take place in more than one way. Human exposure routes include: Dermal (e.g., through the use of cosmetic products containing nanoparticles), inhalation (e.g. nanoparticles in the workplace), ingestion (e.g., food products containing nanoparticles) and injection (e.g., nanotechnology based drug). Despite the wide variety of nanomaterials, concerns have often been raised about free nanoparticles.

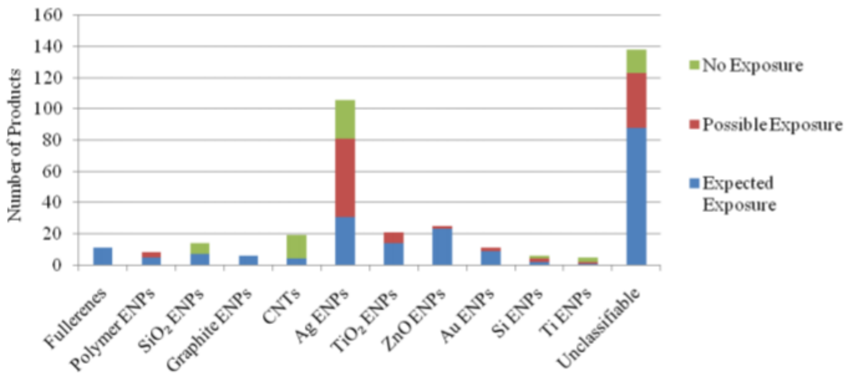

Figure 16. Materials vs. exposure likelihood [39].

The free nanoparticles can be introduced into the environment by direct exit or by disruption of the nanomaterials (e.g., surface–bound nanoparticles or nano sized coatings). Environmental exposure routes are high. A route is made through the waste water system. At present, the main contribution of carbon–based nanoparticles to the discharge of wastewater should be undertaken by research laboratories and manufacturing companies. Consumer products such as cosmetics, creams and detergents are already an important source for other types of nanoparticles, such as titanium dioxide and silver, and it should be assumed that discharges increase with the development of nanotechnology. However, as the development and applications of these materials increase, it must be assumed that this exposure pattern has changed dramatically. Drug and drug trails based on nanoparticles can be thrown around the wastewater system. Drugs are mostly coated and studies show that these coatings can degrade depending on the metabolism in the human body or the conversion to the environment due to UV light. It merely emphasizes the need to examine many possible processes that will change the properties of nanoparticles when released in nature [75]. Another way of exposure to the environment is if there is an effluent from which the nanoparticles are effectively withdrawn from the effluent drainage or waste water treatment plant. Additional ways of environmental exposure are spills resulting from the production, transport and disposal of nanomaterials or products.

Improvement with the help of free nanoparticles may be one of the most promising environmental nanotechnologies, but at the same time it may raise the most worry. The Royal Society and The Royal Academy of Engineering, in fact, recommend that the use of free nanoparticles in environmental applications such as healing be prohibited until the demonstration that the benefits are greater than the risks. Whether or not the produced nanomaterials are in the environment is not yet common; it is important to remember that in the past the concentration of xenobiotic organic chemicals in the environment has increased in proportion to this application–this is only a question before finding nanomaterials in the environment like nanoparticles– if we have the ability to find them. The size of the nanoparticles and the absence of metrological methods to detect them are a huge potential problem in relation to detection and healing both in relation to the fate of the human body and environment. Once a widespread environmental exposure occurs, human exposure through the environment seems almost inevitable; because living organisms of water and sediment can take nanoparticles from water, or it can cause the nanoparticles impregnated to vegetation or sediment to be eaten and thus transport nanoparticles along the food chain [76].

8. Effects of Nano Ecotoxicology for Different Living Organisms

Despite the widespread development of nanotechnology and nanomaterials over the last 10-20 years, researchers have focused on the potential toxicological effects on humans, animals and the environment by exposure to nanomaterials produced [77]. The term "nano eco technology" was developed at the request of a number of scientists and is now seen as a separate scientific discipline to produce data and information on the effects of nanomaterials on humans and the environment [78]. Data on toxicological information and nanomaterials are limited and eco toxicological data are more limited. Some toxicological studies have been carried out on biological systems in the form of nanoparticles, metals, metal oxides, selenium and carbon, but most toxicological studies have been performed with carbon fullerenes. Only a very limited number of eco toxicological studies have been carried out on the effects of nanoparticles on the environmentally harmful species and most studies have been carried out on fullerenes, as in toxicological investigations [79].

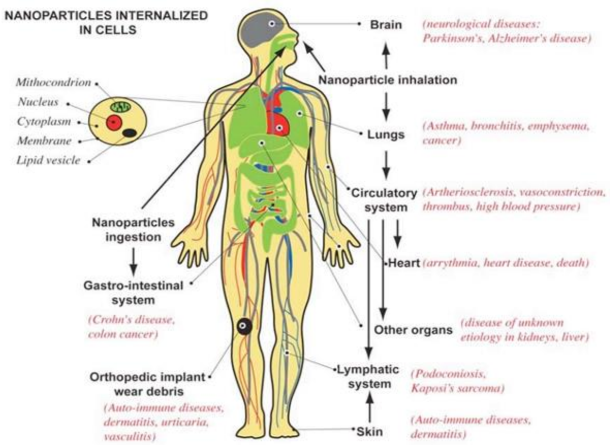

Figure 17. Interaction of nanoparticles with organs [79].

8.1. Nanoparticles Interact with Living Organism

Nanoparticles may have the same dimensions as biological molecules such as proteins. In vital systems, some of the large molecules they meet while absorbing into the tissues and tissues of the body can immediately absorb the surface.

The ability to have "sticky" molecules on the surfaces of nanoparticles depends on the surface properties of the particles and may be suitable for drug delivery applications. Thus, by designing the surface of a nanoparticle to specifically adsorb to the surface of the target cell, it is possible to deliver a drug directly to the cell in a specific cell. However, the interaction with living systems is also influenced by the size of the nanoparticles. For example, nanoparticles not being as large as a few nanometres can reach well into biomolecules that are not possible for larger nanoparticles. Nanoparticles can cross cell membranes. It has been reported that inhaled nanoparticles can reach the blood and to other target sites such as the liver, heart, or blood cells. The main factors in the interaction with living structures are nanoparcosis, the ability of nanoparticles to propagate in the body and their solubility. Some nanoparticles readily dissolve and the effects on living organisms are the same as those of the chemicals they make. However, other nanoparticles do not readily decompose or dissolve. Instead, they can accumulate in biological systems, and such nanoparticles can stay for a long time [80]. There is little detail about the interaction of nanoparticles and biological systems, and more information is needed about the response of living organisms to the presence of nanoparticles with various size, shape, chemical composition and surface properties to understand and classify the toxicity of nanoparticles.

The properties of nanoparticles on the health effects are:
Size–In addition to crossing cell membranes, nanoparticles of any material have a much larger surface area (i.e., surface area compared to volume) than larger particles, as well as being able to access blood and various organs due to their very small size. For this reason, relatively more chemical molecules are found on the surface. This may be one of the reasons that nanoparticles are generally more toxic than larger particles of the same composition.

Chemical composition and surface properties–The toxicity of nanoparticles depends on the chemical composition, as well as on the composition of the chemicals adsorbed on their surfaces. However, the surfaces of nanoparticles can be modified to make them less harmful to health. Shape–Although there is no conclusive final evidence, the health effects of nanoparticles probably depend on their shape. An important example may be a few nanometres in diameter, but nanotubes that can be several micrometres long. A new study exhibited that the toxicity of carbon nanotubes, which seem to produce harmful effects through a completely new mechanism different from the normal toxic powder model, is high [81].

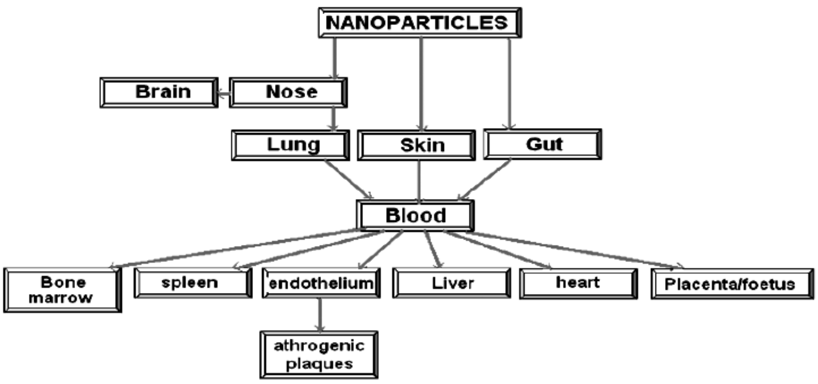

Figure 18. Summary of the hypothetical toxico kinetic pathways [82].

8.2. Inhales of Nanoparticles

The development of engineered nanomaterials is growing exponentially, despite concerns over their potential similarities to environmental nanoparticles being associated with significant cardiorespiratory morbidity and mortality. The mechanisms through which inhalation of nanoparticles could trigger acute cardiovascular events are emerging, but a fundamental unanswered question remains: Do inhaled nanoparticles translocate from the lung in man and directly contribute to the pathogenesis of cardiovascular disease? In complementary clinical and experimental studies, gold nanoparticles were used to evaluate particle translocation, permitting detection by high–resolution inductively coupled mass spectrometry and Raman microscopy. Healthy volunteers were exposed to nanoparticles by acute inhalation, followed by repeated sampling of blood and urine. Gold was detected in the blood and urine within 15 min to 24 h after exposure, and was still present 3 months after exposure. Levels were greater following inhalation of 5 nm (primary diameter) particles compared to 30 nm particles. Studies in mice demonstrated the accumulation in the blood and liver following pulmonary exposure to a broader size range of gold nanoparticles (2–200 nm primary diameter), with translocation markedly greater for particles <10 nm diameter. Gold nanoparticles preferentially accumulated in inflammation–rich vascular lesions of fat–fed –deficient mice. Furthermore, following inhalation, gold particles could be detected in surgical specimens of carotid artery disease from patients at risk of stroke. Translocation of inhaled nanoparticles into the systemic circulation and accumulation at sites of vascular inflammation provides a direct mechanism that can explain the link between environmental nanoparticles and cardiovascular disease and has major implications for risk management in the use of engineered nanomaterials [83].

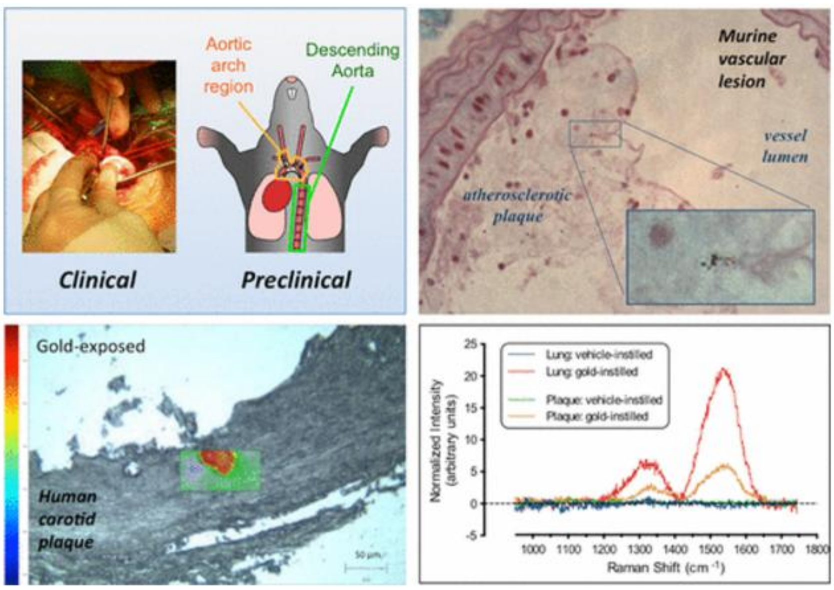

Figure 19. Clinical experiment of inhales and hazards of nanoparticles [84].

8.3. Nanoparticles DNA Damages

The toxicity of CuO nanoparticles (NPs) to human lung epithelial (A549) cells was investigated. CuO NPs (10–100 mg/L) had significant toxicity to A549 cells, whereas CuO bulk particles (BPs) showed much lower toxicity (24 h IC50, 58 and 15 mg/L for CuO BPs and NPs, respectively). Transmission electron microscopic (TEM) analysis demonstrated CuO NP entry into A549 cells and organelles, including lysosomes, mitochondria, and nucleus. Endocytosis was the primary pathway of CuO NPs uptake. CuO NPs (15 mg/L) induced mitochondrial depolarization, possibly mediated by reactive oxygen species (ROS) generation. Intracellular CuO NPs first generate ROS, which subsequently induces the expression of p38 and p53 and ultimately causes DNA damage (Comet assay). It is for the first time confirmed that the primary cytotoxic response is oxidative stress rather than DNA damage. A fraction of the CuO NPs was exported to the extracellular environment. In this study, centrifugal ultrafiltration tubes were successfully employed to determine the dissolved Cu^{2+} from CuO NPs in the cell medium. Dissolved Cu^{2+} ions contributed less than half of the total toxicity caused by CuO NPs, including ROS generation and DNA damage [85].

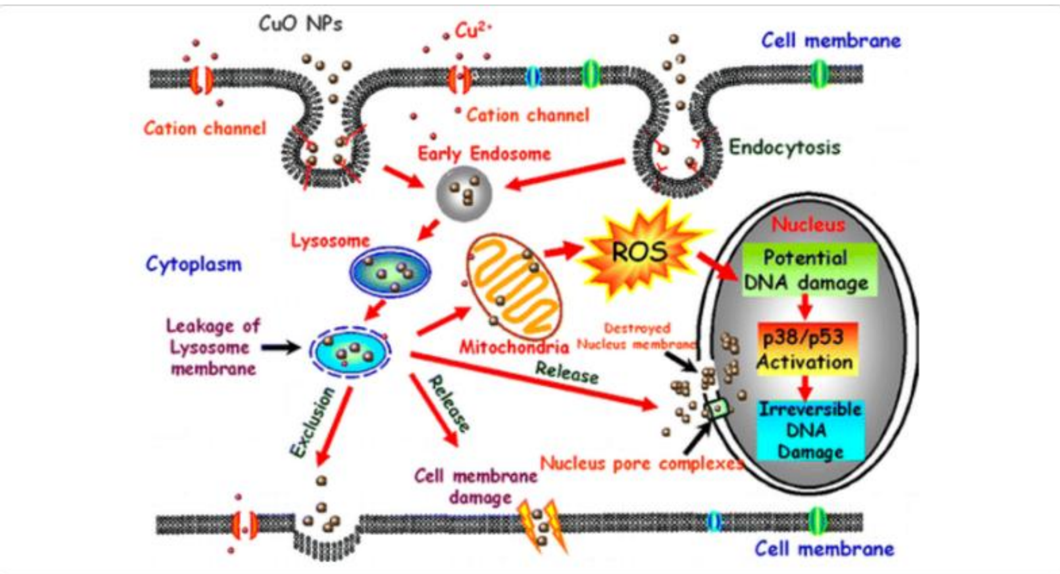

Figure 20. Nanoparticles interacting with DNA [86].

8.4. Bacteria

The impact of nanoparticles on bacteria is crucial because bacteria are the lowest level of many ecosystems and thus the entry of the food chain. The effects of buckminsterfullerene (C_{60}) aggregates on two common soil bacteria E. coli (gram negative) and B. subtilis (gram positive) were investigated by Fortner et al. under rich and little media under aerobic and anaerobic conditions, respectively. At concentrations above 0.4 mg/L, growth was completely depicted in both cultures exposed to both oxygen and light. No inhibition was observed in the rich medium at concentrations up to 2.5 mg/L; This may be due to coating by C_{60} precipitates or proteins in the environment. The emphasis was placed on the observation that surface chemistry did not react with hydroxylated C_{60}, and was consistent with the results obtained by Sayes et al. who investigated the toxicity of human dermal and liver cells. The antibacterial effects of C_{60} were also markedly clearer by Oberdorster compared to the 0.5 mg/L control during experiments with fish in the aquarium. Lyon et al. searched for the effects of four different preparative methods of C_{60} (mixed C_{60}, THF–C_{60}, toluene–C_{60} and PVP–C_{60}) on Bacillus subtilis and found that the four suspensions exhibited a relatively strong antibacterial activity ranging from 0.09 ± 0.01 mg/L–The increase in toxicity was disproportionately higher than the increase in surface area, although there was more antibacterial activity in fractions containing aggregates of 0.7 ± 0.3 mg/L or less. Silver nanoparticles are increasingly being used as antibacterial agents [87–88].

8.5. Crustacean

A number of studies have been performed with the freshwater crustacean Daphnia magna, which is an important ecological important species that furthermore is the most commonly used organisms in regulatory testing of chemicals. The organism can filter up to 16 ml an hour, which entails contact with large amounts of water in its surroundings. Nanoparticles can be taken up via the filtration and hence could lead to potential toxic effects.

Lovern et al. observed some mortality after 48 hours of exposure to 35 mg/L C_{60} (produced by stirring and also known as “nanoC_{60}” or “nC_{60}”), however 50 % mortality was not achieved, and hence an LC50 could not be determined [89].

A considerable higher toxicity of LC50=0.8 mg/L is obtained when using nC_{60} put into solution via the solvent tetrahydrofuran (THF)–which might indicate that residues of THF is bound to or within the C_{60}–aggregates, however whether this is the case in unclear at the moment. The solubility of C_{60} using sonication has also been found to increase toxicity, whereas unfiltered C_{60} dissolved by sonication has been found to cause less toxicity (LC50=8 mg/L). This is attributed to the formation of aggregates, which causes a variation of the bioavailability to the different concentrations. Besides mortality, deviating behaviour was observed in the exposed Daphnia magna in the form of repeated collisions with the glass beakers and swimming in circles at the surface of the water. There were changes in the number of hops, heart rate, and appendage movement after sub toxic levels of exposure to C_{60} and other C_{60}–derivatives. However, titanium dioxide (TiO_2) dissolved via THF has been observed to cause increased mortality in Daphnia magna within 48 hours (LC50=5.5 mg/L), but to a lesser extent than fullerenes, while unfiltered TiO_2 dissolved by sonication did not results in a increasing dose–response relationship, but rather a variation response. Lovern and Klaper have furthermore studied whether THF contributed to the toxicity by comparing TiO_2 manufactured with and without THF and found no difference in toxicity and hence concluded that THF did not contribute to neither the toxicity of TiO_2 or fullerenes.

Experiments with the marine species Acartia tonsa exposed to 22.5 mg/L stirred nC_{60} have been found to cause up to 23 % mortality after 96 hours, however mortality was not significantly different from normal controls. And exposure of Hyella azteca by 7 mg/L stirred nC_{60} in 96 hours did not lead to any visible toxic effects–not even by administration of C_{60} through the feed. Only a limited number of studies have investigated long–term exposure of nanoparticles to crustaceans. Chronic exposure of Daphnia magna with 2.5 mg/L stirred nC_{60} was observed to cause 40 % mortality besides causing sub–lethal effects in the form of reduced reproducibility (fewer offspring) and delayed shift of shield.

Templeton et al. observed an average cumulative life–cycle mortality of 13 ± 4 % in an Estuarine Meiobenthic Copepod Amphiascus tenuiremis after being exposed to single walled carbon nanotube (SWCNT), while mean life–cycle mortalities of 12 ± 3, 19 ± 2, 21 ± 3, and 36 ± 11 % were observed for 0.58, 0.97, 1.6, and 10 mg/L [90].

Exposure to 10 mg/L showed:
1. significantly increased mortalities for the naupliar stage and cumulative life–cycle;
2. a dramatically reduced development success to 51 % for the nauplius to copepodite window, 89 % for the copepodite to adult window, and 34 % overall for the nauplius to adult period;
3. a significantly depressed fertilization rate averaging only 64 ± 13 %.

Templeton also observed that exposure to 1.6 mg/L caused a significantly increase in development rate of 1 day faster, whereas a 6–day significant delay was seen for 10 mg/L.

8.6. Fish

A limited number of studies have been done with fish as test species. In a highly cited study Oberdorster found that 0.5 mg/L C_{60} dissolved in THF caused increased lipid peroxidation in the brain of largemouth bass (Mikropterus salmoides). Lipid peroxidation was found to be decreased in the gills and the liver, which was attributed to reparation enzymes. No protein oxidation was observed in any of the mentioned tissue, however a discharge of the antioxidant glutathione occurred in the liver possibility due to large amount of reactive oxygen molecules stemming from oxidative stress caused by C_{60} [91].

For Pimephales promelas exposed to 1 mg/L THF–dissolved C_{60}, 100 % mortality was obtained within 18 hours, whereas 1 mg/L C_{60} stirred in water did not lead to any mortality within 96 hours. However, at this concentration inhibition of a gene which regulates fat metabolism was observed. No effect was observed in the species Oryzia latipes at 1 mg/L stirred C_{60}, which indicates different inter–species sensitivity toward C_{60}.

Smith et al. observed a dose–dependent rise in ventilation rate, gill pathologies (oedema, altered mucocytes, hyperplasia), and mucus secretion with SWCNT precipitation on the gill mucus in juvenile rainbow trout. Smith et al. also observed:

- Dose–dependent changes in brain and gill Zn or Cu, partly attributed to the solvent;
- A significant increase in Na+K+ATPase activity in the gills and intestine;
- A significant dose–dependent decreases in TBARS especially in the gill, brain and liver; and a significant increase in the total glutathione levels in the gills (28 %) and livers (18 %), compared to the solvent control (15 mg/l SDS).
- Finally, they observed increasing aggressive behaviour; possible aneurisms or swellings on the ventral surface of the cerebellum in the brain and apoptotic bodies and cells in abnormal nuclear division in liver cells.

Recently Kashiwada reported observing 35.6 % lethal effect in embryos of the medaka Oryzias latipes (ST II strain) exposed to 39.4 nm polystyrene nanoparticles at 30 mg/L, but no mortality was observed during the exposure and post exposure to hatch periods at exposure to 1 mg/L. The lethal effect was observed to increase proportionally with the salinity, and 100 % complete lethality occurred at 5 time higher concentrated embryo rearing medium. Kashiwada also found that 474 nm particles showed the highest bioavailability to eggs, and 39.4 nm particles were confirmed to shift into the yolk and gallbladder along with embryonic development. High levels of particles were found in the gills and intestine for adult medaka exposed to 39.4 nm nanoparticles at 10 mg/L, and it is hypothesized that particles pass through the membranes of the gills and/or intestine and enter the circulation [92–93].

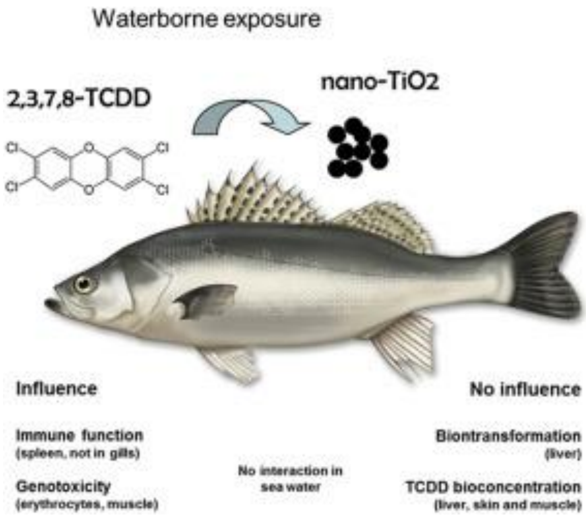

Figure 21. Example of effect of nanoparticles on marine organisms [94].

8.7. Plants

To the best of our knowledge, only one study of phytotoxicity has been conducted and demonstrates that aluminium nanoparticles become less toxic when coated with phenanthrene and emphasize the importance of surface treatment in relation to toxicity of nanoparticles.

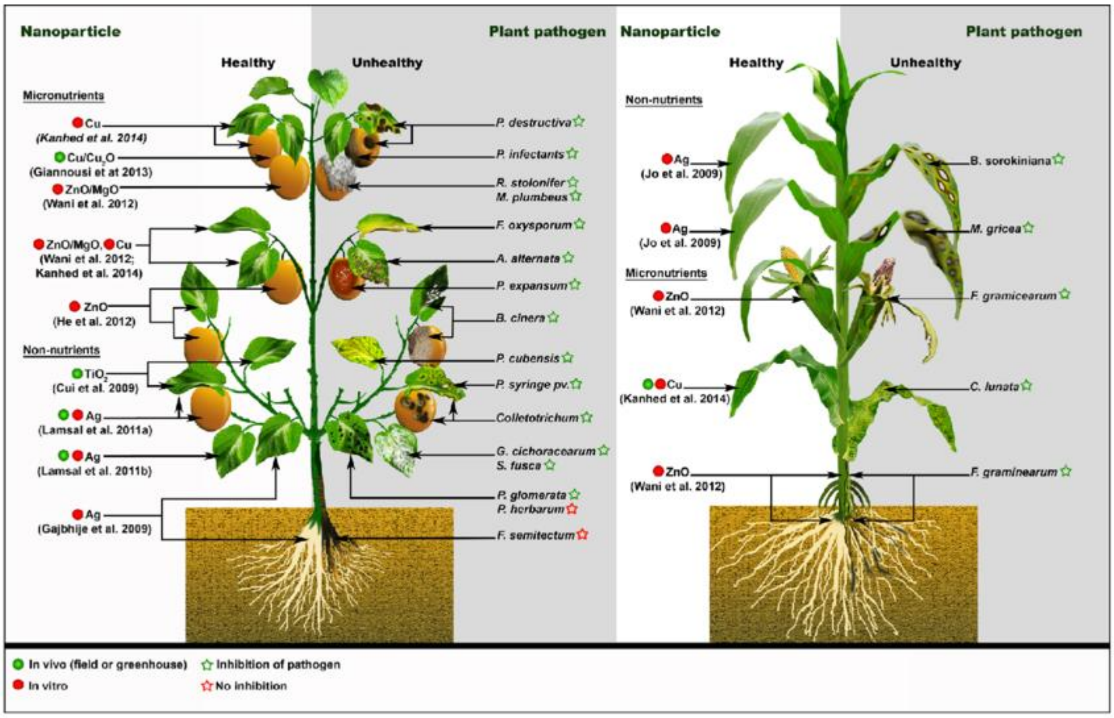

Figure 22. Effect of nanoparticle nutrients and non–nutrients on crop disease [95].

8.8. Interactions in the Environment

Nanoparticles may be used to increase the bioavailability of other chemical entities; So that they can be easily destroyed or the harmful substances can be transported to vulnerable ecosystems [96]. In addition to the toxicity of the nanoparticles themselves, it is also unclear whether nanoparticles increase the bioavailability or toxicity of other xenobiotic in the environment or other substances in the other body. Nanoparticles, such as C_{60}, have many potential uses in the medical field, for example because of their ability to transport drugs to parts of the body that are normally difficult to reach. However, this property may also be a source of adverse toxic effects. In addition, research is being conducted on the application of nanoparticles for the propagation of substances already present in the environment. This continues to increase bioavailability for degradation of microorganisms but it may also increase the uptake and increased toxicity of contaminants in plants and animals, but there is no scientific knowledge.

Nanoparticles are already seen in our food supply. They are used as preservatives to act as thickening and colouring agents to contain bacteria for a longer period of time. Unfortunately, since science is new, it is not necessary for companies to inhibit nanoscale materials on labels. According to news reports, nanoparticles have gums, mint, candy, flushing, pop tarts, coffee pickers, puddings, vitamins and more. We have little science on how these particles can be healthy once in our bodies, but in an animal study at Cornell University, scientists discovered that after eating nanoparticles, they were a change in the lining of intestinal walls. They have indicated that the results exhibit that nanoparticles can make small changes in pathway, such as excessive absorption of other harmful compounds, which can lead to health problems. The news about nanoparticles in food supply is still new and many consumers are still unaware of the potential risks. Just as it is in genetically modified organisms, we are allowed to use the industry without testing the new technology, and we are subjecting all of us to a giant scientific experiment that is still unknown [98].

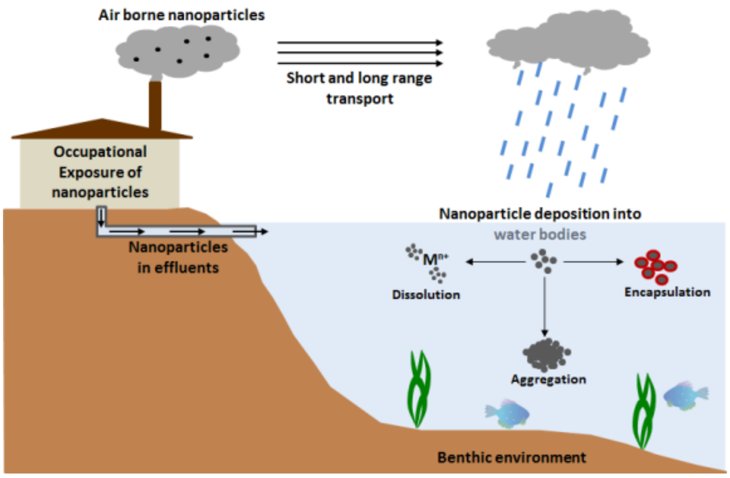

Figure 23. Nanoparticle interacting with ecosystem [97].

9. Identification of Key Hazard Properties

The size is the general reason for nanoparticles to become a topic of debate and concern. The very small dimensions of the nanoparticles increase the specific surface area associated with the mass; which means that even in small quantities, nanoparticles have a large surface area where reactions can take place. If the reaction with an organism's chemical or biological components leads to a toxic response, this response will be developed for nanoparticles. The strengthening of natural toxicity in this way is seen as the main cause of the fact that smaller particles are usually more biologically active and toxic than larger ones of the same material. For example, binding of nanoparticles to proteins, thereby altering their form and activity, may cause specific, toxic responses in the case of inhibition or alteration in one or more specific reactions in the body [99]. In addition to increased reactivity, the small size of nanoparticles means that they can be more easily taken up by the cells, picked up and distributed faster in the organism than their larger counterparts. Depending on the physical and chemical surface properties, it is expected that all nanoparticles will absorb larger molecules once they are taken into an organism by a specific uptake pathway.

Some nanoparticles, such as fullerenes, have been developed specifically for pharmacological applications because of their ability to rapidly diffuse and spread in the human body, even in normally difficult regions of the brain, such as brain tissue. Rapid intake and distribution can also be interpreted as a warning about possible toxicity, but it does not have to be valid at all times. Some nanoparticles have been developed with the intent of being toxic, for example, to kill bacteria or cancer cells, and in such cases toxicity may unintentionally cause adverse effects on humans or the environment [100].

Due to the lack of information and studies, toxicity of nanoparticles is discussed on the basis of ultra–fine particles (UFPs), asbestos and quartz; these dimensions are theoretically included in the definition of nanotechnology. Estimation of toxicity of nanoparticles can be done, for example, on the basis of chemical composition in the USA, where safety data sheets for most nanomaterials report properties and precautions related to bulk material. Such an approach is based on the assumption that it is the determining factor for chemical composition or toxicity. However, many scientific experts agree that the toxicity of nanoparticles should not be predicted and predicted solely based on the toxicity of bulk material.

The increased surface area to mass ratio means that the nanoparticles can be potentially more toxic per mass than the larger particles assuming that the dosage–response relationship will be different when compared to nanoparticles (assuming we do not think from bulk material and suspensions). This property is particularly troublesome in connection with toxicological and eco toxicological experiments because traditional toxicology associates effects with the mass given to the substances [99].

Inhalation studies on rodents have found that ultrafine particles of titanium dioxide in rodents cause greater lung damage when compared to larger fine particles for the same amount of substance. However, if the dose was estimated as surface area instead of mass, ultrafine and fine particles appeared to cause the same effect. This indicates that the surface area may be a better parameter for the analysis of toxicity when comparing different nanoparticle sizes in the same chemical composition. In addition to the surface area, the number of particles has been shown as an important parameter to be used instead of concentration. Although a comparison of ultra–fine particles, fine particles and even nanoparticles of the same substance in a laboratory environment is questionable, the toxicity of ultra–fine particles (such as cooking, burning) from anthropogenic sources can be questioned irrespective of general analogical studies, wood–burning stoves, etc., and nanoparticles, because the chemical composition and structure of ultrafine particles is very heterogeneous when compared to nanoparticles, which are often composed of certain homogeneous particles.

From a chemical point of view, nanoparticles can consist of transition metals, metal oxides, carbon structures, and in principle any other material, and thus toxicity changes as a consequence and it becomes impossible to classify nanoparticles according to their toxicity basis. Finally, the structure of nanoparticles has been shown to have a profound effect on the toxicity of nanoparticles. In a study comparing the cytotoxicity of different carbon–based nanomaterials, it was concluded that single–walled carbon nanotubes were more toxic than multi–walled carbon nanotubes [101].

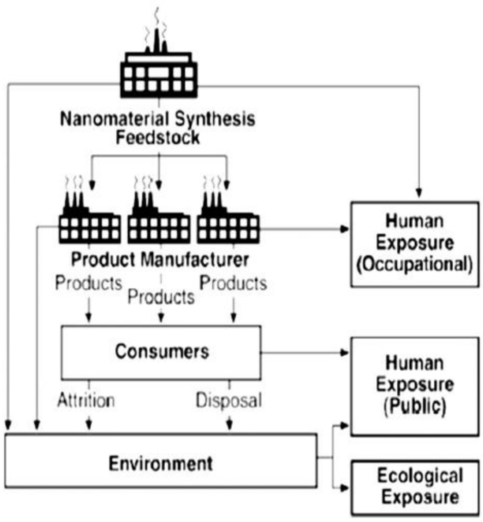

Figure 24. Potentials to release and exposures [92].

9.1. Solubility

Solubility in water is an important factor in predicting the environmental effects of a given substance; because they usually involve transformations and distribution processes, such as bioaccumulation, by contact with water. The solubility of a particular substance can be estimated from its structure and its reactive groups. For example, fullerenes is composed of carbon atoms and forms a very hydrophobic molecule that is not readily soluble in water.

Fortner et al. estimated that the solubility of individual C_{60} in polar solvents (such as water) was 10–9 mg/L. When C_{60} enters the basin with water, the aggregates occur at a size range of 5–500 nm and have an estimated molecular resolution of up to 11 degrees and a solubility of up to 100 mg/L. However, this can only be achieved by rapid and long–term mixing up to two months. C_{60} aggregates can be formed with pH values between 3.75 and 10.25. As indicated, the solubility is affected by the formation of C_{60} aggregates, which can lead to toxicity changes [87].

While aggregates form reactive free radicals that can damage cell membranes, they do not form free radicals preventing aggregation with free C_{60} coatings. Gharbi et al. points out that the double bonds in the C_{60} molecule are accessible as an important prerequisite for their interaction with other biological molecules.

The resolution of C_{60} is less in saline and Zhu et al. can only dissolve up to 22.5 mg/L in 35.5 % sea water. With Fortner et al. studies the total sediment from both the saline and the groundwater solution was found with an ionic strength above 0.1 I, but the aggregates would be stable in surface and underground waters with an ionic strength typically below 0.5 I. The solubility of C_{60} can be increased to about 13,000–100,000 mg /L by chemically modifying the C_{60} molecule with polar functional groups such as hydroxyl. The resolution can be further increased by the use of sonication or none–polar solvents. C_{60} does not behave like molecules or colloids in aqueous systems, but rather acts as a mixture of the two [87, 102].

The chemical properties of individual C_{60} such as log octanol–water partition coefficient and solubility are not suitable for predicting C_{60} aggregate behaviour. Instead, an important parameter such as size and surface chemistry must be applied.

The number of nanoparticles are very different than the solubility of nanoparticles. For example, it has been reported that carbon nanotubes are completely insoluble in water. It should be underlined which method is used for the dissolution of nanoparticles during the construction and interpretation of environmental and toxicological tests.

9.2. Evaporation

Information on the evaporation of C_{60} from aqueous suspensions has not been reported so far in the literature and evaporation is unpredictable at present, as it applies to the vapour pressure and Henry constant. Fullerenes are thought to have not evaporated from aqueous suspensions or solvents since C_{60} still requires C_{60} after evaporation of the C_{60} solvent by evaporation of the solvent [103].

9.3. Sorption

Oberdorster et al. nanoparticles tend to sorb into sediments and soil particles due to their large surface area when compared to mass, and will remain immobilized for this reason. The size alone would have the effect that the transport of nanoparticles would be dominated by diffusion rather than van der Waal forces and London forces, and would enhance surface transport, but collision with surfaces would always lead to sorption [104].

For C_{60} and carbon nanotubes, the chemical structure results in large absorption in the organic matter and hence low mobility, because these substances are composed of carbon. However, Lecoanet et al. found that both C_{60} and carbon nanotubes migrate in a porous environment similar to a sandy underground aquifer and that C_{60}'s single–walled carbon nanotubes are generally transported at a lower rate compared to fullerol and surface modifier C_{60}. The study also exhibits that the modification of the C_{60} on its way out to and from the periphery can have a profound effect on mobility. UV mitigation or microorganisms may result in modified C_{60} with potentially increased mobility, as reactions with naturally occurring enzymes, such as electrolytes or with damp acids, may bind to the surface and increase mobility [105].

9.4. Degradability

Most nanomaterials are likely to be inert, which can often be due to the application of nanomaterials and products produced for durable and hard wearing. Studies, however, suggest that the fullerenes may be biodegradable, while carbon nanotubes are biodegradable [102–103]. It is possible, according to the structure of fullerenes consisting solely of carbon, to use carbon as an energy source, such as microorganisms, for example, with other carbonaceous substances.

Fullerenes have been found to inhibit the proliferation of common soil and water bacteria, suggesting that toxicity can prevent degradability. However, it is possible that biological degradation may be affected by microorganisms other than the tested microorganisms, or that the microorganism may become adaptable after prolonged exposure. In addition, C_{60} can be degraded by UV light and UV irradiation of C_{60} dissolved in hexane results in partial or complete separation of the fullerene structure depending on the concentration [106].

10. Surface Chemistry and Coatings

In addition to the physical and chemical composition of the nanoparticles, it is important to consider any coating or modification of a given nanoparticle. Sayes et al. found that the cytotoxicity of different C_{60} derivatives changed in seven steps and toxicity decreased with increasing number of surface–bound hydroxyl and carbonyl groups. According to Gharbi et al., it is contradictory to previous work supported by Bottini et al. finding increased oxidized carbon nanotube toxicity in immune cells compared to intact carbon nanotubes [88,107–108].

The chemical composition of a given nanoparticle surface affects the bioavailability and surface charge of particles, which are important factors for both toxicology and ecotoxicology. It is suspected that the negative charge on the C_{60} surface may explain the ability of these particles to create oxidative stress in cells. The chemical composition also affects properties such as lipophilicity being important in relation to removal from cell membranes in addition to distribution and transport to tissues and organs in organisms. Coatings can also be designed to be transported to specific organs or cells, which is a major contributor to toxicity. However, it is not known how long the nanoparticles are covered in the human body and/or in the environment, because the surface can be affected by light, for example, when entering the environment. Experiments with non–toxic coated nanoparticles appeared to be multicellular toxic after 30 minutes [109].

11. Prevention of Nanoparticle Exposure

Although the health risks of nanoparticles are not clearly defined, the work practice and engineering control procedures to prevent exposure are well understood. Most measures adopted are similar to standard laboratory practices regarding the use of hazardous chemicals and gases [110]. In addition, other precautions include:

Lab protection and hygiene–regularly laundered lab coats must be worn. Lab coats may not be taken to private homes and laundered. Arm sleeves are required where high levels of exposure or splashes of solutions containing nanoparticles are anticipated. Hand washing facilities must be provided in all labs. Hand washing must be performed after handling nano materials. Standard Penn safety glasses are required when working in any lab. Gloves (disposable nitrile) must be worn when handling nano materials. Clothing should include long pants and closed toed shoes respirators and ventilators are needed to prevent inhalation Dry nanomaterials should be handled only within fume hood, biological safety cabinet, glove box or a vented filtered enclosure. Dry nanomaterials need to be transferred in closed containers. Nanoparticle solutions require to be handled over disposable bench covers. Aerosol producing activities (such as sonication, vortexing and centrifuging) may not be conducted on the open bench. These can be performed in fume hood, biological safety cabinet, glove box or a vented filtered enclosure. Spills of dry nanoparticles must be cleaned with a high efficiency particulate air (HEPA) vacuum. Dry sweeping must not be used. Large spills must be cleaned by electronic health record (EHRS). Lab pressurization must be negative to the hallway. Ventilation should be adequately managed. All solutions and solid materials must be disposed of as hazardous waste following established University guidelines. For now, consumers are left largely in the dark when it comes to knowing whether or not nanoparticles are in our products. Incidentally, the European Food Safety Authority requires that foods containing nanoparticles be labelled. The US Food and Drug Administration (FDA) does not require this of food manufacturers in America.

Some of the precautions below should be taken into account. Beyond that, the best bet is to continue to spread the word, buy from conscientious companies who are willing to disclose their use (or non–use) of nanoparticles, and continue to support legislation that strives for complete and honest disclosure of ingredients in all our products [37].

- Check your product against the list at the Woodrow Wilson International Centre for Scholars' Project on Emerging Nanotechnologies, which identifies which products, including foods and supplements, contain nanomaterials. The list is far from comprehensive, but does give us a place to start.
- Choose locally grown fresh foods as often as possible. Cut back on packaged and processed foods, in which nanoparticles are more likely to be present.
- Choose organic whenever possible. Avoid genetically modified organism (GMO) foods.
- Use natural and safe cosmetic products (especially those that stay on your skin, like sunscreens, moisturizers, and makeup) that do not include nanoparticles in their formulas. Check your products against the Skin Deep Database for more information on any potential nanoparticles [34, 36 and 38].
- Watch out for words like "nano delivery system" which indicates the presence of nanoparticles, but remember that companies are not required to reveal nanoparticles on labels [105].

12. Latest Development in Nanotechnology

Nanotechnology is rapidly gaining traction across a range of industries, from agriculture to water treatment to energy storage. While nanotechnology was first developed in 1959 as a way of manipulating matter at the atomic and molecular level, it wasn't until the early 2000s that it really began to flourish. Today, nanotechnology is one of the most innovative, cutting–edge areas of scientific study and it continues to advance at staggering rates. From scientists at technology–focused companies and institutions like NASA or Lockheed Martin, to students pursuing a nanotechnology degree, leaders in nanotechnology are creating the latest breakthroughs in the field. These breakthroughs are primed for significant worldwide impact.

12.1. Health: Drug Delivery

Today, cancer patients have three treatment options: surgery, chemotherapy or radiation. While the methods are different, the three treatment options are the same: destroying targeted cancer cells with minimal damage to normal tissue. However, according to the National Cancer Institute, "normal tissue or cancer does not erode all three methods risk damage." For example, according to chemotherapy, cytotoxic drugs kill cancerous cells, but are often released in the process to kill healthy cells. This can cause side effects such as hair loss, nausea, pain, nervous system effects, loss of appetite and fatigue. Treatments and reactions vary from patient to patient, but these side effects are common in most cancer patients [111]. For chemotherapy drug carriers, nanoparticles have provided some of the greatest advances in the treatment of cancer. The treatments that use nano–carriers to treat patients can focus on targeting cancerous cells and limiting the damage made to healthy cells.

Clinical translation of nanoparticle–based delivery systems remains challenging on account of their 3D nanostructure and requires robust nano–manufacturing process along with adequate analytical tools and methodologies. By identifying early enough in the development the product critical attributes and understanding their impact on the therapeutic performance, the developers of nano–pharmaceuticals will be better equipped to develop efficient product pipelines. Second–generation products are expected to broaden nano–pharmaceutical global market in the upcoming years [112].
Advantages of nanoparticles are increased bioavailability, dose proportionality, decreased toxicity, smaller dosage form (i.e., smaller tablet), stable dosage forms of drugs which are either unstable or have unacceptably low bioavailability in non–nano particulate dosage forms, increased active agent surface area results in a faster dissolution of the active agent in an aqueous environment, such as the human body, faster dissolution generally equates with greater bioavailability, smaller drug doses, less toxicity and reduction in fed/fasted variability [113].

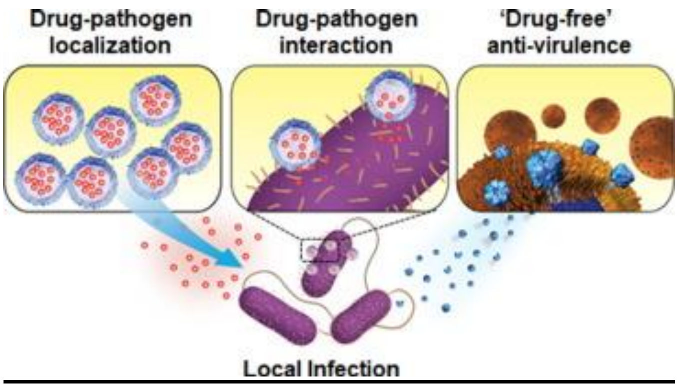

Figure 25. Nanoparticle based drug delivery systems [113].

12.2. Agriculture: Plant Protection and Livestock Productivity

Currently, the world population is growing by 1.13 percent annually with about 7.4 billion people in the world today. Experts predict that these number will continue to rise to more than 9 billion by 2050, with the largest population increase expected in the least developed countries. These estimates have world leaders, including the United Nations Food and Agriculture Organization, foreseeing increased food demand and increased pressure for healthy plants in developing countries. In response to this growing population concern, scientists in nanotechnology have focused on determining how nano–size particles can improve crop and livestock productivity. In addition to being a more recent application of nano–agriculture the potential to increase plant food production, increase food quality and reduce wastage, increase crops, monitor plant growth, increase plant food and animal diseases are very clear [114].

12.3. Water Treatment: Safe Purification

According to the World Health Organisation, “2.6 billion people–half the developing world–lack even a simple ‘improved’ latrine and 1.1 billion people have no access to any type of improved drinking water.” This lack of access to clean, safe water poses dire health risks to much of the world’s population, including: death from diarrheal disease, schistosomiasis infection, and intestinal parasites. Scientists and engineers are focused on applying nanotechnology to resolve these issues and make water safe and purified [115].

12.4. Diseases: Early Detection

Nanotechnology applications earn a noteworthy amount for early disease detection. In fact, scientists are exploring the use of nanoparticles to create a warning or "biomarker" if a cancerous tumour or other disease is found. Since these nanoparticles carry several peptides, theoretically they should send a large number of biomarkers to indicate the presence of a disease. Early diagnosis of diseases such as Alzheimer's and cancer allows treatment and potentially early initiation of treatment [116].

12.5. Energy Storage: Solar Energy

Solar energy is the future of energy storage, but comes with a heavy price tag. By 2014, solar energy accounts for more than one percent of the electricity in the United States and doubles the output of the generator compared to natural gas. Despite the costs associated with solar energy, benefits are important, including sustainability and low maintenance. To accelerate the development of solar energy, researchers are applying nanotechnology to solar energy. For example, through these developments, expectations are improving the absorption of light, improve the efficiency of light, and better thermal storage and transport. Nanotechnology have the potential to increase solar energy efficiency and reduce costs [117].

Today's researchers are expected to make great progress in the near and long–term future of the nanotechnology field as a number of industries continue to make significant progress. Research and development–focused universities offering undergraduate programs in nanotechnology provide students with the opportunity to gain real–world experience in applied nanotechnology and applied research in nanotechnology development [117–118].

12.6. Stronger Materials/High Strength Composites

The new generation of graphite and carbon nanotube–based devices are become lighter, but more powerful than they were made possible with carbon fibre, and become increasingly obvious with regard to automobiles, bicycles and sporting equipment. There are lots of studies for the production of stronger materials/composites by nanotechnology. These materials can be evaluated in many areas for instance dental applications, hip joint applications, armour applications.

Researchers at Massachusetts Institute of Technology (MIT) have designed a structure based on graphene shapes called gyroids predicted will have 10 times the strength of steel while having only 5 % the density of steel. Researchers at University of California (UCLA) have demonstrated a method to make a strong, lightweight metal by adding ceramic silicon carbide nanoparticles to magnesium. ArcelorMital is producing a kind of steel that contains nanoparticles. This material allows them to make thinner gauge, lighter beams and plates. These steel beams and plates are about same weight as aluminium, but can be produced at a lower cost. ArcelorMital is marketing this light weight steel to car manufacturers. Eagle Windpower has used an epoxy containing carbon nanotubes for producing nanotube–polymer composite windmill blades. This results in a strong but lightweight blade, which makes longer windmill blades practical. These longer blades increase the amount of electricity generated by each windmill. Researchers at North Carolina State University have developed a method to straighten the carbon nanotubes as the nanotube–polymer composite is being formed. They found that straightening the nanotubes increased the tensile strength of the nanotube–polymer composite, as well as improving the electrical and thermal conductivity [119].

12.7. Production Scalability

A major challenge is how to produce nanomaterials that make them reasonable. According to Timothy Fisher, Professor of Mechanical Engineering at Purdue University, technologies that can affect major challenge problems such as food, water, energy and the environment must be scalable. A technology using a unique feature of nanomaterials can often improve performance or engineering performance, but it is almost always the case that these technologies are often used as scarce materials (and for this reason, expensive) or slow or complex manufacturing processes (and also expensive) [120].

12.8. More Trading

Over the next few years, nanotubes are expected to evolve significantly in carbon nanotube production technology, particularly in the control of purity and build–up, and in cost savings due to scale economies. Developments will make carbon nanotube materials even more attractive for mechanical engineers. Along with the transformation of automotive, aerospace and sports equipment areas, nanotechnology also facilitates many changes: thinner, more affordable and more durable flat panel displays; Armour materials developed to protect soldiers; sensors for medical tests; more humane and effective treatments for cancer patients; cathode materials developed for safer and longer–lasting Li–ion batteries; and the list goes on. The properties of *carbon nanotubes* have caused researchers and companies to consider using them in several fields [121].

12.9. Sustainability

Mike Nelson, chief technology officer at NanoInk Inc., says nanomaterials and nanostructured surfaces are increasingly being used in many advanced energy storage and conversion projects, and nanomaterials and nano–manufacturing are contributing to more energy–efficient products in both production and use.

Missouri University–Deputy Director of Nanoscience Centre Eric Majzoub said that he can do the thermodynamics of solid–state reactions by controlling them through nanoscale miniaturization and make improvements in energy storage materials such as batteries, super capacitors and hydrogen. Nelson has the nearest short–term effect in terms of sustainability in transportation areas (automobiles and aircraft with more efficient and lighter materials that require less fuel) and three other relevant areas such as lighting, photovoltaics and energy storage. Three of these types of nanotechnologies are similar in terms of using nanostructured surfaces or materials to enhance efficiency from an electronic performance perspective, whether solar batteries or light–emitting diode (LED) lighting, whether they are pillars [122].

12.10. Nano Medicine

The application of nanotechnology is not exciting at all in the biomedical field where both the diagnostic and therapeutic areas are being developed. Houston–based nano–spectra biosciences develops a new therapy using a combination of gold nano–shells and lasers to thermally kill cancer tumours. According to Rice University's professors Dr. Naomi Halas and Dr. Jennifer West, technology promises to destroy tumours with the least damage to neighbouring healthy tissues [123].

Nano spectra CEO John Stroh said he hoped for European approval quite soon and US Food and Drug Administration (FDA) approval after 10 years of development and testing. In the field of diagnosis, nano–sensors that can detect, identify and measure biological substances in body fluids lead to early disease detection and early treatment and the ability of the body to detect environmental pollutants.

Researchers are improving dental implants by adding nanotubes to the surface of the implant material. They have shown that bone adheres better to titanium dioxide nanotubes than to the surface of standard titanium implants. As well they have demonstrated to the ability to load the nanotubes with anti–inflammatory drugs that can be applied directly to the area around the implant [124].

12.11. Nanotechnology for Oilfield Applications

Most of the proposed applications of nanotechnology in the oilfield can be classified into the following six areas: sensing or imaging, enhanced oil recovery (EOR), gas mobility control, drilling and completion, produced fluid treatment, and tight reservoir application. Some work is done on the propagation of nanoparticles and very little work is done on the delivery and recovery of nanoparticles. In addition, a lack of well–defined health, safety and environmental protocols for safe delivery and recovery of nanoparticles can be a showstopper and more focused research is needed in this area. As a remedy, it is proposed focused research and development on the use of naturally–occurring and industrial waste nanoparticles for oilfield applications. Of the six application areas, it is ranked imaging, drilling through unstable zones, tight reservoir applications and EOR as ones having the biggest potential impact. Using nanoparticles to detect hydrocarbon saturation in a reservoir can significantly impact how we plan field development, such as well placement. Similarly, using nano–enhanced drilling fluid to stabilize and drill through unstable zones can increase rate of penetration, reduce drilling cost and minimize environmental impact. Furthermore, using specially–designed nanoparticles to image and prop up induced and naturally occurring fractures in tight reservoirs can lead to sweet spot identification and more prolific wells. With its ability to make reservoir rocks more water–wet, water flooding by nano fluids also has the potential to augment or replace low–salinity water flooding as an EOR method [125–126].

12.12. Nanotechnology Development in Food Packaging

Current nanocomposite technologies to enhance the mechanical and barrier properties of synthetic polymers and biopolymers for food packaging are reviewed. In addition, nanotechnology developments targeting active packaging applications are discussed, including antimicrobial, oxygen scavenging, and shelf–life extension of food. Nanotechnologies that are currently being exploited for the development of intelligent packaging with enhanced communication function are presented, focusing mainly on oxygen, humidity and freshness indicators. Nanostructured coatings that enhance the barrier properties of packaging films are very important today [127].

12.13. Nanotechnology Research in Cancer

Although the incidence of cancer and cancer related deaths in the world has decreased over the past two decades due to improvements in early detection and treatment, cancer still is responsible for a quarter of the deaths in the world. There is much room for improvement on the standard treatments currently available and the National Cancer Institute (NCI) has recognized the potential for nanotechnology and nanomaterials in this area. The NCI Alliance for nanotechnology in cancer was formed in 2004 to support multidisciplinary researchers in the application of nanotechnology to cancer diagnosis and treatment. The researchers in the alliance have been productive in generating innovative solutions to some of the central issues of cancer treatment including how to detect tumours earlier, how to target cancer cells specifically, and how to improve the therapeutic index of existing chemotherapies and radiotherapy treatments. Highly creative ideas are being pursued where novelty in nanomaterial development enables new modalities of detection or therapy. Their discoveries to improve the functionality of nanoparticles for medical applications includes the generation of new platforms, improvements in the manufacturing of nanoparticles and determining the underlying reasons for the movement of nanoparticles in the blood [128–130].

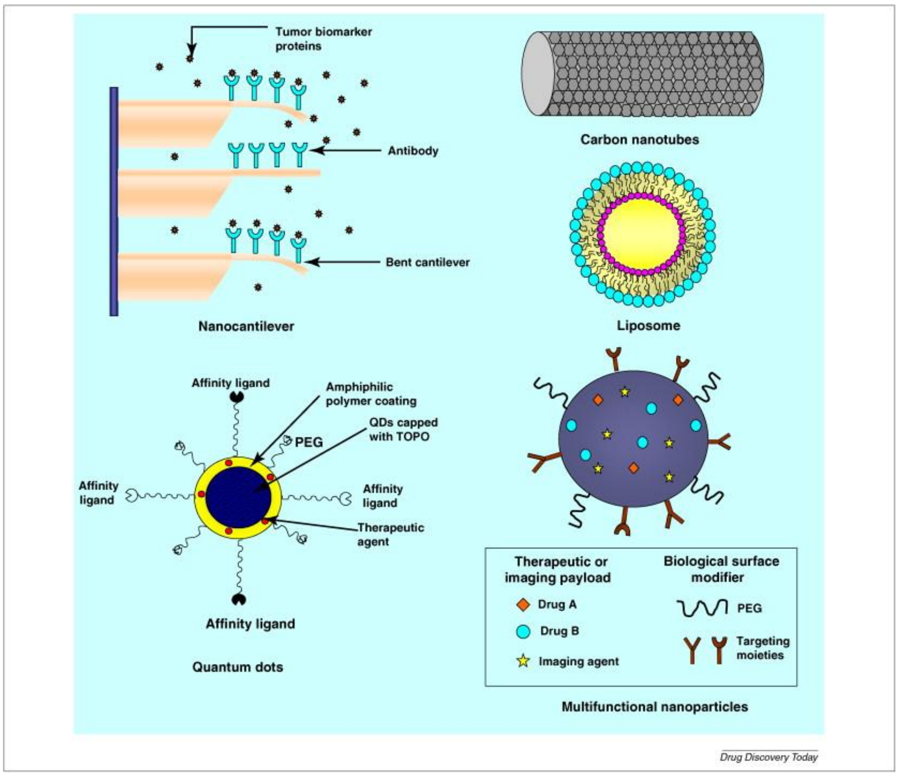

Figure 26. Multifunctional nanoparticles in cancer nanotechnology research [129].

13. Conclusions

Nanoparticles have become one of the most important work areas of our time thanks to the new properties they bring to materials. There are many studies in various fields, which are concentrated in a great extent. The same material produced in nano–size has many innovations thanks to its very different and superior properties when compared to one with larger grain size.

The use of nanoparticles, which are widely available in the fields of energy, medicine, optics, defence, biomolecules, cosmetics and health, is increasing day by day. Nanotubes supplied at very high costs after their first appearance in science and nanotechnology are becoming increasingly widespread, the cost is getting to reasonable levels and new nanomaterials are getting more and more every day. In addition to these superior features of nanoparticles, they also bring various damages to human beings, animals, plants, environment and living organisms.

The usage and prospect of nanoparticles especially in some fields have increased recently. In recent times, there have been very intensive studies and developments in drug delivery, cancer treatment, energy endurance, production of high–strength materials. It seems that researches on nanoparticles will intensively be carried on.

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