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Nanotechnology: Future of Environmental Pollution Control

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Abstract: - Area of science and engineering that will most likely produce the breakthroughs of tomorrow is Nanotechnology.Many technologies are there for effectively treating environmental pollutants. Some pollutants that are highly toxic, persistent, and difficult to treat, present particular challenges. Nanotechnology gives new treatment approaches that are more effective in reducing contaminant levels and more cost effective than currently available techniques. As a revolutionary science and engineering approach, nanotechnology has the potential to have major consequences on the environment. Nanotechnology can be of benefit to environmental protection in applications such as reducing use of raw and manufactured materials (dematerialization), minimizing or eliminating the generation of wastes and effluents, and reducing toxics. The environment is also protected in applications that more effectively treat waste streams and remediate existing polluted sites.

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INTRODUCTION

Nanotechnology refers most broadly to the use of materials with nanoscale(1nm = 10^{-9}m) dimensions, a size range from 1 to 100 nanometers (billionths of a meter). Many things we are already familiar with are nanoscale. Living organisms from bacteria to beetles rely on nanosized protein-based machines that do everything from whipping flagella to flexing muscles. Nanotechnology has been contributing to commercial products for many years; for example, nanometer-sized carbon (carbon black) improves the mechanical properties of tires; nanometer silver particles initiate photographic film development; and nanometer particles are the basis of catalysts critical to the petrochemical industry.

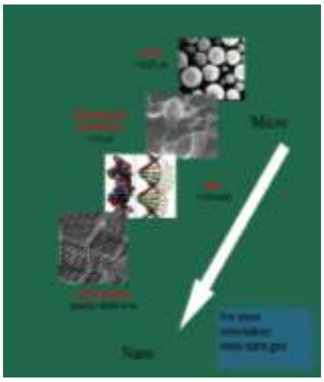


Figure 1: Scale of Things from Micro to Nano (3)

PROPERTY

Nanotechnology results in materials and systems whose structures and components exhibit novel and significantly changed physical, chemical, and biological properties resulting from the ability to control structures and devices at atomic, molecular, and supramolecular levels.

Because of their small size, nanoparticles have very high surface area compared with their bulk equivalent. Thus, nanoparticles are being explored as a means to remove or destroy toxic substances from the environment. Nanoparticles are more reactive and react to a greater extent because of their small size. Nanoparticles have more surface available for chemical interactions. Nanoparticles can also exhibit higher chemical reactivity due to unusual crystal shapes and lattice order.

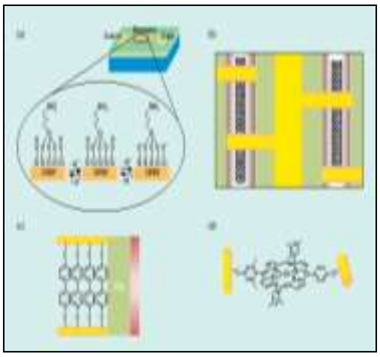
NANOTECHNOLOGY STRUCTURE OVERVIEW

The basic structures of nanotechnology nanoclude, nanoparticles or nanocrystals, nanolayers, and nanotubes. These nanostructures differ in how they are made and how their atoms and molecules are ordered. A nanoparticle—a collection of tens to thousands of atoms measuring about 1–100 nm inaggregate diameter—is the most basic structure in nanotechnology. Such nanoparticles are created atom by atom, so the size, and often the shape, of a particle is controlled by experimental conditions.

These particles can also be described as nanocrystals because the atoms within the particle are highly ordered, or crystalline.

Nanostructures, such as those shown in Figure 2, are often arranged or self-assembled into highly ordered layers. Many naturally occurring biological structures, like membranes, vesicles, and DNA, form because of such self-assembly.

Repeating structures with a tailored periodicity are essential in many applications of nanotechnology, such as photonics, catalysts, and membranes.



(a) Silicon nanowire that detect pH, (b) Carbon Nanotube, (c) Small Organic molecules, and (d) Biomolecules, are examples of material, devices and circuits that could be used for pollutant sensing, prevention and treatment.

POLLUTION PREVENTION

Pollution prevention refers to “source reduction” and other practices that efficiently use raw materials, energy, water, or other resources to reduce or eliminate creation of waste. This strategy also includes using less toxic and renewable reagents and processing materials, where possible, and the production of more environmentally benign manufactured products.

As an emerging and multidisciplinary field, nanoscale science and engineering has enjoyed an explosive development over the last decade or so. Meanwhile, the unique physical and chemical properties of nanoscale materials have attracted growing interest in their potential environmental applications for tackling traditionally difficult remediation problems.

Nanotechnology plays a vital role in air and water pollution control.

Air Pollution: Air pollution can be remediated using nanotechnology in several ways. One is through the use of nano-catalysts with increased surface area for gaseous reactions. Catalysts work by speeding up chemical reactions that transform harmful vapors from cars and industrial plants into harmless gases. Catalysts currently in use include a nanofiber catalyst made of manganese oxide that removes volatile organic compounds from industrial smokestacks Other methods are still in development. Another approach uses nanostructured membranes that have pores small enough to separate methane or carbon dioxide from exhaust. carbon nanotubes (CNT) are used for trapping greenhouse gas emissions caused by coal mining and power generation. CNT can trap gases up to a hundred times faster than other methods, allowing integration into large-scale industrial plants and power stations. This new technology both processes and separates large volumes of gas effectively, unlike conventional membranes that can only do one or the other effectively.

Water Pollution: As with air pollution, harmful pollutants in water can be converted into harmless chemicals through chemical reactions. Trichloroethene, a dangerous pollutant commonly found in industrial wastewater, can be catalyzed and treated by nanoparticles. Studies have shown that these “materials should be highly suitable as hydrodehalogenation and reduction catalysts for the remediation of various organic and inorganic groundwater contaminants”. Nanotechnology eases the water cleansing process because inserting nanoparticles into underground water sources is cheaper and more efficient than pumping water for treatment. The deionization method of using nano-sized fibers as electrodes is not only cheaper, but also more energy efficient. Traditional water filtering systems use semi-permeable membranes for electrodialysis or reverse osmosis. Decreasing the pore size of the membrane to the nanometer range would increase the selectivity of the molecules allowed to pass through. Membranes that can even filter out viruses are now available.

Also widely used in separation, purification, and decontamination processes are ion exchange resins, which are organic polymer substrate with nano-sized pores on the surface where ions are trapped and exchanged for other ions. Ion exchange resins are mostly used for water softening and water purification. In water, poisonous elements like heavy metals are replaced by sodium or potassium. However, ion exchange resins are easily damaged or contaminated by iron, organic matter, bacteria, and chlorine. Recent developments of nano-wires made of potassium manganese oxide can clean up oil and other organic pollutants while making oil recovery possible. These nanowires form a mesh that absorbs up to twenty times its weight in hydrophobic liquids while rejecting water with its water repelling coating. Since the potassium manganese oxide is very stable even at high temperatures, the oil can be boiled off the nanowires and both the oil and the nanowires can then be reused. One of the earliest and still most commonly cited applications of nanoparticles is the dechlorination of chlorinated hydrocarbons such as TCE and PCBs using bimetallic nanoparticles.

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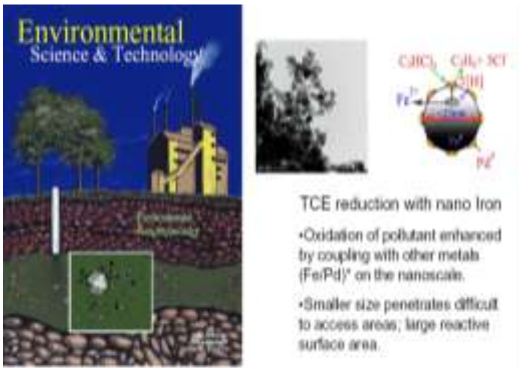

Figure 2: Remediation of Groundwater by Nano Iron

Chlorinated solvent dense non aqueous phase liquid (DNAPL), such as trichloroethylene (TCE), acts as a long-term source of hazardous groundwater contamination and presents a challenging remediation problem. Conventional approaches such as pump and treat or soil vapor extraction are not effective at remediating DNAPL-impacted sites. The main problem with current technologies is that they cannot remove the DNAPL droplets trapped between the fine soil particulates, so these droplets act as a perennial source of groundwater contamination. Existing technologies would take decades or centuries to remediate these sites to acceptable regulatory end points. Delivering nano-scale iron in situ has been proposed as a viable and potentially cost-effective method for DNAPL source zone treatment.

A specific application of nanotechnology for pollution treatment has been in the area of photo catalytic oxidation of organic pollutants. Researchers have developed a "sense and shoot" approach for photo catalytic degradation of organic contaminants in water. When zinc oxide nanoparticles (ZnO) are exposed to UV radiation, they fluoresce. In the presence of chlorinated organic pollutants, the ZnO oxidizes the pollutant, and its fluorescent signal is reduced. The pollutant is “sensed” (fluorescence lowered) and “shot” (oxidized). The fluorescence signal is restored on completion of the reaction. Thus, the energy-consuming oxidation stage only occurs when the pollutants are present.

Photocatalytic oxidation for decontaminating water using zinc oxide might prove to be more versatile than the commonly used titanium dioxide because ZnO senses the presence of the pollutants in addition to destroying the organic molecules. This type of multifunctionality is highly desirable for environmental applications.

SUMMARY

Nanotechnology has been developed to achieve the purpose of maintaining environmental sustainability. Technologies that have been developed include technologies which can enhance and improve the conventional technological capabilities and new technologies which replace the conventional technologies.

The water and ground water purification process using nanotechnology can use iron nanoparticles, nanofibres, nanoenzymes and nanofiltration techniques. Despite being applied in cleaning and water purification, nanotechnology can also be applied to clean the air from toxic gases such as CO and VOCs using CNTs, nanoparticles and other adsorbents. Nanoparticles and nanotubes can also be applied as a sensor for toxic substances, particularly substances that are difficult to detect with conventional technology because they have a very small in size and concentration.

In this way nanotechnology proves more effective in contamination reduction and more economic technology in environmental pollution control than present technology.

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