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Review Article
Revolution of Nanotechnology in Air Pollution

Elham F. Mohamed

Abstract

Importance of the field: Environmental contamination is one of the important issues that the world is confronting today, and it is expanding with each passing year and leading to grave and harmful effect to the earth. At present, the air contains various pollutants like CO, chlorofluorocarbons, volatile organic compounds, hydrocarbons, and nitrogen oxides. Water and soil are also contaminated with organic and inorganic compounds; the major sources for water and soil contamination are sewage water, industrial effluents, and random use of pesticides, fertilizers, and oil spills. In parallel, the rapid growth of nanotechnology has gained a great deal of interest in the applications of nanomaterial's potential in improved systems for monitoring and cleanup including all the three phases of environment . It can develop the pollutants sensing and detection and help in the improvement of novel remediation technologies.
Areas covered in this review: In this review, we discuss the recent progress towards the use of nanotechnology in a variety of above-mentioned applications. Furthermore, we expand upon the current progress in nanomaterial engineering approaches describing several recent examples that are utilized to enhance stability, catalytic efficiency, and utilization of alternate oxidants.
What the reader will gain: The review will provide a comprehensive knowledge in the definition of nanoparticles, and the nanotechnology concept, design of nanomaterial for potentially practical purposes. Finally, we provide a prospective on the future aspects of nanotechnology and its applications in air pollution remediation.
Take home message: Because of its wide applications, academic researchers, environmental scientists, and health care providers are expected to gain current knowledge and future prospects of the practical use of nanomaterial in environmental fields.

Keywords:
Nanotechnologies; Environemental contamination; Air pollution; Monitoring; Remediation

Air Pollution Department, Environmental Research Division, National Research Centre, Dokki, Giza, Egypt, elham_farouk0000@yahoo.com

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1. Introduction

Nanotechnologies are referred to the design, characterisation, production and application of structures, devices and systems by changing shape and size at the nanometre scale. Nanotechnology is characterized by the use of very small manufactured particles (<100 nm), called nanoparticles (NPs) or ultrafine particles. Nanoparticles (nano-scale particles = NSPs) are atomic or molecular aggregates with dimension between 1 and 100 nm that can drastically modify their physico-chemical properties compared with the bulk material [1]. Nanoparticles can be made from a variety of bulk materials and they can act depending on chemical composition, size or shape of the particles. They are more reactive and more mobile in nature. Nanoparticles are broadly in two groups of organic and inorganic nanoparticles. Organic nanoparticles include carbon nanoparticles (fullerenes) while some of the inorganic nanoparticles include magnetic nanoparticles, noble metal nanoparticles (e.g. gold and silver) and semiconductor nanoparticles (e.g. titanium dioxide and zinc oxide). Nanotechnology includes a wide range of tools, techniques and applications and is widely perceived among the most important technologies of the 21st century. Manufactured nanomaterials present Physicochemical, superficial and optoelectronic, which solve difficult problems that can not be treated with conventional technologies.Today, NT is one of the new scientific fields since it incorporates knowledge from the different fields of Informatics, Physics, Medicine, Biology, Engineering, and Chemistry [2]. Environmental pollution is one of the greatest problems that the world is facing today, and it is increasing with every passing year and causing grave and irreparable damage to the earth. Nanomaterials, because of their novel physical and chemical characteristics, have great promise to combat environment pollution. Avariety of materials in their nano form like iron, titanium dioxide, silica, zinc oxide, carbon nanotube, dendrimers, polymers, etc. are increasingly being used to make the air clean, to purify water, and to decontaminate soil. Nanotechnology is also being used to make renewable energy cheaper and more efficient.

2. Fundamental properties of nanomaterials

Nanomaterials have unique properties particularly because of the nanoscale features. Due to enormous surface area to mass ratio, nanoparticles exhibit exclusive properties [3]. As the size of the material is reduced, and the nanoscale level is reached, it is possible that the same material will display totally different properties (different melting point, conductivity, etc.).In other words, the properties of materials can be size-dependent [4]. Properties like electrical conductivity, colour, strength and weight change when the nanoscale level is reached: the same metal can become a semiconductor or an insulator at the nanoscale level.Nanomaterials have superior properties than the bulk substance such as:

- Increased surface area to volume ratios

- Mechanical strength
- Thermal stability
- Catalytic activity
- Electrical conductivity
- Magnetic properties
- Optical properties

3. Methods of NPs Synthesis

The technology used for production of nanomaterials is classified into two processes (1) top down process (2) bottom up process (Fig.1) [5].Top down process: it involves the breaking down of a large piece of a bluk material to generate required smaller nano structure through etching or milling from the bulk material. The bottom up process: it involves the process of building up of the atom or molecular constituent into a large nano structured material. This produces NPs beginning from atoms of gas or liquid based on atomic coversion or molecular condensations.

4. Application areas of nanotechnology

Nanoscale materials find use in a variety of different areas, such as electronic, magnetic and optoelectronic, biomedical, pharmaceutical, cosmetic, energy, environmental, catalytic, and materials applications. [5-7]. Due to the great potential of this technology, there has been a worldwide increase in nanotechnology research investment [8]. Some potential applications are represented in Fig.2.

5. Nanotechnology and air pollution control

Remediation is the science of pollutants removal from the environment using chemical or biological means. Recent advancements have made the control and reduction of contaminants in air,soil, sediments and water the major environmental issue. Nanoparticles offer numerous advantages owing to their small size and high surface area.Nanotechnology offers great diversity in the types of materials- carbon nanotubes, nanoscale zeolites, dendrimers, enzymes, bimetallic particles and metal oxides that can be used for the purpose of remediation [9-11]. Applications of nanomaterials and nano-technologies for reducing indoor or outdoor air pollution/improving indoor or outdoor air quality are addressed in this section. The nano-based technologies and materials for reduction of air pollution/improvement of air quality can be divided into two main groups based on area of application, namely uses targeting outdoor air pollution/quality issues and uses targeting indoor air quality issues. This could be mainly divided into three categories; adsorption , degradation , and filteration (Fig.3) [12,13].

5.1. Adsorption

Carbon nanostructures have extremely physical properties like average pore diameter, pore volume, and surface area making them significant for industrial application as nanoadsorbents with high selectivity, affinity, and capacity. Further, the highly reactive surface sites or structures bonds can also play an important role in the adsorption [14, 15]. Air contaminants can be remediated and treated by various methods using nanomaterials as adsorbents [14-16]. Carbon nanotubes deposited on quartz filters used to eliminate and monitor the VOCs and other air pollutants by out by π- π interactions (Fig. 4) [17].Nano-adsorptive materials acting as a "super adsorbent" for several air pollutants like harmful gases and volatile organics via [18]:

- hydrogen bonding,
- electrostatic forces,
- π–π interactions, and
- van der Waals forces .

5.2. Degradation

Nanocatalysts are promising in ameliorating air quality and for reducing air pollutants to a lesser extent. Nanocatalytic system allows rapid and selective chemical transformations with excellent product yield coupled with the facility of catalyst recovery as compared with other conventional catalysts. Figure 5 represents scheme of comperative efficiency of advantages and disadvantages of traditional photocatalystsand nanocatalysts [19].Some materials such as titanium dioxide (TiO_2), zinc oxide (ZnO) and tungsten oxide (WO_3) may serve as photocatalysts.In relation to the environment remediation, photocatalysts are able to oxidize organic pollutants into nontoxic materials.Using the principle of a semiconductor, organic molecules can be oxidized by light. At a sufficient level of light, the charge transfer process will occur from the valence band to the conduction band causing the surrounding substance to be oxidized. Through the development of nanotechnology, semiconductor photocatalysts are modified in terms of reactivity and selectivity [20].

5.3. Filtration by Nanofilters

Nanotechnology can also be employed for the fabrication of nanofilters, nano-adsorbents and nanomembranes with specific properties to be used for decontaminating water and air[63-64].. As with other applications, it is the ability to manipulate matter at a molecular level that makes nanotechnology so promising in this field, together with the small size and high surface-to-volume ratio of nanomaterials that are employed in the fabrication of these products. In recent years, silver nanoparticles. Because of their antibacterial effectiveness and low toxicity towards mammalian cells, silver nanoparticles filters have become one of the most common nanomaterials used in air filtration devices [21]. Nanosilver is incorporated into these different materials through various impregnation techniques (sprayed, painted over the product, incorporated into plastics, etc.).

Consequently, nanotechnology exhibits remarkable features for advanced and multifunctional treatment processes that can enhance air pollution treatment performance via adsorption, degradation and filtration techniques. In brief, comparison of some nanoparticles applications in air remediation by both preventing the formation of secondary by-products and decomposing some of toxic pollutants was summarized in Table 1.

5. Risk assessment of nanotechnology

Nanotechnology becomes an influential and achievable tool in our lifetime. We require a real sustainable environment to survive with a quality life. In order to restore the environment to its original perfect state and establish sustainability nanotechnology has unlimited potential, we should focus on the unprecedented security and environmental benefits of the nanotechnology, as well as the potential problems. Yet, the nanotechnology development now is irregular; a greatly designed at additional economic growth and less is at environmental sustainability. Understanding of the molecular nanotechnology's benefits is needed by system integration approaches for this need to educate researchers about the potential benefits and risks of the technology, and introduce ethical guidelines into professional associations. At the last, further research and development to environmental remediation is required for real environmental sustainability.

6. Conclusions

Nanotechnology has been developed to achieve the purpose of maintaining environmental sustainability. With developing different aspects of nanotechnology, the broader environmental impacts of that will also need to be considered. Such considerations might include models to determine potential benefits of reduction or prevention of pollutants from industrial sources. The air purification process using nanotechnology can use adsorptive nanoparticles, catalytic nanoparticles and nanofiltration.Nanotechnology can also be applied to clean the air from toxic gases such as CO, VOCs and dioxins.Nanotechnology can also be applied to prevent the creation of pollution. Its applications include the synthesis of green materials, coatings and biocides to prevent the release of hazardous substances into the environment. Although nanotechnology has many applications in the fields of environmental technology, it needs to be studied further to assess its risk. This is in accordance with the principle that the more sophisticated the technologies, the greater the risks they pose.

7. Future Perspectives

- Nanocatalysts for sustainable air purification are mostly still under development or just at the start of being ready for practical use.
- Turning the investment via the nanotechnology research and allowing integration into large-scale environmental applications.
- Encouragement the "industrial ecosystem" around the world and using nanotechnology in recycling different wastes, this essentially means the use of wastes to produce new useful materials or compounds.
- Developing and optimizing new nanocatalysts for different applications in air pollution control sector.
- Incorporating of green chemistry to create environmental friendly products.
- This is to create novel nanomaterials that are eco-friendly, cost effective and stable for application in the areas of environmental air pollution remediation.

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Table1. Comparison of different nanomaterials efficiency for removal of air pollutants

Nanoparticles	Target pollutants	Observation	Advantages	References
Silica nanoparticles (SiNPs)	Atmospheric lead (Pb)	High adsorption capacity of Pb	Large surface area and negative charged groups in the SiNPs	[22]
Ag/SBA-15 nanocomposites	Carbon monoxide (CO)	Oxidation of 98% of CO	Increase the silver content leading to increased its catalytic activity	[23]
Aligned carbon nanotube	Aerosols	High removal efficiency	When the number of CNTs layers increased, the filtration efficiency increased	[24]
Nanosilver-TiO_2 nanofibers	NOx, VOCs	Decomposition efficiency was 21% for NOx and 30% for VOCs	Nanosilver inclusion increased the removal efficiency	[25]
Titanium dioxide nanoparticles (TNPs)	Sulfur dioxide (SO_2)	High removal efficiency of SO_2	In the absence of irradiation, the main product of SO_2 adsorption was found to be $(SO_3)^{2-}$, while irradiation resulted in oxidation and formation of adsorbed $(SO_4)^{2-}$	[26]
Ruthenium nanoparticle catalysts (Ru/Al_2O_3)	N_2, N_2O	High activity in N_2O decomposition	Up to 90% conversion of N_2O for long reaction time	[27]

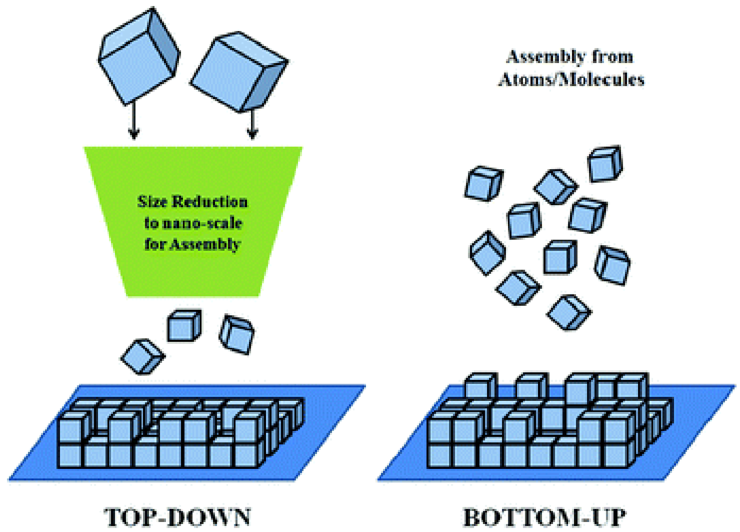

Fig.1 Top down process and bottom up process of NPs Synthesis

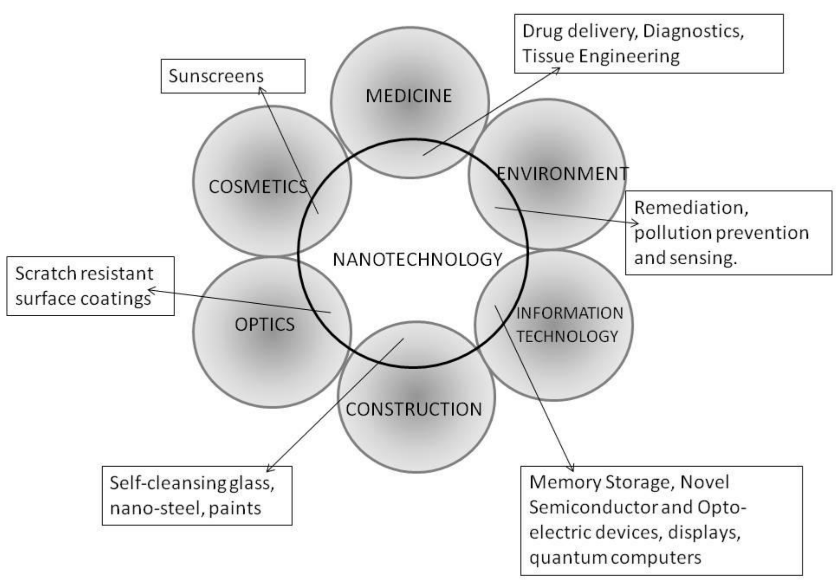

Fig.2 Nanotechnology areas of applications

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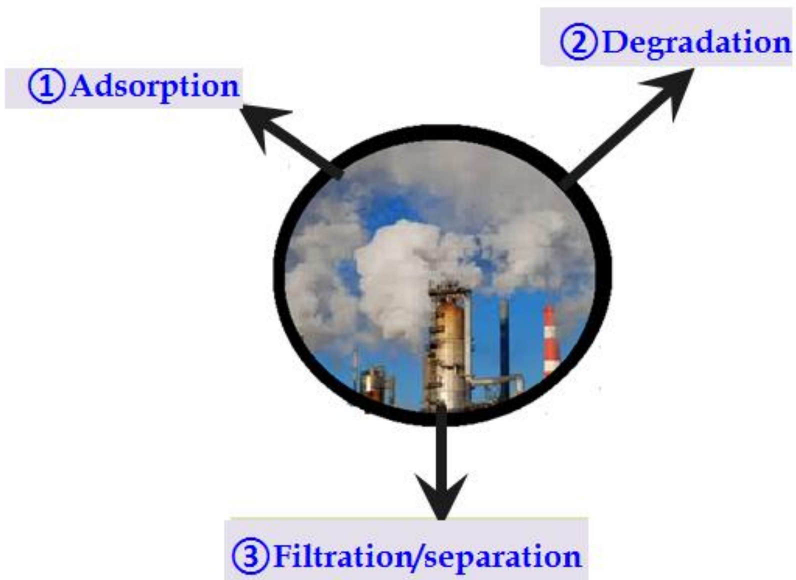

Fig.3 Nanotechnology application in air pollution remediation

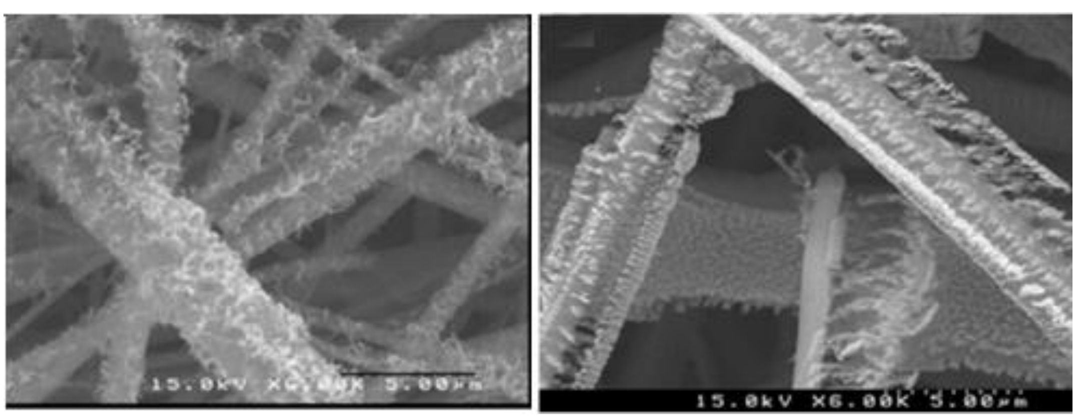

Fig.4 Carbon nanostructures deposited on quartz filters

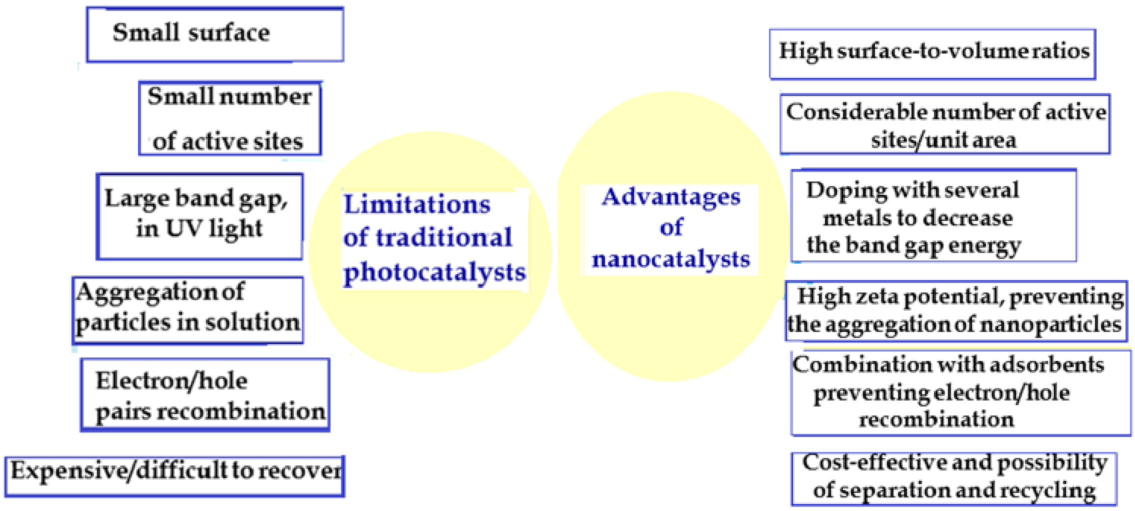

Fig.5 Comperative efficiency of traditional photocatalysts and nanocatalysts