Chapter 9
Nanoparticle Toxicity in Water, Soil, Microbes, Plant and Animals

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Abstract Nanotechnology is defined as the design, synthesis and application of materials, devices whose size and shape have been engineered at the nanoscale. The building blocks of nanotechnology are nanoparticles. Nanoparticles are broadly classified as natural nanoparticles and anthropogenic nanoparticles. This chapter presents first the definitions, principles and applications of nanomaterials. Then the toxicity of nanomaterials on soil, water, food, microbes, plants and animals is detailed.

Keywords Nanoparticles • Toxicity • Water • Soil • Microbes • Bacteria • Plants • Animals

9.1 Introduction

The building blocks of nanotechnology are nanoparticles (Biswas and Wu 2005). The term nanoparticles is derived from the word 'nanos' meaning tiny. Particles that are measured in nanoscale level, i.e. 0.1–100 nm in diameter, are termed as nanoparticles (Royal society and Royal Academy of Engineering 2004). They have been present on earth and used by mankind for millions of years (Nowack and Bucheli 2007). Nanotechnology is defined as the design, synthesis and application of materials, devices whose size and shape have been engineered at the nanoscale (Buzea et al. 2007). It has bridged the gap among various other existing technologies of present scenario. It has mingled chemistry, physics, biology, engineering and technology, bioinformatics and biotechnology in such a manner that has offered a novel

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concept of interdisciplinary research. Nanoparticles play a key role and are known as the backbone of this technology due to their distinguishing and incomparable properties. The small size offers a large surface area as compared to their bulk counter parts (Biswas and Wu 2005). The large surface to volume ratio, surface charge, geometry and state of existence decide their relative reactivity.

Nanoparticles are broadly classified as natural nanoparticles and manmade (anthropogenic) nanoparticles. Anthropogenic nanoparticles are further sub divided into unintentional and intentional/engineered nanoparticles. A variety of nanoparticles are introduced in the environment by various natural processes. Volcanic eruptions, forest fires, weathering phenomenon and soil erosion driven by water and wind are the sources of natural nanoparticles (Smita et al. 2012). Whereas, biological origin i.e. viral particles (Hogan et al. 2004), Pollen fragments (McMurry et al. 2000). Coal fired combustion systems and incinerators (Chang et al. 2004); automobiles and diesel powered vehicles (Kittelson 1998); welding processes industrial boilers, fire places, automobiles, diesel (Vincent and Clement 2000); trucks, and meat-cooking operations (Hildemann et al. 1991) are the sources of unintentional anthropogenic nanoparticles. The intentional/engineered nanoparticle i.e. carbon containing nanoparticles (fullerence, carbon nanotubes etc.) inorganic nanoparticles (metal nanoparticles like nano silver, nano gold, titanium dioxide nanoparticles, zinc oxide nanoparticles etc.), organic and inorganic nanohybrids (Sajid et al. 2015) are synthesized by following two approaches i.e. either top down or bottom up method.

The engineered nanoparticles have been exploited in every sector of society. They have become a compulsive content of today's smart products. Their rapidly increasing application in textiles, electronics, pharmaceutics, cosmetics and environmental remediation is noticeable and calls for their impact assessment (Royal society and Royal Academy of Engineering 2004). Table 9.1 corroborates the application of different nanoforms.

In the present review we have taken an attempt to commemorate the toxicity imposed by the nanoparticles on every sphere of life forms. Brief information about toxic effect of nanoparticles on the environment, microbes, animals and plants has been discussed in this article. The possible preventive measures and future challenges are also mentioned.

9.2 Nanotechnology, an Old Concept

The concept of nanotechnology was proposed early in 1959 by a physicist Richard Feynman in a lecture-"There's Plenty of Room at the Bottom" at a meeting of the American Physical Society and was honored by Nobel prize for this valuable contribution. Whereas, the term nanotechnology was coined by Norio Taniguchi in 1974. Unknowingly, the people were using the nanoparticles in their work place. Evidences of nanotechnology's existence in the middle ages are drawn from the stained glasses of various old churches. The glass windows of European cathedrals

Table 9.1 Application of nanoparticles

Nanoparticle	Sector	Use	Product	Reference
Silver (Ag)	Textile	As casuals	T-shirt, socks, sports clothing, shoe	Benn and Westerhoff (2008)
	Food packaging:	As antimicrobial agent	Blue moon goods fresh box silver	Cushen et al. (2012)
			Nanoparticle food storage container	Alfadul and Elneshwy (2010)
		As antimicrobial agent	Nano Care Technology Ltd. Antibacterial	Bouwmeester et al. (2007)
		As antimicrobial agent	Sunriver industrial nanosilver fresh food bag	Huang et al. (2011)
	Implants and medical devices	Dental hygeine	Toothpaste	Reidy et al. (2013)
		Treatment of eye condition		Reidy et al. (2013)
		Application in plastic		Reidy et al. (2013)
		To produce surgical meshes		Reidy et al. (2013)
		Vascular prosthesis		Reidy et al. (2013)
		Ventricular drainage catheters		Reidy et al. (2013)
		In surface coating of respirators		Cushen et al. (2012)
		Due to plasmonic property used in	Biosensor	Austin et al. (2011)
		In reducing secondary bacteremia	Acticoat	Reidy et al. (2013)
	Consumer products	In water treatment process/		Reidy et al. (2013)
		Silver impregnated (<100 nm)	Water filter	Nowack et al. (2011)
		Surface coatings, paints and washing machine		Reidy et al. (2013)
				Reidy et al. (2013)

(continued)

Table 9.1 (continued)

Nanoparticle	Sector	Use	Product	Reference
			Air filters	Reidy et al. (2013)
			Vaccum cleaners	Klaine et al. (2008)
			Phones	Klaine et al. (2008)
			Laptops	Klaine et al. (2008)
			Toys	Klaine et al. (2008)
			Baby products	Cerkez et al. (2012)
	Other products	In disinfection	Disinfecting spray	Wijnhoven et al. (2009)
		Imparting fragrance	Deodrants	Lorenz et al. (2011)
			Other cosmetics	Lorenz et al. (2011)
		As antifungal agent	Fungicide	Wright et al. (1999)
TiO_2	Domestic purpose	In cleaning items	Detergent	Kaida et al. (2004)
			Toothpaste	Kaida et al. (2004)
			Window panes	Remédios et al. (2012)
			Ceramic tiles	Remédios et al. (2012)
		Medical implants	Biosensor	Remédios et al. (2012)
	Commercial purpose	Displays	Television screen	Remédios et al. (2012)
			Computer moniters	Remédios et al. (2012)
		As photocatalyst:	Solar cells	Klaine et al. (2008)
			Batteries	Remédios et al. (2012)
	Food products			Remédios et al. (2012)
	Environmental remediation	As decontaminant		Esterkin et al. (2005)

(continued)

Table 9.1 (continued)

Nanoparticle	Sector	Use	Product	Reference
ZnO	Cosmetics	As UV light scattering additive	Sunscreen	Serpone, et al. (2007)
			Toothpaste	Serpone et al. (2007)
			Beauty products	Serpone et al. (2007)
		In electronic items		Song et al. (2010)
		In textiles		Dastjerdi and Montazer (2010)
		As essential ingredient in:	Antifouling paints	IPPIC (2012)
CuO	Electronics and technology		Lithium batteries	Sau et al. (2010)
Gold nanoparticles (Au)	Electonics	Used in conducting Inks/ Films		Klaine et al. (2008)
Iron oxide			Lipstick	Remédios et al. (2012)
		As detoxifying agent		Zhang (2003)
Alumina			Shampoo	Klaine et al. (2008)
CeO_2 cerium dioxide		As combustion catalyst	Diesel fuel	Park et al. (2008)
	Metallurgical and glass/ ceramic application		Solar cells	Serpone et al. (2007)
			Gas sensors	
			Oxygen pumps	Lin et al. (2006)
Carbon nanotubes	Commercial application	Polymer composites	Lubricants, machinable ceramics,	Remédios et al. (2012)
		Structural composites	Magnetic materials, military battle suits	Remédios et al. (2012)
		Conductive coatings		Remédios et al. (2012)
		Electromagnetic shielding		Remédios et al. (2012)
	Medical application	Orthopedic implants		Klaine et al. (2008)
		Automotive industries		Klaine et al. (2008)
	Others	In water purification system		Klaine et al. (2008)
		Adhesives		Klaine et al. (2008)

(continued)

Table 9.1 (continued)

Nanoparticle	Sector	Use	Product	Reference
Quantum dots	Electronics and technology		(Insulators Semiconductors Magnetic materials)	
			Solar cells	Royal society (2004)
			Photovoltaic cells	Royal society (2004)
			Security inks	Royal society (2004)
			Photonics	Royal society (2004)
			Telecommunication	Alivisatos et al. (2005)
	Medical application	In biological imaging	As markers	Hoet et al. (2004)
			As targeted therapeutics	Alivisatos et al. (2005)
Dendrimers	Medical devices	In drug delivery		Royal society (2004)
		As surface modifiers for enantioselective catalysis	Macrocapsules	Klaine et al. (2008)
			Nanolatex	Klaine et al. (2008)
			Coloured hlasses	Klaine et al. (2008)
			Chemical sensors	Klaine et al. (2008)
			Modified electrodes	Klaine et al. (2008)
			DNA transfecting agents	Klaine et al. (2008)
		As therapeutic agent	Hydrogels	Klaine et al. (2008)
			DNA chips	Klaine et al. (2008)
Nano composites	Vehicular application	Packaging auto- parts		Royal society (2004)
Carbon black			Plastic fillers	Hoet et al. (2004)
Fumed silica	Vehicular application	Used in car tyres and plastic fillers		Hoet et al. (2004)
Silica	Gene delivery			Ravi Kumar et al. (2004)

are live examples of this. The historical aspect of nanotechnology from the most primitive time to the middle age was commemorated by (Daniel and Astruc 2004). Due to very astonishing optical properties of nanoparticles they have been used since the fourth century, the prominent example of which is the dichroic glass of Lycurgus cup whereas, the use of nanomaterials in industrial sectors begins in twentieth century (Horikoshi and Serpone 2013). Use of silver nanoparticles as an antiseptic agent has been documented early in Rig veda. Various metals in nano form occupies a remarkable place in ayurvedic, sidhha and unani system of medicine due to their terrific potential in curing a wide range of diseases and abnormalities.

9.3 Distinguishing Properties of Nanoparticles

Before highlighting the hazardousness of nanoparticles the expected factors that are responsible for nanoparticle toxicity are size, shape, nature, reactivity, mobility, stability and surface chemical charge (Sajid et al. 2015). Property of the material changes in nanoparticle regime. Activity of the nanoparticles are strongly governed by their stability which is attained by the provision of ideal capping agents. Temperature, pressure and long term incubation governs the texture and consistency of the nano regime material due to the onset of aggregation or agglomeration among the nanopopulation.

9.4 Effect of Nanoparticles on the Environment

Environment harbors all the things that exist within itself. Any alteration in the environment gradually affects its state, constituents and vice-Versa. Environment consists of two factors broadly classified as biotic and abiotic factor. Nanoparticles that are expelled in the environment either naturally or by anthropogenic means, Spontaneously through natural phenomenon or by engineered sources imparts/leads to some changes in them. The inhalation of atmospheric nanoparticle has caused 60,000 deaths per year reported by US Environmental Protection Agency (EPA) and also these Nanoparticles directly get transferred in to the brain Oberdorster et al. (2004) and Raloff (2003). This is due to the large surface area which has resulted in direct generation of reactive oxygen species that are known as harmful oxyradicals, having the potential to attack DNA, proteins and membranes too as a result of which the cell gets injured Brown et al. (2001). In addition they show affinity towards the transition metals and organic chemical pollutants that enhances the level of toxicity to a greater extent Cheng et al. (2004) Route of entry of nanoparticles varies with the type of habitat. Figure 9.1 reflects the possible route of nanoparticle exposure to various life form in brief. In terrestrial organisms they may enter via inhalation or ingestion Brigger et al. (2002) whereas, in case of the aquatic animals they enter via direct passage across gill and other external surface epithelia as reported by Moore

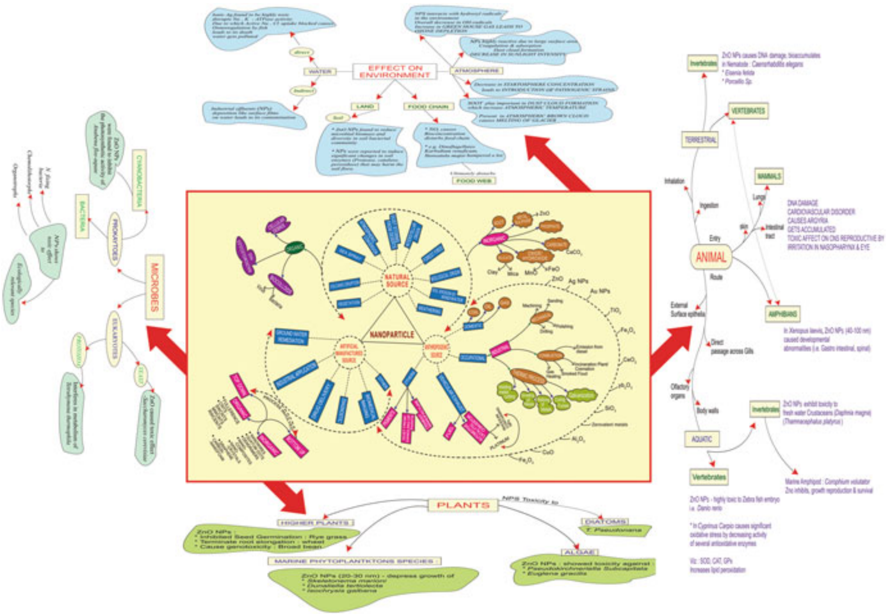

Fig. 9.1 Showing the sources of nanoparticles and their impact on various components of ecosystem

(2006). At cellular level engineered nanoparticles (single wall nanotubes) are responsible for swelling of the endoplasmic reticulum, it causes vacuolar changes. Additionally, high concentration of multiwalled nanotubes were found to be responsible for the degeneration, enlargement and rarefaction of macrophage cell's nucleus Jia et al. (2005).

In a nutshell, this can be clearly stated that nanoparticles (1–100 nm) can be life threatening. Source may vary but once entered in the environment they may harm every level of ecosystem.

9.4.1 Effect of Nanoparticles on Atmosphere

Accumulation of nanoparticle in the environment leads to generation of various environmentally toxic processes like dust cloud formation, Soot formation (Regional haze). These processes occur as a result of burning of organic waste materials found in nature that has been responsible for melting of Himalayan Glaciers Gustafsson et al. (2009). These are actually the naturally occurring nanoparticles that interfere with the natural resources. Incomplete combustion of fossil fuels increases risk of exposure to pathogenic species as suggested by Hua et al. (2007). According to Manning et al. (2005) others ill effects include abnormalities in level of environmental hydroxyl radical concentration. Wilson et al. (22007) reported the increase in ozone depletion mechanism by these tiny creatures that may be attributed due to change in tempaerature of stratospheric layer as reported by Tromp et al. (2003), Smita et al. (2012). According to Strawa et al. 2010 nanoparticles take part in the coarse material formation which is the major cause of global warming in present scenario.

9.4.2 Effect on Soil

The ultimate sink of every component in environment is soil and so as for nanoparticles. These tiny tools end up their journey in the soil or become dormant for some time. Soil is a natural reservoir for a wide variety of micro flora as it offer conducive environment for growth and survival of biological indicators. In turn they offer nutrients in the form of enzyme that take part in decomposition of soil content and improve the quality of soil by executing this cyclic process. In a broad sense their exists mutualism. The long term dormancy period of nanoparticles may evoke serious issues on the health of its inhabitant i.e. contribute in reducing the fertility of soil thereby causing an imbalance in the soil ecosystem (Kennedy and Smith 1995). Common ENPs include the metal ENPs (elemental Ag, Au, Fe etc.), fullerenes (grouping Buckminster fullerenes, CNTs, nanocones etc.), metal oxides (TiO_2, CuO, FeO_2, ZnO, Al_2O_3, SiO_2 etc.), complex compounds (Co–Zn–Fe oxide), quantum dots often coated with a polymer e.g. cadmium–selenide (CdSe) and organic polymers (dendrimers, polystyrene, etc.) Dinesh et al. 2012. Fortner et al. (2005) performed toxicity study of C_{60} aggregates on soil inhabiting *E. Coli* and *B. subtilis* bacteria. They found it to be toxic even at low concentration marked by reduced growth (>0.4 ppm). more over, this concentration has lowered the rate of aerobic respiration up to 4 ppm. Thus may interfere with soil development (pedogenesis) or behavior (e.g., crusting and dispersion) Klaine et al. (2008), Cameron et al. (1915).

9.4.3 Effect of Nanoparticle on Water

Domestic and Industrial wastes (may contain Nanoparticles in aggregate or colloidal form) expelled in the water bodies viz. ponds, rivers, sea etc. increases the threat of nanoparticle contamination**.** Discharges usually contains organic (protenaceous and polysaccharide from the microbes) and inorganic matter (heavy metal oxides) that make the water bodies unfit for use. It has been suggested that Ionic silver has found to be highly toxic that disrupts Na+K+− ATPase enzyme activity due to which active Na+ and Cl− uptake is blocked that causes Osmoregulation by fishes, leads to death of fishes thereby contaminate the water as studied by Tang and Wang (2004).

Nanoparticles may also accumulate on the surface microlayers of the oceans, presenting a route of aerosol exposure risk to marine birds and mammals, as well as the organisms living on the surface microlayer due to their hydrophobic nature. Kennedy et al. (2004), Simkiss K. (1990).

9.4.4 Effect of Nanoparticles on Food Chain

Starting from the primary producer (Plants) to that of the tertiary consumers (insects/animals). At every successive level nano-particles reflects their involvement by being entered in their metabolic pathway through active and passive transport. Confirmatory reports have been published by Holbrook et al. (2008), Lin et al. (2009) that shows their harmful effect in the food chain. Their small size offers large surface area that imparts them high potential to carry toxic materials i.e. such as lipophilic pollutants and heavy metals Baun et al. (2008) to enter the system.

9.4.5 Effect of Nanoparticles on Agriculture Production

About 70 % of India's economy is based on agricultural practices. The formation of dust clouds has found to be highly hazardous. Burning of wood for cooking and other purposes and the incomplete combustion of biomass give rise to natural nanoparticle. Their existence in environment has resulted in brown cloud formation which has remarkably lowered the sunlight intensity in south Asia. These pollution clouds have been indulged in the reduction of monsoon season in India. The productivity of chief crop plants like rice, wheat and soybean has immensely hampered as reported by UNEP 2002. Asian brown clouds are found to be loaded with large amount of soot and black carbon. These complexly degradable materials contributes to increase in melting of glaciers thereby blocking the availability of water to various glacier fed rivers as commemorated by Gustafsson et al. (2009). Water scarcity contributes in low yield of food crops.

9.5 Effect of Nanoparticles on Microbes

Nanoparticles not only affected abiotic factors rather have also been observed to pose harmful effects on microscopic creatures too ranging from the prokaryotes to Eukaryotes. For example – Akhavan and Ghaderi (2010) investigated the toxicity of graphene and graphene oxide damages the cell membrane of both the Gram-negative bacteria *Escherichia coli* and the Gram-positive bacteria *Staphylococcus aureus* by their sharp edges. A long descriptive about nanoparticles impact on micro flora has been expressed in Table 9.2.

Table 9.2 Harmful effect of nanoparticles on microorganisms

Test organism	Nanoparticle	Toxic effects	Reference
Bacterial *Sp.*	C60 (water suspension)	Antibacterial to broad range	Lyon et al. (2005, 2006), and Sayes et al. (2004)
Bacterial *Sp.*	C60 (encapsulated in polyvinylpyrrolidone)	Antibacterial to broad range	Kai et al. (2003)
Gm +veBacterial *Sp.*	Carboxyfullerence (malonic acid derivative)	Bactericidal effect	Mashino et al. (1999) and Tsao et al. (2002).
Gm +veBacterial *Sp.*	Hydroxylated fullerence	Bactericidal effect	Rozhkov et al. (2003)
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	C60 derivative with pyrrolidine groups	Inhibit its growth by interfering with energy metabolism	Mashino et al. (1999, 2003)
Gm +veBacterial *Sp.* ***(Mycobacteria Sp.)***	Other derivative of C60	Inhibit its growth	Babynin et al. (2002) and Bosi et al. (2000)
Gm –veBacterial *Sp.* ***(Salmonella typhimurium)***	Other derivative of C60: (carbon nanotube)	Antibacterial and antimutagenic effect	Babynin et al. (2002) and Bosi et al. (2000)
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	(SWCNT)	Antibacterial(cell membrane damage)	Kang et al. (2007) and Wei et al. (2007)
Bacterial *Sp.*	(MWCNT)	Cytotoxic in nature	Biswas and Wu (2005)
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	Metallic: quantum dots (uncoated)	Toxic causes oxidative damage to cell membrane	Kloepfer et al. (2005) and Hardman (2006)
Gm +veBacterial *Sp.* ***(Bacillus Subtilis)***	Metallic: quantum dots (uncoated)	Toxic causes oxidative damage to cell membrane	Kloepfer et al. (2005) and Hardman (2006)
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	Silver	Highly toxic (in environmental condition)	Chernousova and Epple (2013)
Bacterial *Sp.*	Silver	Bactericidal effect	Sondi and Salopek-Sondi (2004) and Morones et al. (2005)
Virus	Silver	Viricidal effect	Sondi and Salopek-Sondi (2004) and Morones et al. (2005)
Gm +veBacterial *Sp.* ***(Staphylococcus aureus)***	Gold	Low toxic	Nyberg et al. (2008) and Goodman et al. (2004)
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	Gold	Low toxic	Nyberg et al. (2008) and Goodman et al. (2004)
Gm –veBacterial *Sp.* ***(Shewanella oneidensis)***	Metal oxides: magnetite	Low toxic	De Windt et al. (2006)

(continued)

Table 9.2 (continued)

Test organism	Nanoparticle	Toxic effects	Reference
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	TiO_2	Accelerates solar disinfection by photocatalytic activity and (ROS)	Rincon and Pulgarin (2004) and Wolfrum et al. (2002)
Gm +veBacterial *Sp.* ***(Micrococcus luteus)***	TiO_2	Accelerates solar disinfection by photocatalytic activity and (ROS)	Rincon and Pulgarin (2004) and Wolfrum et al. (2002)
Gm +veBacterial *Sp.* ***(Bacillus Subtilis)***	TiO_2	Accelerates solar disinfection by photocatalytic activity and (ROS)	Rincon and Pulgarin (2004) and.Wolfrum et al. (2002)
Fungal Sp. ***(Aspergillus niger)***	TiO_2	Accelerates solar disinfection by photocatalytic activity and (ROS)	Rincon and Pulgarin (2004) and Wolfrum et al. (2002)
Gm +veBacterial *Sp.* ***(Bacillus Subtilis)***	MgO	Antibacterial effect	Huang et al. (2005)
Gm +veBacterial *Sp.* ***(Staphylococcus aureus)***	MgO	Antibacterial effect	Huang et al. (2005)
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	CeO_2	Antimicrobial effect	Thill et al. (2006)
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	Zno (uncoated)	Highly toxic	Bondarenko et al. (2012)
Gm +veBacterial *Sp.* ***(Bacillus Subtilis)***	Zno	Antibacterial activity	Sawai et al. (1995,1996)
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	Zno	Antibacterial activity	Sawai et al. (1995,1996)
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	ZnO (20 nm)	100 % mortality at 20 mg/ml of Zno	Jiang et al. (2009)
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	ZnO (10–30 nm)	Prevented growth at 500 mg/ml of ZnO	Premanathan et al. (2011)
Bacterial *Sp.*	SiO_2	Mild toxicity due to (ROS) production	Adams et al. (2006)
Gm –veBacterial *Sp.* ***(E. Coli Sp.)***	CuO (uncoated)	Highly toxic	Bondarenko et al. (2012)
Gm –veBacterial *Sp.*:-			
P. aeroginosa	CuO (80–160 nm)	Greatly affects the growth of these PGPR	Mahapatra et al. (2008)
Klebsiella puemoniae	CuO (80–160 nm)	Greatly affects the growth of these PGPR	Mahapatra et al. (2008)

(continued)

Table 9.2 (continued)

Test organism	Nanoparticle	Toxic effects	Reference
Salmonella Paratyphi	CuO (80–160 nm)	Greatly affects the growth of these PGPR	Mahapatra et al. (2008)
Shigella Strain	CuO (80–160 nm)	Greatly affects the growth of these PGPR	Mahapatra et al. (2008)
P. aeroginosa	Iron oxide nanoparticles	Reacts with peroxides present in environment,	Saliba et al. (2006) and Mishra and Kumar (2009)
		Generates free radical, which are highly toxic	
P. putida	Iron oxide nanoparticles	Reacts with peroxides present in environment,	Saliba et al. (2006) and Mishra and Kumar (2009)
		Generates free radical, which are highly toxic	
P. fluorescens	Iron oxide nanoparticles	Reacts with peroxides present in environment,	Saliba et al. (2006) and Mishra and Kumar (2009)
		Generates free radical, which are highly toxic	

9.5.1 Effect of Nanoparticles on Nitrogen Fixing Bacteria (Cyanobacteria & Others)

Cyanobacteria are integral part of producer community as they are the largest nitrogen fixer globallydue to the presence of nif gene and other ideal characteristics they are capable of fixing the atmospheric nitrogen themselves and serves as Biofertilizers thereby play a significant role in the growth of greenery. Due to the presence of oxygenic photosynthetic system they are capable of maintaining the equilibrium of earth atmosphere. These certain properties drag them in the list of essentials that vitally contribute for balancing the environment and nature. Brayner et al. (2010) performed the eco-toxicological investigation of ZnO Nanoparticles by taking Anabaena flos-aquae cyanobacteria and *Euglena gracilis* euglenoid microalgae as the experimental organism. ZnO Nanoparticles were synthesized by polyol process in which s trin-octylphosphine oxide (TOPO) and polyoxyethylene stearyl ether (Brij-76) were used as protective agents to control the particle size and shape. In the present investigation effect of ZnO nanoparticles on photosynthetic activity of the selected organisms was corroborated. In the case of Anabaena flos-aquae, addition of ZnO, ZnO-TOPO, and ZnO-Brij-76 induces stress which causes a progressive decline in the photosynthetic rate. Among these three different types of nanoparticles only ZnO-TOPO causes a fall in photosynthetic rate followed by cell death. However, In case of *Euglena gracilis*, all the nanoparticles were found to be indulged in cell death which was confirmed by doing the TEM analysis of their ultra thin sections. It reveals that polysaccharides produced by Anabaena flos-aquae avoid particle internalization after contact with ZnO and ZnO-Brij- 76 nanoparticles. Ma et al. (2013) suggested that nanoparticles have been found to interfere in the metabolic pathway of nitrogen fixing bacteria as well.

9.5.2 Effect of Nanoparticles on Plant Growth Promoting Rhizobacteria

Plant growth promoting rhizobacteria (PGPR) like *P. aeruginosa, P. putida, P. fluorescens, B. subtilis* and soil Nitrogen cycle bacteria viz., nitrifying bacteria and denitrifying bacteria have shown varying degrees of inhibition when exposed to ENPs in pure culture conditions or aqueous suspensions Mishra and Kumar (2009). Metal oxide nanoparticles of Cu (80–160 nm) were tested for antibacterial activity against plant growth promoting *Klebsiella pneumoniae, P. aeruginosa, Salmonella paratyphi* and *Shigella strains* Mahapatra et al. (2008). Iron and copper based nanoparticles are presumed to react with peroxides present in the environment generating free radicals known to be highly toxic to microorganisms like *P. aeruginosa* Saliba et al. (2006).

9.5.3 Effect of Nanoparticles on Eukaryotes

Likewise, the prokaryotes nanoparticles adversely affects the growth and metabolism of eukaryotes. Kasemets et al. (2009) has shown the toxic effect of ZnO nanoparticles on the unicellular Fungi i. e. yeast (*Saccharomyces cerevisiae*). Mortimer et al. (2010) suggested the toxicity of ZnO nanoparticles against free living Protozoan Sp. *(Tetrahymena thermophila).*

9.6 Effect of Nanoparticles on Plants

9.6.1 Effect of Nanoparticles on Algae & Diatom (Lower Plants)

Due to the adsorption of TiO_2 nanoparticles on the surface of algae, its weight becomes double as a result of this its floating capacity decreases and low surface gets exposed to sunlight leads to a gradual fall in photosynthetic rate as suggested by Navarro et al. (2008). In case of a green algae i.e. *Desmodesmus subspicatus*, TiO_2 nanoparticles were found to be toxic by Hund-Rinke and Simon (2006). ZnO nanoparticles showed toxicity against *Euglena gracilis* Euglinoid Brayner et al. (2010). Marine diatom *T. pseudonana* was found to be susceptible to ZnO nanoparticles and exhibit toxicity as reported by Miao et al. (2010).

9.6.2 Effect of Nanoparticles on Marine Phytoplanktons

Population growth studies on four marine phytoplanktons has been conducted by Miller et al. (2010) to assess the toxicity estimation of two metal oxide nanoparticle i.e. ZnO and TiO_2. Salty water bodies comprises a vast portion of earth and a repeated history of waste disposition has been in a common practice since ancient time, whether by accidental or intentional means. Marine phytoplanktons are adversely affected by engineered nanoparticles. In order to assess the sublethal effect of two selected metal NPs a modeling approach (Dynamic Energy Budget (DEB) framework) was employed in which They have found that ZnO nanoparticles depressed the growth rate of *Skeietonema marioni, Thalassiosira pseudonana, Dunaliella tertiolecta* and *Isochrysis galbana* by 50–70 %. Reproduction and early stage developmental study has been conducted by Nielsen et al. (2008). They have selected a marine brown algae *Fucus serratus* to test against manufactured Carbon black nanoparticle. Inference clearly states a great changes. Carbon black nanoparticles when subjected to the sperm suspension and embryo culture gets agglomerate thereby causing a decline in the fertilization success at a concentration of 100 mgl^{-1}.

9.7 Effect of Nanoparticles on Higher Plants

Nanoparticles are found to be indulged in the formation of reactive oxygen species in some higher plants explained by Navarro et al. (2008). Accumulation of nanoparticle takes place on the leaf lamina and on stomatal tissues causes an imbalance in the equilibrium inside outside the leaf and ultimately in plants Da Silva et al. (2006). Accumulation of nanoparticle on photosynthetic surfaces causes shading effects, i.e. reduced sun light availability and hence reduced photosynthetic rate Smita et al. (2012). Carbon nanotubes diminished rice yields and made wheat more prone to other pollutants Wild and Jones (2009) due to the asbestos-like behaviour of carbon nanotubes. Also, aluminium nanoparticle have been identified to inhibit root growth in various economically important plant species by interacting with root surface Canas et al. (2008), Yang and Watts (2005).

9.7.1 Phytotoxicity by Nanoparticles

Y. K. Mushtaq (2011) demonstrated The effects of Fe_3O_4, TiO_2, and carbon nanoparticles on cucumber plants. These nanoparticles exhibits the potential to negatively affect seed germination rate, root elongation, and germination index. Another study performed by Kumari et al. (2011) on the harsh effect of ZnO nanoparticles supports their toxic nature. Growing use of ZnO nanoparticles in the daily consumer products calls for an alert after their significant investigation. Workers have done a depth study by determining the Mitotic index (MI), micronuclei index (MN index), chromosomal aberration index, and lipid peroxidation of the root cells of *A. cepa* (grown hydroponically). They have treated the model organism with four different concentrations of ZnO nanoparticles dispersions (25, 50, 75, and 100 gml^{-1}). It was observed that MI decreases with the increase in concentration of ZnO nanoparticles to the contrary MN index and chromosomal index increases steadily. in the ZnO nanoparticles treated cells, the total count of micronucleated cell were higher than control set up which corroborates the genotoxic effect of ZnO nanoparticles on plant community.

9.7.2 Genotoxicity by Nanoparticles

Atha and collaborators (2012) reported for the first time that copper oxide Nanoparticles damaged DNA in some agricultural and grassland plants *(Raphanus sativus, Lolium perenne*, and *Lolium rigidum*). Mutation occurs in the crop plants that blocks their growth and results in gradual fall in productivity. Through this fraction of investigation they have clearified that metal nanoparticles acts as a carrier/mediator for DNA damage in all the living community including mammalian cell, plants and even the microscopic beings i.e. bacteria (Table 9.3).

Table 9.3 Harmful effect of nanoparticles on plants

Nanoparticle	Plant name	Harmful effect	Reference
	ALGAE:		
ZnO	***Pseudokirchneriella subcapitata***	Toxic interfere in metabolic pathway	Aruoja et al. (2009)
ZnO	***Anabaena flos-aquae***	Inhibit photosynthetic activity	Brayner et al. (2010)
Ag Nanoparticles	***unknown***	Highly toxic	Albright and Wilson (1974)
ZnO	***Euglena gracilis***	Cause cell death	Brayner et al. (2010)
ZnO (20 nm)	Marine diatom: ***T. pseudonana***	Found to be toxic	Miao et al. (2010)

(continued)

Table 9.3 (continued)

Nanoparticle	Plant name	Harmful effect	Reference
TiO_2	Unknown	Adsorbs on algal cell surface, affecting its ability to float.	Navarro et al. (2008)
		Reduced sunlight availability for photosynthesis	Navarro et al. (2008)
TiO_2	***Desmodesmus subpicatus***	Found to be toxic	Hund-Rinke and Simon (2006)
ZnO	***Allium cepa***	Exert cytotoxic & genotoxic effect	Kumari et al. (2011)
		Lipid peroxidation	Kumari et al. (2011)
		Decrease of the mitotic index	Kumari et al. (2011)
		Increase of the micronuclei	Kumari et al. (2011)
		Increase of chromosomal abberation index	Kumari et al. (2011)
ZnO	unknown	Penetrate plant system and may interfere with	Anita K. Patlolla (2013)
		intracellular components causing damage to cell division	Anita K. Patlolla (2013)
ZnO	***Triticum aestivum***	Makes it more vulnerable to other pollutants	Wild and Jones (2009)
		Reduced its biomass	Du et al. (2011)
		Due to dissolution of nanoparticles to Zn ions, facilitation of toxic Zn uptake occurs	Du et al. (2011)
ZnO 2000 mg/l	***Rye grass***	Inhibit germination of seed	Lin and Xing (2007)
		Terminate root elongation	Lin and Xing (2007)
ZnO	***Lepidium sativum*** (Garden cress)	Affects root elongation	Manzo et al. (2011)
ZnO	***Vicia faba*** (Broad bean)	Cause genotoxicity	Manzo et al. (2011)
ZnO (20–30 nm) at 1 mg/l	Marine phytoplankton species:		
	Skeletonema marioni	Depresses growth rate by 50–75 %	Miller et al. (2010)
	Thalassiosira pseudonana	Depresses growth rate by 50–75 %	Miller et al. (2010)
	Dunaliella tertiolecta	Depresses growth rate by 50–75 %	Miller et al. (2010)
	Isochrysis galbana	Depresses growth rate by 50–75 %	Miller et al. (2010)

(continued)

Table 9.3 (continued)

Nanoparticle	Plant name	Harmful effect	Reference
Carbon nanotubes	Economically important plants	Inhibit root elongation	Canas et al. (2008) and Yang and Watts (2005)
Aluminium nanoparticles	Economically important plants	Inhibit root elongation	Canas et al. (2008) and Yang and Watts (2005)
CNanoparticles	***Oryzae Sativa* (Rice)**	Diminishes yield	Wild and Jones (2009)
CuO	***Rhaphanus sativus***	Diminishes yield	Wild and Jones (2009)
CuO	***Lolium perenne***	Diminishes yield	Wild and Jones (2009)
CuO	***Lolium rigidum***	DNA damage, thus inhibits plant growth	Atha et al. (2012)
CuO (1000 mg/l)	***Cucurbita pepo***	Reduced emerging root length	Stampoulis et al. (2009)
Ag nanoparticles	***Cucurbita pepo***	Decrease plant biomass and transpiration	Remédios et al. (2012)
Yb_2o_3	Higher Plant Sp.	Affects root elongation	Ma et al. (2010)
	Cucumis sativus	Yb_2O_3 deposits were found in cytoplasm of root cells which are toxic in nature	Zhang et al. (2012)
CeO_2	Higher Plant Sp.	Affects root elongation	Ma et al. (2010)
La_2O_3	Higher Plant Sp.	Affects root elongation	Ma et al. (2010)
Gd_2O_3	Higher Plant Sp.	Affects root elongation	Ma et al. (2010)

9.8 Effect of Nanoparticles on Aquatic Organisms

To assess the merits and demerits of engineered nanoparticles several comparative studies has been done since time immemorial. These documentation provide a thorough and in depth study of the other face of a coin say the negative impacts of nanomaterials. Nanoparticles are being exploited and used in diversified applications. And being a multifunctional paradigm researchers have warned to use this versatile tool in an ecofriendly manner. Deleterious effects of nanoparticles are being experienced by atmosphere and land than how could the water bodies that covers 71 % of the earth surface will be ignorant and its inhabitant as well carbon nanotubes and fullerenes found to be potentially harmful especially to benthic organisms Velzeboer et al. (2011). Several researchers have excavated the harmful effects of nanomaterials by following different types of approaches. In recent years Blinova et al. (2010), have performed a comparative analysis of acute toxicity test of CuO and ZnO nanoparticles between crustaceans and protozoan population found in an artificially prepared fresh water ecosystem and a natural water body. In the study acute toxicity of crustaceans *Daphnia magna* and *Thamnocephalus platyurus* and protozoan *Tetrahymena thermophila* was determined.

9.9 Effect of Nanoparticles on Terrestrial Organisms

9.9.1 Effect of Nanoparticles on Terrestrial Invertebrates

Invertebrates cover a large group of animals ranging from top to bottom trophic levels of ecosystem. They are involved in various physiological phenomenon i.e. pollination, soil formation etc. Their occurrence differ from one habitat to the other and are considered as bioindicators (symbol of environmental change). Being an integral part of environment obviously this group of organisms encounters with the nanoparticles. In this section authors have tried to reflect the effect of nanoparticles on Annelids.

9.9.2 Effect of Nanoparticles on Annelids

Agricultural practices are the most important and widely used occupation cum source of income world wide. In order to earn the livelihood and growing demand of requirements one has to look for an effective and environmentally safe tool to reach the target of high productivity without compromising with the chemical based fertilizers and pesticides that has proved to be indulged in the formation of waste lands by successively decreasing the humus and fertility rate of the soil ultimately leading to a major cause of Bioaccumulation and biomagnification. Organic farming is the best alternative in which earthworms play the most significant role. Keeping in view the immense importance of earthworms in agriculture and zooming application of engineered nanoparticles in almost every sector of society studies has been conducted to see the effect of TiO_2 and ZnO nanoparticles by growing earthworms *Eisenia fetida* in an artificially created soil system by Hu et al. (2010). Distilled water at a concentration of, 0.1, 0.5, 1.0 or 5.0 g kg1 of Nanoparticles were prepared and earthworms were placed in that soil system for 7 days. By using Acute toxicity test and Comet assay concentration of Ti and Zn in earthworms was determined. It was observed that when doses of TiO_2 and ZnO were greater than 1.0 g kg^{-1} Zn accumulated in higher concentration than Ti and this leads to hyperaccumulation of Zn in the mitochondria of its gut cells which causes DNA damage. The cellulose activity was also inhibited at the dose level of 5.0 g kg^{1} of ZnO nanoparticles. Likewise, Khare et al. (2011) reported the toxicity of TiO_2 and ZnO nanoparticles less than 25 nm and 100 nm on the nematode (*Caenorhabditis elegans*). In this study toxicity of small and large sized nanoparticles of ZnO and TiO_2 were compared. It was found that small sized (25 nm) ZnO nanoparticles. were more toxic than that of the small (25 nm) and large sized (100 nm) TiO_2 nanoparticles.

9.9.3 Effect of Nanoparticles on Vertebrates

In the previous sections an attempt has been made to throw light upon the effect of nanoparticles on various abiotic and biotic factors of the environment. In this section the hazardous effect of inorganic nanoparticles i.e. ZnO has been demonstrated on two groups of vertebrates i.e. amphibians and mammals.

9.9.4 Effect of Nanoparticles on Amphibians

ZnO nanoparticles brought about developmental abnormalities in amphibians. Metallic nanoparticles have been found to cause deleterious effect up on encountered life forms. Among them ZnO, TiO_2, Fe_2O_3, and CuO nanomaterials (20–100 nm) were subjected to access their effect on amphibians in a study conducted by Nations et al. (2011a) on *Xenopus laevis* by employing the Frog Embryo Teratogenesis Assay Xenopus (FETAX) protocol. Experimental organism was subjected to dispersed nanomaterials at a concentration upto 1000 mg L^{-1} for TiO_2, Fe_2O_3, CuO, and ZnO. It was observed that inspite of causing mortality to the test specie these causes developmental abnormalities among them Viz.gastrointestinal, spinal, and other abnormalities. However, at a concentration of 10.3 mg L^{-1} of ZnO leads to total malformation. This study confers the harmful effects of ZnO nanoparticles. so its use and production needs to be checked for future perspective.

9.9.5 Effect of Nanoparticles on Mammals

Nanoparticles have been found to cause a number of serious problems such as cytotoxicity. Copper nanoparticles while incubated with zinc ions remains normal but when exposed to large sized ZnO nanoparticles. (at a non toxic concentration 6.25 μg/ml) its cytotoxic activity enhances gradually, also synergistic activity becomes strong. This is due to the presence of large sized ZnO nanoparticles which brings about the alteration in the human hepatoma cell line HepG2 Li et al. (2015) Table 9.4.

Table 9.4 Harmful effect of nanoparticles on animals

Test system	Nanoparticle	Harmful effect	Reference
Nematodes: (*Caenorhabditis elegans)*	TiO_2	Decrease in reproduction potential	Roh et al. (2009)
		Increased enzyme induction & protein formation	Roh et al. (2009)
Largemouth bass *(Micropterus salmoides)*	FullerenceC_{60}(0.5–1 mg/l)	Significant lipid peroxidation in brain	
		Total glutathione levels were marginally depleted in gills	Oberdörster (2004)
Daphnia magna	C_{60}water suspension (9 mg/l)	High rate of mortality has been noticed	Zhu et al. (2006)
Fathhead minnow	C_{60}water suspension (2.5–5 mg/l)	The peroxisomal lipid transport protein PMP70 was significantly reduced in the minnow	Oberdörster et al. (2006)
Zebrafish *(Danio rerio)*	C_{60}(prepared with benzene, THF, and acetone)	Suffered delayed embryo & larval development	
	(1.5 mg/l)	Decreased survival and hatching rates	Zhu et al. (2007)
Eukaryotic unicellular protozoan:	Carbon nanotubes	Observed pericardial edema	Zhu et al. (2006)
Stylonychia mytilus	MWCNT sonicated (1 mg/l)	Colocalization of CNTs within the mitochondria,	Zhu et al. (2006)
		Damage to micronucleus, macronucleus, and membrane	Gimbert et al. (2007)
Rainbow trout *(Oncorhynchus mykiss)*	Single-walled sonicated	Significant increases of $Na^{+}K^{+}$-adenosine triphosphatase	Gimbert et al. (2007)
		(ATPase) activity observed in the gills and intestine	
		Oxidative stress–linked effects observed	Gimbert et al. (2007)
Zebrafish *(Danio rerio)*	DWCNTs (240 mg/l)	Delay in hatching	Gulson and Wong (2006)
Zebrafish *(Danio rerio)*	Metallic copper (1.5 mg/l)	Gill injury and lethality observed	Seaman and Bertsch (2000)
		Acute toxicity observed	Seaman and Bertsch (2000)
Freshwater mussels *(Elliptio complanata)*	Quantum dots: cadmium telluride (CdTe)	Observed reduction in phagocytic activity	Karathanasis (1999)
		Lipid peroxidation increased at higher concentrations	Karathanasis (1999)
Mice	Graphene oxide [0–100 mg/L]	Down-regulation of genes, disturbance of cell energy metabolism, transduction	Wang et al. (2011)

(continued)

Table 9.4 (continued)

Test system	Nanoparticle	Harmful effect	Reference
Rats	SWCNT 1 or 5 mg kg71	Multifocal macrophage containing granulomas in lung	Warheit et al. (2004)
Guinea pigs	MWCNT 2.5 mg in 0.5 ml	Caused 'organising pneumonitis', pulmonary lesions	Grubek-Jaworska et al. (2006)
Mice	SWCNT 2-mg	SWCNT produced some activation of the histocompatibility complex, in CD4þ/CD8þT-cells	Koyama et al. (2006)
Rats	TiO_2 particles, rods or dots 1 or 5 mg	Produced transient inflammatory and cell injury effects	Warheit et al. (2006)
Rats	Ultrafine cadmium oxide 70 mg m^{-3}	Increased percentage of neutrophils	Warheit et al. (2006)
		Multifocal alveolar inflammation	Warheit et al. (2006)
		Showed elevated blood Cd.	Takenaka et al. (2004)
Rats	Ultrafine metallic nickel 0.15,–2.54 mg m^{-3}	Increase in pulmonary nickel,	Serita et al. (1999)
		Increase in lung weight	Serita et al. (1999)
		Accumulation of foamy alveolar macrophages (AM),	Serita et al. (1999)
		Generated AM indicating alveolar lipoproteinosis,	Serita et al. (1999)
		Acute calcification of the degenerated AM.	Serita et al. (1999)
Mouse spermatogonial stem cell line	Silver nanoparticles 5–100 mg ml71	Mitochondrial function are adversely affected,	
		Cells show increased LDH leakage	Braydich-Stolle et al. (2005)
Rat lung cells	Silver nanoparticles	Reduction in lung function and inflammatory lesions	Sung et al. (2008)
Sprague-Dawley rats		Silver nanoparticles accumulation in olfactory bulb and subsequent translocation to the brain	Kim et al. (2008a, b)
Rat liver cells	Silver nanoparticles	Cell leakage and reduction of mitochondrial function	Hussain et al. (2005)
Mouse fibroblast	Silver nanoparticles	50 µg/ml induced apoptosis to 43.4 % of cells	Arora et al. (2009)

(continued)

Table 9.4 (continued)

Test system	Nanoparticle	Harmful effect	Reference
HUMAN:			
Skin	Silver nanoparticles	Argyria-irreversible pigmentation of skin & argyrosis- pigmentation of eyes	Chen and Schluesener (2007)
Epithelium layer	Silver nanoparticles	Severe damage	Boosalis, et al. (1987)
Skin	Silver nanoparticles	Discolouration of the skin	Armitage et al. (1996) and Greene and Su (1987)
Eye	Silver nanoparticles	Severe irritation	Panyala et al. (2008)
Nose	Silver nanoparticles	Severe irritation	Panyala et al. (2008)
Brain	Silver nanoparticles	Neurotoxic damage	Cheng et al. (2004)
Male reproductive system	Silver nanoparticles	Cross blood-testes barrier,deposit in the testes, adversly effects sperm cells	Borm and Kreyling (2004)
Blood cells	Silver nanoparticles	Intensive toxic effect on PBMCs & inhibits phytohaemagglutinin-induced	Shin et al. (2007)
		Cytokine production	
Keratinocytes & fibroblasts	Acticoat, aquacel, Ag & contreet foam	Most significant cytotoxic effect	Panyala et al. (2008)
Cell	Ag nanoparticles >44.0 μg ml^{-1}	Necrotic in nature	Panyala et al. (2008)
Central nervous system (CNS)	Silver nanoparticles	Prolonged exposure leads to cerebral ataxia	Aaseth et al. (1981)
Respiratory system: (Lungs)	Silver nanoparticles	Produce surface radical and reactive oxygen specie, toxic to alveolar surface	Chen and Schluesener (2007)
(Lungs)	Silver nanoparticles	Induce oxidative stress in lungs epithelial cells	Limbach et al. (2007)
(Lungs)	Silver nanoparticles	Irritation in respiratory tract	Rosenman et al. (1987)
Brain	Silver nanoparticles	Manic depressive psychosis leads to ruptured aortic aneurysm, finally death	Dietl et al. (1984)
Skin	Silver nanoparticles	Cutaneous side effects: hypersensitivity reaction, allergic contact dermatitis, erythema multiforme	Fisher et al. (2003)

(continued)

Table 9.4 (continued)

Test system	Nanoparticle	Harmful effect	Reference
Lung	Pristine and MWCNTs	Alteration in its architecture, collapsed thick walled alveoli, presence of microhaemorrhagic foci	Coccini et al. (2013)
Human chest cavity	MWCNTs	Causes inflammation, production of scars/lesions, leads to mesothelioma	Poland et al. (2008)
Nucleus	C60 fullerence	Accumulate along nuclear membrane, penetrate and cause DNA damage	Porter et al. (2006)
Metabolic process in rats, human, mice	C60 fullerence	Reduce activity of hepatic enzymes i.e. glutathione	Iwata et al. (1998)
Blood and haematopoitic system	C60 fullerence	Triggered hemolysis of 40–50 % of cells	Bosi et al. (2004)
Human (HEK293) embryo kidney cell	SWCNTs – 0.78–200 $\mu g/ml^{-1}$	Inhibition of HEK293 cell proliferation, induced cell apoptosis, and decreased cellular adhesive ability	Cui et al. (2005)
Human bronchial epithelial cells(BEAS 2B)	TiO_2 nanoparticles (10 or 20 nm)	Cause DNA damage, lipid peroxidation and damage to nucleus	Gurr et al. (2005)
Human lung cell	Carbon nanotubes	Inflammation and oxidative stress	Pulskamp et al. (2007)
Human lung cell	Carbon black	Inflammation and oxidative stress	Monteiller et al. (2007)
Human lung cell	Silica	Inflammation and oxidative stress	Lin et al. (2006)
Human lung cell	Metal and metal oxides	Inflammation and oxidative stress	Limbach et al. (2007)
Human cancer cells	Graphene oxide [0–100 mg/L]	Oxidative stress	Zhang et al. (2010)

9.10 Conclusion

Nanoparticles are the most promising and widely exploited resources of present time. Their surface properties makes them unique, thus they are being used in every sector of society. To make and prove this technology as a boon we need to take some simple measures. By taking care while handling the engineered nanomaterials, by properlystudying the fate of the synthesized nanoparticle, also by implementing ecofriendly techniques that consumes minimum energy, labour and cost effective methods we can add beauty to our living world inspite of accelerating the pollution rate. Use of chemically engineered nanoparticles should be minimizes. Establishment of regulatory guidelines for nanoparticle synthesis is the urgent call, which should be followed by both the developed and developing nations. Now it's the need of time that without delaying the slogan of "GO Green" should be practiced not in words but in work. One thing is to be kept in mind i.e. the life cycle of engineered material should be well studied and the large scale synthesis of them should be executed on the basis of their fate in the environment. In the quest of innovation and advancement environmental issues are becoming more serious and uncontrolled. So, let's shake a leg towards the betterment of the earth in which we are living in.

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