POLLUTION PREVENTION AND CONTROL USING NANOTECHNOLOGY

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Abstract-- Environmental nanotechnology is considered to play a key role in the shaping of current environmental engineering and science. Environmental nanotechnology is considered to play a key role in the shaping of current environmental engineering and science. Environmental nanotechnology is considered to play a key role in the shaping of current environmental engineering and science. The issue of environmental pollution has become a hot subject in today's world. Environmental pollution, mainly caused by toxic chemicals, includes air, water, and soil pollution. This pollution results not only in the destruction of biodiversity, but also the degradation of human health. Pollution levels that are increasing day by day need better developments or technological discoveries immediately. Nanotechnology is an upcoming technology that can provide solution for combating pollution by controlling shape and size of materials at the nanoscale. Nanotechnology has three main capabilities that can be applied in the fields of environment, including the cleanup (remediation) and purification, the detection of contaminants (sensing and detection), and the pollution prevention. This article provides comprehensive information regarding the role of nanotechnology in pollution prevention. Due to its large surface area and high surface energy, the nanoparticles have the ability to absorb large amount of pollutants or catalyze reactions at a much faster rate, thus reducing energy consumption during degradation or helps in preventing release of contaminants.
Keywords: Environment, nanotechnology, pollution, remediation, sensing, prevention

I. 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). These minuscule particles are subject to the physical and chemical laws, that otherwise; do not apply to the particles of larger sizes. Due to enormous surface area to mass ratio, nanoparticles exhibit exclusive properties. These special properties and the large surface area of nano-particles prove valuable for engineering effective energy management and pollution control techniques. For example, if super-strength plastics could replace metal in cars, trucks, planes, and other heavy machinery, there would be enormous energy savings and consequent reduction in pollution.

II. STRUCTURE OF NANOTECHNOLOGY

The basic structures of nanotechnology include, nanoparticles or nanocrystals, nanolayers, and nanotubes. These nanostructures differ in the way they are made and the way their atoms and molecules are ordered. A nanoparticle is a collection of tens to thousands of atoms measuring about 1–100 nm in aggregate diameter is the most basic structure in nanotechnology.

Such nanoparticles are created atom by atom, so the size and 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 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.

III. POLLUTION PREVENTION AND CONTROL

The term “Pollution” has many definitions, one being “the presence of a substance in the environment whose chemical composition or quantity prevents the functioning of natural processes and produces undesirable environmental and health effects” [1] . Pollution prevention is defined as the reduction of pollutants at the source. With growing urbanization and increasing population, pollution has become the biggest environmental challenge. Moreover, the technological advancement has also given rise to new pollutants which are increasing at an alarming rate and are above the self remediating ability of the environment. There is an urgent need to find technologies that would reduce these rates/pollution levels to risk-free status in quick and easy manner. Nanotechnology is being explored to provide new solution for cleaning environment and improving the performance of conventional technologies. This technology is also explored for combating pollution by reducing the release or preventing the formation of pollutants. US National Nanotechnology initiative has identified “Environmental improvement” as one of the eight crosscutting areas of nanotechnology [2]. The basic concept of pollution control on a molecular level is separating specific elements and molecules from a mixture of atoms and molecules [3].

3.1 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 vapours 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 [4]. Another approach uses nanostructured membranes that have pores small enough to separate methane or carbon dioxide from exhaust [5]. Carbon Nano Tubes (CNT) can trap gases upto 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. In 2006, Japanese researchers found a way to collect the soot filtered out of diesel fuel emissions and recycle it into manufacturing material for CNT [6]. The diesel soot is used to synthesize the single-walled CNT filter through laser vaporization so that essentially, the filtered waste becomes the filter.

3.2 Water Pollution

Nanotechnology eases the water cleansing process because inserting nanoparticles into underground water sources is cheaper and more efficient than pumping water for treatment [7]. The deionization method of using nano-sized fibers as an electrode is not only cheaper, but also more energy efficient [8]. 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 [9]. Nanotechnology is 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 (10). Ion exchange resins are mostly used for water softening and water purification.

3.3 Cleaning Up Oil Spills

According to the U.S. Environmental Protection Agency (EPA), about 14,000 oil spills are reported each year [11]. Dispersing agents, gelling agents and biological agents are most commonly used for cleaning up oil spills. However, none of these methods can recover the oil lost. Recent developments of nano-wires made of potassium manganese oxide can clean up oil and other organic pollutants while making oil recovery possible [12]. 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 [12].

VI. NANOTECHNOLOGY FOR POLLUTION PREVENTION

Prevention of pollution refers to a reduction in pollution sources and other practices that utilize raw materials, energy, utilities and other resources effectively in order to reduce or eliminate waste generation.

Nanotechnology offers many innovative strategies to reduce waste production in various processes such as improving manufacturing processes, reducing hazardous chemicals, reducing greenhouse gas emissions and reducing the use of biodegradable plastics.

4.1 Environmentally friendly materials

The application of nanotechnology is able to create an environmentally friendly substance or material, replacing widely used toxic materials. For example, liquid crystalline display (LCD) computer screens that are more energy efficient and less toxic have largely replaced the screen cathode ray tubes (CRTs) which contain many toxic materials. LCDs also do not contain lead and consume less energy compared with CRT computer screens. The use of carbon natotubes (CNTs) in computer screens may further reduce the impact on the environment by eliminating toxic heavy metals, reducing material and energy needs drastically, as well as improving performance according to customer needs. In addition, the application of nanotechnology in composite materials has the potential to produce a material with better mechanical and other properties. This is because nanotechnology has the ability to produce structures that are lighter and smaller without degrading the quality of existing properties. The advantage of this technology is the increased robustness, reduced system costs and whole replacement, as well as reduced environmental impact. Examples of environmentally friendly materials that can be produced using nanotechnology are: biodegradable plastics made from polymers with a molecular structure that is easy to decompose; nanocrystalline composite materials that are not toxic to replace the lithium–graphite electrodes in rechargeable batteries; and glass with self-cleaning ability.

4.2 Textile products and antimicrobial coating

An antimicrobial coating is needed in various applications, such as protecting surfaces and medical equipment or to reduce the attacks from microorganisms. Conventional spray and coating methods for this purpose already exist, but further development is needed in this area because more and more microbes are becoming resistant to widely used antibiotic treatment. To prevent the attachment of bacteria, the topography of the surface of nanocoating with a specific function is shown to be important. Antifouling surface coatings have been investigated for applications in instruments and medical equipment, household appliances and ships. A widely used antimicrobial coating nanomaterial is silver (Ag). The antibacterial properties of silver are due to the formation of Ag^{+} ions by bulk metals when they are oxidized. In fact, silverware appliances have antimicrobial activity only if the species is oxidized at the surface. Silver ions affect the oxidative stress in the bacterial cell wall which has an influence on the ability of bacteria to perform respiration. Silver has been proven to be toxic to many types of bacteria, both gram-negative and gram-positive, and fungi. In recent years, nanoparticles of silver called as nanosilver have been added to some consumer products to provide antimicrobial properties.[13] The types of products are very broad, covering household appliances, personal clothing, sports apparel, refrigerators, washing machines, air-filtering equipment, spray disinfectant and cosmetics. Nanosilver is included in the material and equipment through various impregnation techniques (sprayed, painted on the surface of the product, mixed in plastic, etc.).

4.3 Green manufacturing

The manufacturing process is always accompanied by a wide range of waste production which is harmful to the environment. Ideally, the manufacturing process should be designed to minimize raw material usage, waste production and energy consumption. Green manufacturing is a common name that widely covers methods and technologies to achieve these goals. Green manufacturing includes the development of industrial processes (e.g. water-based processes take precedence over organic solvent-based processes), a reduction in the use of hazardous substances, i.e. metals, the development of green chemicals which are less harmful to the environment and the use of energy-efficient processes[14]. An example of green nanotechnology is the development of microemulsions (aqueous) as an alternative to Volatile Organic Compounds (VOCs) in the cleaning industry. Toxic and carcinogenic compounds, such as chloroform, hexane and perchloroethylene, are commonly used in the cleaning industry, textiles industry and oil extraction. Microemulsions containing nano-sized aggregates can be used as receptors for the extraction of specific molecules at the nanoscale level.

V. CONCLUSION

Nanotechnology's potential and promise have steadily been growing throughout the years. The world is quickly accepting and adapting to this new addition to the scientific toolbox. Although there are many obstacles to overcome in implementing this technology for common usage, science is constantly refining, developing, and making breakthroughs. Doubtless, nanotechnology and in particular the nanoparticles will have great positive effects on the various fields of environmental technology. Still, the major limitation would be the lack of information regarding the toxicity of engineered nanoparticles.

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