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TURNING TO NANOTECHNOLOGY FOR POLLUTION CONTROL: APPLICATIONS OF NANOPARTICLES

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ABSTRACT

Environmental nanotechnology is considered to play a key role in the shaping of current environmental engineering and science. Looking at the nanoscale has stimulated the development and use of novel and cost-effective technologies for remediation, pollution detection, catalysis and others. However, there is also a wide debate about the safety of nanoparticles and their potential impact on environment and biota, not only among scientists but also the public. Especially the new field of nanotoxicology has received a lot of attention in recent years.Nanotechnology and the environment – is it therefore a Janus-faced relationship? There is the huge hope that nanotechnological applications and products will lead to a cleaner and healthier environment. Maintaining and re-improving the quality of water, air and soil, so that the Earth will be able to support human and other life sustainably, are one of the great challenges of our time. The scarcity of water, in terms of both quantity and quality, poses a significant threat to the well-being of people, especially in developing countries. Great hope is placed on the role that nanotechnology can play in providing clean water to these countries in an efficient and cheap way. On the other hand, the discussion about the potential adverse effects of nanoparticles has increased steadily in recent years and is a top priority in agencies all over the world.

During the last twenty years, scientists have been looking towards nanotechnology for the answer to problems in medicine, computer science, ecology and even sports. In particular, new and better techniques for pollution control are emerging as nanoparticles push the limits and capabilities of technology.

Nanoparticles, defined as particles 1-100 nanometers in length (one nanometer being the equivalent of one billionth of a meter) hold enormous potential for the future of science. Their small size opens up possibilities for targeting very specific points, such as diseased cells in a body without affecting healthy cells. In addition, elemental properties can change rather dramatically at the nanometer range: some become better at conducting heat or reflecting light, some change color, some get stronger, and some change or develop magnetic properties. Certain plastics at the nanometer range have the strength of steel. The super-strength and other special properties emerge because microscale flaws between molecules are absent at the nanoscale. Nanoparticles without these flaws allow materials to reach the maximum strength of their chemical bonds.

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. Batteries are also being improved using nanoscale materials that allow them to deliver more power faster. Nano-materials that absorb enough light for conversion into electrical energy have also been used to recharge batteries. Other environmentally-friendly technologies include energy efficient non-thermal white LED's, and SolarStucco, a self-cleaning coating that decomposes organic pollutants using photocatalysts.

Nanotechnology and Pollution Control

Pollution results from resource production and consumption, which in their current state are very wasteful. Most waste cannot be reintegrated into the environment effectively or cheaply. Thus, processes like petroleum and coal extraction, transportation, and consumption continue to result in photochemical smog, acid-mine drainage, oil slicks, acid rain, and fly ash. In his paper for the Foresight Institute, Stephen Gillett identifies the "Promethean Paradigm": the inefficient dependence on heat for energy since burning fuel discards much of its free energy during the conversion of chemical energy into heat and then to mechanical energy. Biological systems, on the other hand, efficiently oxidize fuel through molecular-scale mechanisms without extracting the chemical energy through thermalization. Overcoming the Promethean Paradigm requires controlling reactions at the nanoscale. Thus, nanofabrication holds much potential for effective pollution control, but it currently faces many problems that prevent it from mass commercialization — particularly its high cost.

The basic concept of pollution control on a molecular level is separating specific elements and molecules from a mixture of atoms and molecules. The current method for separating atoms is thermal partitioning, which uses heat to force phase changes. However, the preparation of reagents and the procedure itself are costly and inefficient. Current methods of energy extraction utilize combustion to create heat energy, most of which is wasted and results in unwanted byproducts that require purification and proper disposal. Theoretically, these high costs could be solved with the nanostructuring of highly specific catalysts that will be much more efficient. Unfortunately, we have yet to find an optimal way of obtaining the particles in workable form. Current means are essentially "shake and bake" methods called wet-chemical synthesis, which allows for very limited control on the final product and may still result in unwanted byproducts.

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. John Zhu of the University of Queensland is researching carbon nanotubes (CNT) 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. For his work, Zhu received an $85,000 Foundation Research Excellence Award.

The substances filtered out still presented a problem for disposal, as removing waste from the air only to return it to the ground leaves no net benefits. 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. The diesel soot is used to synthesize the single-walled CNT filter through laser vaporization so that essentially, the filtered waste becomes the filter.

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.

Cleaning Up Oil Spills

According to the U.S. Environmental Protection Agency (EPA), about 14,000 oil spills are reported each year. 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. 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.

In 2005, Hurricane Katrina damaged or destroyed more than thirty oil platforms and nine refineries. The Interface Science Corporation successfully launched a new oil remediation and recovery application, which used the water repelling nanowires to clean up the oil spilled by the damaged oil platforms and refineries.

Concerns

In 2009, NanoImpactNet, the European Network on Health and Environmental Nanomaterials will hold its first conference to study the impact of nanomaterials on health and environment. The small size of nanoparticles warrants investigation of the consequences of inhalation and absorption of these particles and their effects inside the body, as they are small enough to penetrate the skin and diffuse through cell membranes. The special properties of nanoparticles inside the body are unclear and unpredictable. Also, many are worried about the effects of nanoparticles on the environment. New branches of science such as eco-nanotoxicology have arisen to study the movement of nanomaterials through the biosphere. We do not yet know how much will be absorbed by the soil, air, or water, and how severely the widespread presence of nanoparticles in the environment will impact the ecosystem. To address these concerns, NanoImpactNet aims to set up regulations and legislation to ensure that nanoparticles, with so much potential for cleaning up pollution, will not become a new form of Pollution themselves.

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.

References

1. 1. S. L. Gillett, Nanotechnology: Clean Energy and Resources for the Future (2002). Available at http://www.foresight.org/impact/whitepaper_illos_rev3.PDF (5 January 2009)

2. S.L. Gillett, Nanotechnology. 7, 177-182 (1996)
3. A. McLaughlin, Pollution control technology wins Royal Society award (20 February 2007). Available at http://www.bath.ac.uk/news/2007/2/20/merceraward.html (29 November 2008)
4. Air Pollution and Nanotechnology. Available at http://www.understandingnano.com/air.html (18 December 2008)
5. J. Zhu, Dr John Zhu, School of Engineering (19 September 2007). Available at http://www.uq.edu.au/research/index.html?page=68941&pid=68941 (15 December 2008)
6. T. Uchida et al., Japanese Journal of Applied Physics 45, 8027-8029 (2006).
7. M.O. Nutt, J.B. Hughes, M.S. Wong, Environmental Science & Technology 39, 1346–1353 (2005).
8. Water Pollution and Nanotechnology. Available at http://www.understandingnano.com/water.html (17 December 2008).
9. F. Tepper, L. Kaledin, Virus and Protein Separation Using Nano Alumina Fiber Media. Available at http://www.argonide.com/Paper%20PREP%2007-final.pdf (5 January 2009)
10. D. Alchin, Ion Exchange Resins. Available at http://www.nzic.org.nz/ChemProcesses/water/13D.pdf (18 December 2008.
11. U.S. Environmental Protection Agency, Response to Oil Spills (18 September 2008). Available at http://www.epa.gov/emergencies/content/learning/response.htm (31 December 2008)
12. J. Yuan et al., Nature Nanotechnology 3, 332-336 (2008).
13. United States Department of Commerce, Hurricane Katrina Service Assessment Report. (June 2006). Available at http://www.weather.gov/os/assessments/pdfs/Katrina.pdf (17 December 2008).
14. B. Lamba, Nanotechnology for recovery and reuse of spilled oil. (9 September 2005). Available at http://www.physorg.com/news6358.html (10 December 2008).