



# Chapter-18

## NANO-SOLUTIONS FOR ENVIRONMENTAL SUSTAINABILITY: TRANSFORMING AND PRESERVING THE PLANET

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**ABSTRACT**

*Environmental deterioration is one among the most important concerns confronting the world today. It becomes worse every year and has an adverse impact on the environment as well as human health. The primary sources of contamination include sewage water, industrial effluents, haphazard pesticide and fertilizer use, and oil spills. Exposure to these toxins has been linked with a variety of health issues including respiratory ailments, cardiovascular disease, and cancer. Indeed, nanobiotechnology has emerged as an extremely viable and promising tool for addressing the complex concerns associated with environmental and human health challenges. Nanoparticles and nanomaterials produced by nanobiotechnology possess several advantages, including increased surface area, reactivity, and biocompatibility. These characteristics allow for the invention of novel pollution detection and remediation strategies, along with novel drug delivery systems and diagnostic devices. Nanotechnology enhances the strength of many materials and equipment, along with the efficiency of monitoring equipment, environmental pollution abatement, and the production of renewable energy. This chapter emphasizes the critical need of nanobiotechnology to address the environmental issues and human health. We can pave the way for more effective pollution management techniques, greater healthcare results, and a healthier, more sustainable future for everybody by using nanobiotechnology's capabilities.*

**Keywords:** *Environmental pollution, Human health, Nanobiotechnology, Nanoparticles, Pollution remediation, Biosensors, Drug delivery.*

**18.1 INTRODUCTION**

Nanobiotechnology has its origins in ancient times, with pioneering studies including the use of nanoparticles for medical purposes. Its formal inception, however, happened in the latter half of the 20th century, following advancements in nanomaterial production and biological research. Nano, which in Greek means "dwarf," refers to dimensions of the magnitude  $10^{-9}$  [1]. There are numerous interpretations of nanotechnology. Most of them are technical in nature, usually involving the making of structures smaller than 100 nm, or 100 millionths of a millimeter. However, nanobiotechnology, like all technologies, may have unexpected repercussions that harm the environment, both inside the human body and in the natural ecosystem. Nanobiotechnology has rapidly developed employs in medical care, with the development of targeted drug delivery systems, nanoparticle-based imaging agents, and nanoscale biosensors. These breakthroughs transformed diagnostics and therapies. Science must assess the environmental and health complications of this new technology while utilizing it for sustainability, health, and ecological benefits [2]. The study of nanoscale materials and devices, including their design, production, characterization, and application, is known as nanotechnology. This subclassification of technology in the

scientific disciplines of colloidal science, biology, physics, chemistry, and others comprises the analysis of phenomena and the manipulation of tiny materials. [3-5].

Nanotechnology has an impact on a variety of disciplines, including engineering, biology, chemistry, computing, material science, military applications, and communications, in addition to its medical, ethical, mental, legal, and environmental applications. By conserving raw resources, energy, and water, as well as by lowering greenhouse emissions and dangerous wastes, nanotechnological goods, processes, and applications are anticipated to make a substantial contribution to environmental and climatic protection. Therefore, employing nanomaterials promises to have positive effects on sustainability and the environment. It can facilitate the development of new cleanup technologies and enhance the identification and sensing of contaminants. Moreover, it assists to environmental sustainability by providing effective pollutant removal, water purification, and eco-friendly agriculture using nanomaterials and bioremediation. Understanding how nanoparticles originate and grow dynamically (for example, in the combustion system) paves the way for the creation of effective approaches for preventing the formation of pollutants in the first instance and limiting their emissions. Although there is little certainty that nanobiotechnology could solve maximum environmental issues, there is still little knowledge on how nanoparticles affect the environment, even if in some cases it has been shows that chemical composition, size, and form can have a negative impact. Nanoparticles typically range in size from 20 to 15,000 atoms, are smaller than 100 nanometers, and exist at the boundary between the quantum and Newtonian scales. They can be made from various materials and in a diversity of shapes, including spheres, rods, wires, and tubes [6,7]. Formation and application of nanoparticles in biomedical sciences is among the most significant advancements in nanotechnology and nanoscience research. It has opened the way for precision medicine, allowing for personalized medicines based on an individual's genetic composition. Nanoscale diagnostics and customized drug delivery technologies are revolutionizing medical care. The most prevalent forms of nanoparticles currently in use, possible benefits for them in biological and environmental research, and any possible detrimental effects on the environment and human health that may result from their use. In this chapter, we present a brief overview of the transformative significance of nano-solutions in achieving health and environmental sustainability.

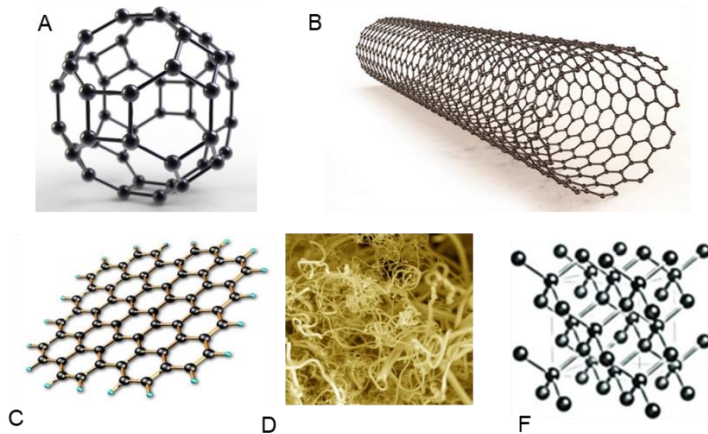
## **18.2 NANOPARTICLES CLASSIFICATION AND COMPOSITION**

Nanoparticles are employed in a range of applications due to their distinct properties such as higher chemical reactivity, optical, magnetic, and electrochemical [8]. Aside from the material they are made of, nanoparticles can vary in size, shape, and

dimension [9]. Nanoparticle are classified into four types based on their dimensions. One is zero-dimensions (0D) where the length, breadth, and height of nanoparticle are all fixed at nano scale ((typically < 100 nanometers) for example nano dots and fullerenes. In one-dimensional (1D) nanoparticle, 2 of their dimensions are in the nano scale for example examples nanowires and carbon-nanotubes. In Two-dimensional (2D) nanoparticles, 1 of their dimensions are in the nano scale, example Graphene. Three-dimensional (3D) nanoparticle is not confined in the nano scale any of the dimensions. The surface may have surface differences and be uniform or asymmetrical. Some nanoparticles, which are either loosely scattered or aggregated, contain one or more single or multiple crystal solids<sub>[10]</sub>. In order to increase the characteristics and lower the cost of production, numerous synthesis techniques are either being invented or refined.

- **Composition of Nanoparticles:** They can be composed of a wide variety of materials, including metals, semiconductors, polymers, and ceramics. The three core compositions of nanoparticle are inorganic, carbon-based, and organic.
- **Inorganic Nanoparticles:** Non-carbon-based nanoparticles are referred to as inorganic nanoparticles. They are usually divided into two categories: metal nanoparticles and metal oxide nanoparticles. Metal-based nanoparticles are those created by either destructive or constructive means from metals down to nanometric sizes. Nearly every metal can be synthesised into its nanoparticle form [11]. Aluminum (Al), cadmium (Cd), cobalt (Co), copper (Cu), gold (Au), iron (Fe), lead (Pb), silver (Ag), and zinc are the most often employed metals for the creation of nanoparticles (Zn). Sizes between 10 and 100 nm, high surface area to volume ratio, pore size, surface charge density, crystalline and amorphous structures, spherical and cylindrical shapes, colour, reactivity and sensitivity to environmental factors like air, moisture, heat, and sunlight are just a few of the distinguishing characteristics of the nanoparticles. However, the properties of the corresponding metal-based nanoparticles are modified by the creation of metal oxide-based nanoparticles. For instance, iron nanoparticles (Fe) rapidly oxidise to iron oxide (Fe<sub>2</sub>O<sub>3</sub>) at ambient temperature, increasing their reactivity in comparison to iron nanoparticles. The primary reasons for synthesising metal oxide nanoparticles are their improved reactivity and effectiveness [12]. They include Silicon dioxide (SiO<sub>2</sub>), Titanium oxide (TiO<sub>2</sub>), Zinc oxide, Iron oxide (Fe<sub>2</sub>O<sub>3</sub>), Cerium oxide (CeO<sub>2</sub>), and Aluminum oxide (Al<sub>2</sub>O<sub>3</sub>) (ZnO). Comparing these nanoparticles to their metal counterparts reveals that they have extraordinary qualities.

- **Carbon-based Nanoparticles:** Carbon-based nanoparticles are those formed completely of carbon. They are shown in Figure as fullerenes, graphene, carbon nanotubes (CNT), carbon nanofibers, carbon black, and occasionally activated carbon in nano size. Fullerenes (C<sub>60</sub>), a spherical carbon molecule held together by sp<sup>2</sup> hybridization, are composed of carbon atoms. The spherical structure is made up of 28 to 1500 carbon atoms and has a diameter of up to 8.2 nm for single layers and 4 to 36 nm for multilayered fullerenes. An allotrope of carbon is graphene. Carbon atoms are arranged in a hexagonal honeycomb lattice in a two-dimensional flat surface to form graphene. The graphene sheet typically has a thickness of 1 nm. Carbon Nano Tubes (CNT) are nanotubes made of graphene nanofoil with a honeycomb lattice of carbon atoms that are wound into hollow cylinders. Single-layer CNTs have a diameter as small as 0.7 nm, while multi-layered CNTs have a diameter of 100 nm. Nanotube lengths range from a few micrometres to several millimetres. Either the ends are hollow or a half fullerene molecule closes them. Carbon nanofiber, or CNT, is made from the same graphene nanofoils as CNT but is twisted into a cone- or cup-shaped structure as opposed to a conventional cylindrical tube. Carbon Black, a carbon-based amorphous substance, typically has a spherical shape and a diameter of 20 to 70 nm. Because of the powerful interconnections between particles, aggregates of around 500 nm in size are generated. *Figure 18.1 depicts the Carbon-Based Nanoparticles, fullerenes, nanotube, graphene, carbon nanofibers, diamond.*



**Figure 18.1: Carbon Based Nanoparticles: (A) fullerenes, (B) nanotube, (C) graphene, (D) carbon nanofibers, (E) carbon black, (F) diamond**

- Organic Nanoparticles:** Organic nanoparticles are also carbon-based nanoparticles. These nanoparticles are usually used in numerous fields, including biomedical sciences such as medicine, drug delivery, imaging, sensing, and materials science. Common names for organic nanoparticles or nonpolymers include dendrimers, micelles, liposomes, and ferritin. These nanoparticles are biodegradable, non-toxic, and some of them, like micelles and liposomes, have hollow centers that give them the name "nanocapsules" and make them sensitive to electromagnetic radiation like heat and light [13]. They could be a potential alternative for drug management because of their distinctive qualities. Aside from their regular properties like size, composition, surface shape, etc., their field of applications and efficiency are determined by the drug carrying capacity, stability, and delivery systems, whether entrapped drug or adsorbed drug system. Since they are effective and may be injected on specific body locations, which is also known as targeted medication administration, organic nanoparticles are most frequently utilized in the biomedical area. *Figure 18.2 shows organic nanoparticles, liposomes, dendrimers, micelles.*

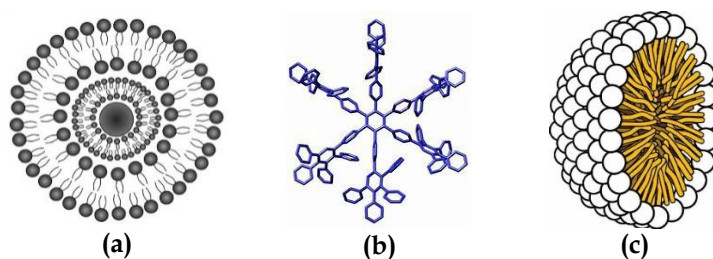


Figure 18.2: Organic Nanoparticles: (a) Liposomes, (b) Dendrimers, (c) micelles [41]

### 18.3 APPLICATIONS OF NANOTECHNOLOGY IN ENVIRONMENT SUSTAINABILITY

The usage of engineered nanoparticles in commercial and residential applications is growing, which results in the release of these substances into the environment. Understanding these nanoparticles' mobility, reactivity, ecotoxicity, and persistency is essential to assess the harm they pose to the environment [14,15]. The furthestmost significant exposure channels for evaluating environmental concerns are engineering material uses, which might enhance the concentration of nanoparticles in groundwater and soil.

- i. **Nanoparticles in wastewater treatment:** One of the greatest significant issues the world is currently dealing with is water contamination. In addition to having an

influence on the environment and human health, water poisoning also has financial and social implications. There are numerous commercial and non-commercial approaches used to combat this problem, which is getting worse every day as a result of technology development. Another excellent and cutting-edge method for treating waste water is nanotechnology. There are some factors that contribute to nanotechnology's success, and researchers are continually exploring ways to expand its applications. Nanoparticles have extraordinarily strong absorbing, interacting, and reacting capabilities due to their small size and high concentration of atoms at the surface. It can also be used with aqueous solutions to exhibit colloid behavior. Because of their small size, nanoparticles can conserve energy, which can ultimately result in cost savings. Nanoparticles offer a huge advantage over other traditional methods in treating water at depths and in any place.

- When titanium nanoparticles and exchange-based resin are impregnated with material containing iron hydroxide, nanomaterials are particularly effective at eradicate arsenic from drinking water. The study also looked into the use of titanium as an adsorbent to take arsenic out of water in a packed bed reactor environment. To eliminate arsenic from drinking water, iron oxide is sometimes utilized as coated sand in affluent nations [16].
- Environmental contamination is caused by water contaminants. The environmental protection benefits from the polymer-based nanomaterial. According to studies, the integration of nanoclay can achieve water purification using polymer material. Enhancing hydrophobicity aids in promoting the qualities of nanocomposite materials. Applications that come into touch with damp environments clearly show the advantages of incorporating nanoclay particles into nanomaterials [17].
- Metal oxide nanoparticles are excellent catalysts for a variety of oxidation processes. They have a potent catalytic reaction with pollution molecules and transform them into compounds that are environmentally friendly [18]. These nanomaterials have several distinctive qualities, such as nano size, strong reactivity, and larger surface area. Particularly, TiO<sub>2</sub> photocatalysis is crucial in the removal of various pollutants from surface water.
- These days, many contaminants, including those based on organics and even present in trace amounts, are found in water resources. These pollutants are extremely harmful to human health. Typically, water pollution is removed via the flocculation and chlorination processes. These traditional filtration methods have

some shortcomings. These kinds of systems are less effective at completely eliminating pollutants, and they also produce some sludge in water resources, which has serious negative effects on the environment [19]. As a result, it was used to prevent the formation of sludge in water resources since nanomembranes do not permit the passage of any solid particles into water.

- Since certain nanomaterials have exceptional physical, electrical, and chemical properties, such as magnetic and carbon nanotubes, they can be used as sensor components. Therefore, these sensors might provide a way to keep an eye on the quality of the water. Because nanomaterial-based sensors have optical features that increase their sensitivity and selectivity for detecting pollutants, they are utilized to detect various contaminants [20].
- ii. **Nanoparticle Sensors and Detectors:** Sensing of pollutants and other chemicals is crucial for the development of safe and efficient manufacturing processes as well as for protecting public health. Effective sensors are becoming more and more necessary because to the increase in potential terrorist attacks, and they are being used in numerous homeland security applications. The previous 20 years have seen advancements in sensor technology, with a focus on downsizing. Sensors have used a variety of nanostructured materials. Single-walled carbon nanotubes' (SWCNTs') electrical resistance has been discovered to dramatically vary when exposed to gases like NO<sub>x</sub>. It has been shown that chemically functionalized SWCNTs with covalently bonded poly m-aminobenzene sulfonic acid have increased ammonia sensor performance, allowing for better sensitivities (as low as 5 ppm) than conventional solid-state sensors [21]. Silicon nanowires with boron doping have been developed, and they work as incredibly sensitive sensors for both chemical and biological species [22]. To test miniature nanoparticle-based gas sensors, Kennedy et. al have created a fully automated gas sensing and electronic parameter measuring system. These methods make it possible to quickly optimise gas sensor designs and comprehend their size-dependent characteristics. Zinc oxide (ZnO) nanostructures' gas-sensing characteristics were discovered to exhibit a sensitive response, high selectivity, and a very quick response time to extremely low concentrations of ethyl alcohol. It has been demonstrated that gas-phase synthesized single crystal ZnO nanowires are extremely sensitive to oxygen concentrations, with enhanced sensitivity at smaller wire radii [23]. To increase the concentration range over which oxygen could be detected, the detection sensitivity of these nanowires could be modified by changing the gate voltage of the n-type semiconductor.

- iii. **Microbial Monitoring and Detection:** Although there are less applications of nanoparticles in environmental research than in biological research, Quantum Dots (QDs) have been effectively used as a fluorescence labelling device in microbial identification. Wheat germ agglutinin (WGA), a lectin frequently found in gram-positive bacteria, could be coupled with thiolated CdSe-core QDs [24]. This QD-conjugated WGA can attach to sialic acid and N-acetylglucosaminyl residues on bacterial cell walls via interacting with bacterial cells. A substrate like iron, which is necessary for the growth of injurious microbes inside a human host, can be bio-conjugated with QDs. Normally, pathogenic bacteria have receptors for transferrin, the host's own shuttle protein, and can use transferrin to obtain iron [25]. Transferrin-conjugated QDs can be delivered through the membrane into metabolically active cells of iron-deficient *Staphylococcus aureus* and then identified under fluorescent excitation using this metabolism-specific technique. In contrast, nonpathogenic bacteria show no QD signal.

Nanoparticles in a fluorescent labelling system in microfluidic devices can speed up the identification and monitoring of microorganisms even more. For instance, a straightforward microfluidic tool has been developed for the quick detection of viruses in aqueous environments. Rapid bacterial detection at the single-cell level can be accomplished by further developing nanoparticle-based fluorescent reporting devices [26]. To do this, hundreds of fluorescent dye molecules were encapsulated in a protective silica matrix, dramatically increasing the fluorescence intensity of individual nanoparticles. These nanoparticles of modified silica were employed in immunological experiments after being coupled with antigens unique to *Escherichia coli* strain O157.

- iv. **Nano-bioremediation:** Nano-bioremediation refers to the treatment of various environmental pollutants such as heavy metals, organic, and inorganic pollutants using a variety of nanoparticles/nanomaterials, plants, and microorganisms such as bacteria, fungi, and other microorganisms. This technique, which is still in its infancy, is used to clean the environment by removing impurities. Currently employed nano-bioremediation technologies include bioremediation, incineration, chemical and physical remediation. With recent developments, bioremediation now offers a cost-effective and environmentally responsible way to remove toxins from the environment. Nanomaterials have many uses in the field of environmental research, including separating out clean water from polluted water, detecting, and cleaning up a variety of environmental contaminants (such as trash and harmful compounds) found in nature. These technologies offer a number of key benefits, including high competence, the ability to select certain metals, the lack of any special dietary needs, and the

potential for metal recovery. Currently, a variety of nanomaterials are used, including biological nanomaterials, carbon-type nanomaterials, polymer nanomaterials, nanocomposites, and oxide nanoparticles [27]. Aside from these numerous uses, nanoparticles have discovered a successful method of treating heavy metals [28].

- v. **Cleaning Up of Oil Spills:** Petroleum spills have a detrimental effect on the health of living things, necessitating the cleanup of soils on the shoreline. Oil spills are currently a huge issue all over the world. Such things happen when enormous ships go down in the mid of the sea. Huge amounts of hydrocarbons are secretly released into the environment during an oil spill, harming aquatic life and the ocean life that slowly combines with nearby streams and other water bodies. Therefore, a range of microorganisms have been favored for the treatment of such sites and play a significant part in the cleanup of oil spills through bioremediation because they are better adjusted/adapted to the conditions necessitating treatment by bioremediation. *Bacillus subtilis*, among the many bacteria discovered, has demonstrated degradation of pollutants such n-alkanes, among the most dangerous classes. Some efficient oil remediation methods must be available for the cleanup procedure. There are numerous techniques, including solvent extraction, phytoremediation, electrokinetic bioremediation, thermal technologies, etc., that have had some effect on the technology used to clean up the ocean's oil spill [29]. Nanotechnology is currently essential to every branch of science and engineering. The process of cleaning up after an oil spill has also been impacted by nanotechnology. Microbial communities have been used to clean up oil spills utilizing a number of different strategies that have been suggested but have not yet been put into practice.
- vi. **Green Chemistry and Environmental Sustainability:** Green chemistry and nanotechnology are intended to reduce risks to human health and the environment while improving the efficiency of products in the chemical supply chain. As a fast-evolving field, nanotechnology offers an educational framework for examining the impact and application of green chemistry in the real world. Both are designed to bring in a new age of technical growth and are driven by a wide range of ingenuity [30]. Environmental chemistry is a subfield of sustainable chemistry that refers to basic chemical ideas like the p-block elements (C, N, O, P, and S) as "nutrients" and "salts" as the cause of "salinity" in soils and surface waters. Pollutants disrupt the normal nutrient cycles, and salinity lowers the quality of soil and waters, degrading the natural environment as a whole. Similar to how rising atmospheric carbon dioxide levels cause rivers and oceans to

become more acidic, this effect disrupts aquatic ecosystems. Furthermore, the largest worry when it comes to addressing environmental sustainability is the environment's growing toxicity as a result of chemical waste in the soils, air, and surface waters. Intuitively, sustainable chemistry entails involvement with the development of new intelligent materials and, by extension, with nanotechnology and its anticipated connections to the world's clean energy needs. With its emphasis on the creation of new smart materials for energy storage, production, and conversion, for improving agricultural productivity, water purification and desalination food processing, building construction, health monitoring, and pest control, rapidly developing nano-chemistry is perhaps the most significant example of cutting-edge sustainable chemistry. The solar energy sector is growing as a result of the quick development of photovoltaic devices and carbon nanotube solar cells, among other applications. In a similar vein, hydrogen is being promoted as a workable, alternative clean energy source through the development of nano-catalysts for its synthesis and hydrogen storage devices based on carbon nanotubes. So, by offering procedures and goods that directly benefit humanity without affecting the environment, sustainable chemistry via nano-chemical directly engages with environmental sustainability.

- vii. **Sensors for environmental monitoring:** The development of nano sensors for environmental pollutants is accelerating, and as this review has shown, novel and inventive combinations of nanomaterials and recognition agents are constantly being developed. The drawbacks of first-generation sensors, such as nonspecific binding, particle size variation, nanoparticle aggregation, and nanoparticle stability, are being addressed by recent advances in sensor design. Although there are still concerns about the assay's selectivity and sensitivity in complicated environmental matrices, more and more papers are employing representative matrices to show how stable and selective their sensors are. If people are to be given the ability to understand and assess their environment, the resilience of field deployable sensors is a requirement [31]. Due to their simple construction, quick detection, high sensitivity, and selectivity, as well as their simplicity in use with the naked eye, colorimetric sensors and biosensors show promising potential for the detection of metallic cations, anions, organic dyes, drugs, pesticides, and other toxic pollutants [32].
- viii. **Nano-sensors in soil remediation:** Nano-sensors are proving to be effective tools for agricultural applications. They provide a significant improvement over conventional chemical and biological approaches in terms of selectivity, speed, and sensitivity. Microbe and pollutant detection can be done with nano-sensors.

The soil moisture nano-sensors—also referred to as nano-biosensors—combine knowledge from biology, chemistry, and nanotechnology. The presence of gases, smells, chemical pollutants, infections, and even changes in the environment can all be detected using nano-sensors. A lot of water and labor waste can be avoided by monitoring soil moisture levels and managing irrigation systems (turning on the system when the moisture level drops below a specific predefined value). These sensor types make farming automation simpler. They are employed in regulated contexts as well [33].

- ix. **Nano-sensors in Air Quality Monitoring:** A measurement of the state of the air in relation to human needs is known as air quality. In laboratory studies, the excellent sensitivity and specificity of nanostructured resistive sensors have been demonstrated for the detection of atmospheric pollutants (such as NO<sub>2</sub> and CO) [34,35]. Sensors are ideal for several global environmental, automotive, and industrial applications and are easily capable of detecting and measuring flammable and pollutant gases in parts per billion (ppb).

## **18.4 LIMITATIONS AND RISKS OF NANOTECHNOLOGY TO HUMAN HEALTH AND THE ENVIRONMENT**

Despite receiving a lot of attention for their use in biological research, nanoparticles may have negative consequences on human health and the environment, according to several research [36]. Waste from the production and use of these nanoparticles is projected to end up in a number of ecosystems. Humans have a significant likelihood of coming into contact with these nanoparticles by inhalation, cutaneous adsorption, and digesting. When evaluating the potential health impacts of ultrafine particles, the rate of deposition and removal is crucial. Inhaled ultrafine particles can efficiently deposit in human lungs (40 - 50% deposition fraction of 40-nm particles) primarily by diffusion, and a significant portion deposits in the alveoli [37]. Most of the PM<sub>2.5</sub> is composed of fine sub micrometer particles, which have a slower rate of deposition and a lesser fraction that deposits in the alveoli. The overwhelming number of nanoparticles reduces the alveolar macrophages' capacity to eliminate foreign particles [38,39].

There is relatively little consensus regarding the risks and consequences of nanotechnology on the environment. Following is a summary of the potential environmental impact brought on by nanotechnology:

- High energy consumption is an outcome of the high energy required for manufacturing nanoparticles.

- Dissemination of hazardous, long-lasting nanomaterials that cause environmental damage.
- Lower rates of recycling and recovery.
- Environmental implications of other lifecycle stages also not clear.
- Lacks trained engineers and workers causing further concerns.

Unfortunately, graphene-based composites may also harm the environment in other ways. Graphene has remarkable qualities, and its products might help the environment and the economy. It is challenging to remove graphene from waste, because its hazardous properties are unclear.

- Unexpected reactions from graphene to environmental materials and biological systems are possible.
- A lot of study has previously been done on the polymer nanocomposites' ability to resist fire, and graphene has a good thermal conductivity. However, if graphene becomes contaminated with other compounds during the process, scientists caution that it could pose a fire risk.

There are numerous negative effects of nanotechnology on the environment, such as increased toxicological pollution on the environment due to the uncertain shape, size, and chemical compositions of some nanotechnology products. Nanoparticles have higher surface areas than bulk materials, which can cause more damage to the human body and environment compared to bulk particles (or nanomaterials). It is unclear what impact carbon nanotubes (CNTs) will have when they are present in soils, sediments, and natural waterways at low concentrations, but they appear to have health consequences similar to asbestos when they come into contact with lung epithelia [40].

## **18.5 CONCLUSION**

In a number of ways, nanotechnology will continue to advance, benefit society, and improve the environment. The use of nanotechnology for the benefit of humanity is currently the focus of numerous researchers, engineers, and scientists. Nanoscale materials will improve the products' functionality, weight savings, energy efficiency, and environmental friendliness. Nanoparticles have a significant potential to replace existing materials since they possess distinctive features such as magnetic, optical, electrical, and high structural qualities. It is probable to design highly selective, sensitive, and focused sensors owing to nanoparticles' capacity to be coated with a variety of ligands and adjust surface area/volume ratio by modifying their shape. The

ability of nanoparticles to adsorb the most amount of air pollutants is due to their enormous surface area, which can also be used to remove air contaminants by adsorption. By producing an ecologically friendly substance or material, substituting commonly used harmful materials, and having a less environmental impact, nanotechnology is also utilized to prevent the manufacture of pollutants or contaminants. With the practice of nanotechnology, doctors can now diagnose ailments earlier and detect diseases in their early stages. Many severe diseases may also now be treated quickly and easily. More targeted study will be required for this technology because numerous applications of nanotechnology still need to be developed. Researchers and scientists have focused on nanotechnology in all fields of science and technology, opening up new study pathways into NPs and a myriad of new alternatives.

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