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Review of Nanotechnology Applications in Science and Engineering

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ABSTRACT: Nanotechnology is helping to considerably improve, even revolutionize, many technology and industry sectors: information technology, energy, environmental science, medicine, homeland security, food safety, and transportation, among many others. Today's nanotechnology harnesses current progress in chemistry, physics, materials science, and biotechnology to create novel materials that have unique properties because their structures are determined on the nanometer scale. This paper summarizes the various applications of nanotechnology in recent decades.

Keywords: Nanotechnology, Environmental Science, Agriculture, Food safety, Engineering.

INTRODUCTION

Sustainable Energy Application

The difficulty of meeting the world's energy demand is compounded by the growing need to protect our environment. Many scientists are looking into ways to develop clean, affordable, and renewable energy sources, along with means to reduce energy consumption and lessen toxicity burdens on the environment. Prototype solar panels incorporating nanotechnology are more efficient than standard designs in converting sunlight to electricity, promising inexpensive solar power in the future. Nanostructured solar cells already are cheaper to manufacture and easier to install, since they can use print-like manufacturing processes and can be made in flexible rolls rather than discrete panels. Nanotechnology is improving the efficiency of fuel production from normal and low-grade raw petroleum materials through better catalysis, as well as fuel consumption efficiency in vehicles and power plants through higher-efficiency combustion and decreased friction (Low et al., 2015). Nano-bioengineering of enzymes is aiming to enable conversion of cellulose into ethanol for fuel, from wood chips, corn stalks (not just the kernels, as today), and unfertilized perennial grasses (Chaturvedi and Dave, 2014). Figure 1 shows some application of nanotechnology.

Nanotechnology is already being used in numerous new kinds of batteries that are less flammable, quicker-charging, more efficient, lighter weight, and that have a higher power density and hold electrical charge longer (Jalaja et al., 2016; Najim et al., 2015; Maine et al., 2014). One new lithium-ion battery type uses a common, nontoxic virus in an environmentally benign production process. Nanostructured materials are being pursued to greatly improve hydrogen membrane and storage materials and the catalysts needed to realize fuel cells for alternative transportation technologies at reduced cost. Researchers are also working to develop a safe, lightweight hydrogen fuel tank. Various Nano science-based options are being pursued to convert waste heat in computers, automobiles, homes, power plants, to usable electrical power (Pratsinis, 2016; Sabet et al., 2016).

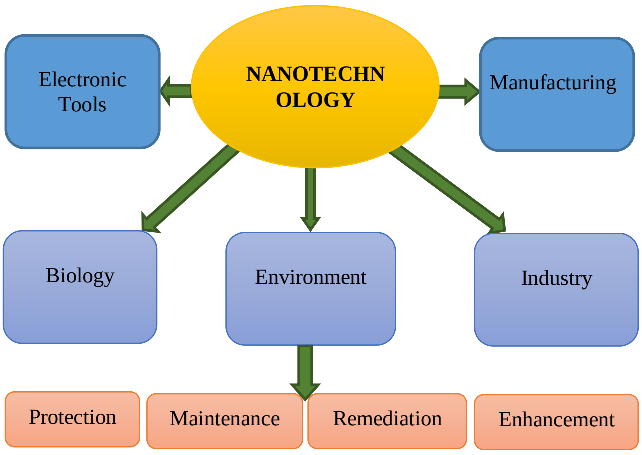

Figure 1. Application of nanotechnology in science and environmental science (Jalaja et al., 2016).

To power mobile electronic devices, researchers are developing thin-film solar electric panels that can be fitted onto computer cases and flexible piezoelectric nanowires woven into clothing to generate usable energy on-the-go from light, friction, and/or body heat. Energy efficiency products are increasing in number and kinds of application. In addition to those noted above, they include more efficient lighting systems for vastly reduced energy consumption for illumination; lighter and stronger vehicle chassis materials for the transportation sector; lower energy consumption in advanced electronics; low-friction nano-engineered lubricants for all kinds of higher-efficiency machine gears, pumps, and fans; light-responsive smart coatings for glass to complement alternative heating/cooling schemes; and high-light-intensity, fast-recharging lanterns for emergency crews. Besides lighter cars and machinery that requires less fuel, and alternative fuel and energy sources, there are many eco-friendly applications for nanotechnology, such as materials that provide clean water from polluted water sources in both large-scale and portable applications, and ones that detect and clean up environmental contaminants.

Nanotechnology could help meet the need for affordable, clean drinking water through rapid, low-cost detection of impurities in and filtration and purification of water (Rabbani et al., 2016; Sobolev and Shah, 2015; Mishra et al., 2012).

Nanoparticles will someday be used to clean industrial water pollutants in ground water through chemical reactions that render them harmless, at much lower cost than methods that require pumping the water out of the ground for treatment. Nanotechnology has the real potential to revolutionize a wide array of medical and biotechnology tools and procedures so that they are more personalized, portable, cheaper, safer, and easier to administer. Below are some examples of important advances in these areas. Nanotechnology has been used in the early diagnosis of atherosclerosis, or the build-up of plaque in arteries. Researchers have developed an imaging technology to measure the amount of an antibody-nanoparticle complex that accumulates specifically in plaque. Clinical scientists are able to monitor the development of plaque as well as its disappearance following treatment. Gold nanoparticles can be used to detect early-stage Alzheimer's disease (Fan et al., 2016; Sadeghi et al., 2016; Tarafdar et al., 2015).

Sensors and Medicine Application

Molecular imaging for the early detection where sensitive biosensors constructed of nanoscale components (e.g., nano-cantilevers, nanowires, and nano-channels) can recognize genetic and molecular events and have reporting capabilities, thereby offering the potential to detect rare molecular signals associated with malignancy. Multifunctional therapeutics where a nanoparticle serves as a platform to facilitate its specific targeting to cancer cells and delivery of a potent treatment, minimizing the risk to normal tissues. Research enablers such as microfluidic chip-based Nano labs capable of monitoring and manipulating individual cells and Nano scale probes to track the movements of cells and individual molecules as they move about in their environments. Nano-bio systems, Medical, and Health Applications.

Nanotechnology has the real potential to revolutionize a wide array of medical and procedures so that they are more personalized, portable, cheaper, safer, and easier to administer. Below are some examples of important advances in these areas (George, 2015, Ng et al., 2015; Weiss, 2015; Yashveer et al., 2014; Schulte et al., 2014; Boisseau and Loubaton, 2011).

Quantum dots are semiconducting nanocrystals that can enhance biological imaging for medical diagnostics. When illuminated with ultraviolet light, they emit a wide spectrum of bright colours that can be used to locate and identify specific kinds of cells and biological activities. These crystals offer optical up to 1,000 times better than conventional dyes used in many biological tests, such as MRIs, and render significantly more information. Multifunctional therapeutics where a nanoparticle serves as a platform to facilitate its specific targeting to cancer cells and delivery of a potent treatment, minimizing the risk to normal tissues (Adam et al., 2015, Milliron, 2014, Peterson et al., 2014, Schnitzenbaumer and Dukovic, 2014).

Research enablers such as microfluidic chip-based nano-labs capable of monitoring and manipulating individual cells and Nano scale probes to track the movements of cells and individual molecules as they move about in their environments. Research is underway to use nanotechnology to spur the growth of nerve cells, e.g., in damaged spinal cord or brain cells. In one method, a nanostructured gel fills the space between existing cells and encourages new cells to grow. There is early work on this in the optical nerves of hamsters. Another method is exploring use of Nano fibers to regenerate damaged spinal nerves in mice (Liu et al., 2015, Raspa et al., 2015, Tam et al., 2014, Guo et al., 2014, Kim et al., 2014).

Future Transportation Applications

Nano-engineering of steel, concrete, asphalt, and other cementations materials, and their recycled forms, offers great promise in terms of improving the performance, resiliency, and longevity of highway and transportation infrastructure components while reducing their cost. New systems may incorporate innovative capabilities into traditional infrastructure materials, such as the ability to generate or transmit energy. Nano scale sensors and devices may provide cost-effective continuous structural monitoring of the condition and performance of bridges, tunnels, rails, parking structures, and pavements over time. Nano scale sensors and devices may also support an enhanced transportation infrastructure that can communicate with vehicle-based systems to help drivers maintain lane position, avoid collisions, adjust travel routes to circumnavigate congestion, and other such activities (Agzenai et al., 2015; Firoozi et al., 2015; Golestani et al., 2015; Singh and Sangita, 2015, Sobolev, 2015; De Nicola et al., 2015; Chuah et al., 2014; Firoozi et al., 2014; Wong, 2014; Yusoff et al., 2014).

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Nanotechnology for Environmental Protection

In the last few decades, highly toxic organic compounds have been synthesized and released into the environment in order to be used directly or indirectly over a long period. Among some of these elements are pesticides, fuels, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs) (Jones, 2007). Some combined chemical compounds resist highly against biodegradation via native flora in comparison with organic substances easily degraded through introduction into the environment. Thus, dangerous chemical compounds have been one of the most serious issues in the contemporary world. The management of contaminated soil and ground water is a major environmental concern. The presence of elevated concentrations of a wide range of contaminants in soils, sediments and surface-and ground waters, affects the health of millions of people worldwide (Pereira et al., 2003). Current clean up technology is not significantly and economically adequate to solve all of today’s clean up needs.

Nanotechnology is one of the most important trends in science and perceived as one of the key technologies of the present century (Zhang and Elliot, 2006). Nanotechnology could be a powerful tool in dealing with pollution remediation. Several studies indicate that combining nanoparticles with conventional treatment could increase the efficiency of contaminants removal, such as organic materials. In Zhang’s report (Rickerby and Morrison, 2007), nano scale iron particles are very effective for the transformation and detoxification of a wide variety of common environmental contaminants, such as chlorinated organic solvents, organochlorine pesticides, and PCBs. Nanoparticles remain reactive towards contaminants in soil and water for extended periods of time and rapid in situ reactions have been observed with TCE reduction up to 99% in a few days after the nanoparticle injection. Many researchers have shown that engineered nanoparticles such as TiO_2 and ZnO, carbon nanotube, metallic nanoparticles (e.g., iron, nickel) magnetic nanoparticles and amphiphilic polyurethane nanoparticles could be useful for remediation and treatment of contaminated water, soil or air.

Application of nanotechnology in environmental science is categorized into four parts: remediation, protection, maintenance, and enhancement. Among these four, remediation is known as the most rapid growing category, protection and maintenance make the main part of nanotechnology application in environmental science, while environmental enhancement represents the smallest part of nanotechnology application categories. Nanoparticles can be utilized in air and water treatment, mesoporous elements for green chemistry, catalytic applications and environmental molecular science. Along with decreasing the size of the particles, they gain new chemical, electronic and physical properties. Advantages include improved adsorption and unique catalytic properties that can accelerate oxidation or reduction reactions with different contaminants for particle that are less than 10 nm (Cosgun et al., 2015). Nanoscale materials have been at a number of contaminated sites with preliminary reports of success. Nanotechnology is also able to improve the environment via presenting influential control and preventing of contamination. For environmental treatment, different implementations of nanotechnology have been successfully implemented at the laboratory scale. However, mostly these applications need confirmation of their effectiveness and safety in the field. Traditional remediation technologies have indicated confined efficacy in reduction of the concentration of contaminations in air, water, and soil. According to Boehm (Dang et al., 2015) nanomaterials can act more remarkably and influentially as filtration media in comparison with bigger particles with the same chemicals (Yang et al., 1999).

Remedial Technology by Nanomaterials

In general nanoparticles are smaller than 100 nanometers contain 20-15000 atoms, and exist in a realm that straddle the quantum and Newtonian scales. They can be produced from different materials in different shapes such as, spheres, rods, wires and tubes. Nanotechnology is an emerging advanced technology for solving environmental problems. The result in innovative nanotechnology development such as nano sorbent, nano catalyst, bioactive nanoparticles, nano structured catalytic membranes and nanoparticle enhanced filtration, provides unprecedented opportunity in changing all costly and limited conventional water treatments. There are two major properties that makes nanoparticles attractive: firstly, nanoparticles are extremely small in size (1 - 100 nm), which provides higher surface area per unit mass compared to the media produced by conventional methods. Secondly, the molecular level manipulations proceeded in nano particle production facilitates incorporation of desired structural and functional characteristics (e.g., surface area, pore size, structure and surface functional groups) on the adsorption surface.

Yang (1999) observed activated carbons were utilized largely as traditional adsorbents in European countries for the removal of dioxins from the gaseous emissions of waste incineration. Also, according to Mahdavian (2010) the removal of chemical contaminations from a polluted area is a necessary step toward accomplishing the aim of environmental remediation. Many studies have focused on more effective materials in adsorbing pollutants that are widely various. Previously, montmorillonite and bentonites were used to adsorb oils spills since they were known as the smallest particles and could adsorb tremendous amounts of chemicals.

Bowman et al. (2003) shows that for the removal of contamination, the process can be divided into two main groups. The first process as a sorption in which, the contaminant is removed from solution due to the sorption of the contaminant to the medium. Indeed, the process of sorption is pretty fast, but finally the maximum capacity of the compounds should be replaced by new materials. An alternate type of process is degradation or transformation materials. Ideally, the contaminant will be transformed to a non-toxic compound after coming in contact with the material. Degradation reaction tends to be kinetically slow relative to sorption reactions, and thick material beds may be necessary to provide the required the residence time. Generally, the application of nanomaterials for environmental remediation considers breaking up the pollutants into non-toxic elements and absorbing the pollutants for rendering the insoluble chemical materials in order to decrease migration. Liu et al. (2014) reported that MWNT was an effective adsorbent for removal of chlorinated aromatic compounds (including PCBs) from insulating oil. Figure 2 show the scheme of the generation of covalently bound surface acidic groups on MWNT.

Various applications of nanotechnologies for environmental remediation have been successfully demonstrated at the laboratory scale but, in the majority of cases, these still require verification of their efficacy and safety in the field. Various treatment techniques and processes have been used to remove the pollutants from contaminated soil and water. Among all the approaches proposed, adsorption is one of the most popular methods and is currently considered as an effective, efficient, and economic method for soil and water purification (Liu et al., 2014).

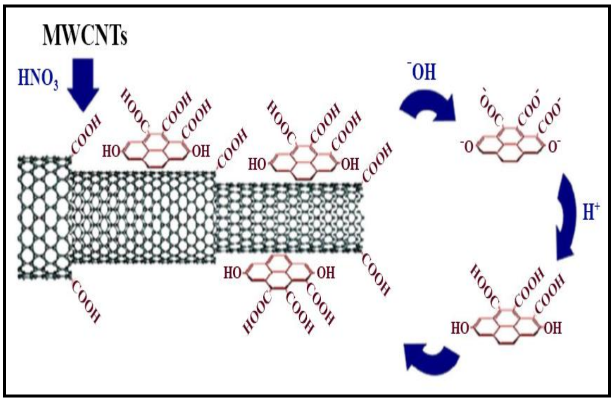

Figure 2. Simplified scheme of the generation of covalently bound surface acidic groups (Liu et al., 2014)

Application of Nanotechnology in Remediation

Nanomaterials have also been used to remediate contaminated groundwater and subsurface source areas of contamination at hazardous waste sites. Early treatment remedies for groundwater contamination were primarily pump-and-treat operations. Because of the relatively high cost and often lengthy operating periods for these remedies, the use of in situ treatment technologies is increasing.

Since the early 1990s, site project managers have taken advantage of the properties of metallic substances such as elemental iron to degrade chlorinated solvent plumes in groundwater. One example of an in situ treatment technology for chlorinated solvent plumes is the installation of a trench filled with macroscale zero-valent iron to form a permeable reactive barrier (PRB) (Elliot, 2006). Recent research indicates that nanoscale zerovalent iron (nZVI) may prove more effective and less costly than macroscale ZVI under similar environmental conditions. For example, in laboratory and field-scale studies, nZVI particles have been shown to degrade trichloroethene (TCE), a common contaminant at Superfund sites, more rapidly and completely than larger ZVI particles. Also, nZVI can be injected directly into a contaminated aquifer, eliminating the need to dig a trench and install a PRB. Research indicates that injecting nZVI particles into areas within aquifers that are sources of chlorinated hydrocarbon contamination may result in faster, more effective groundwater cleanups than traditional pump-and-treat methods or PRBs. Research indicates that nanoparticles such as nZVI, bi-metallic nanoscale particles (BNPs), and emulsified zero-valent iron (EZVI) may chemically reduce the following contaminants effectively: perchloroethylene (PCE), TCE, cis- 1, 2-dichloroethylene (c-DCE), vinyl chloride (VC), and 1-1-1-tetrachloroethane (TCA), along with polychlorinated biphenyls (PCBs), halogenated aromatics, nitroaromatics, and metals such as arsenic or chromium. Two of the important degradation reactions for chlorinated solvents are reductive dechlorination and beta elimination. Beta elimination, which occurs most frequently when the contaminant comes into direct contact with the iron, follows the pathway [56]. Reductive dechlorination, which occurs under the reducing conditions fostered by nZVI in groundwater, follows the pathway of PCE→ TCE→ DCE→ VC→ ethane (Phenrat, 2007).

Nanoparticles can be highly reactive due to their large surface area to volume ratio and the presence of a greater number of reactive sites. This allows for increased contact with contaminants, thereby resulting in rapid reduction of contaminant concentrations. Because of their minute size, nanoparticles may pervade very small spaces in the subsurface and remain suspended in groundwater, which would allow the particles to travel farther than macro-sized particles and achieve wider distribution. However, as discussed in the 'Limitations' section, bare iron nanoparticles may not travel very far from the injection point. It is important to note that there is variability among iron nanoparticles, even if they have the same chemical composition (Liu et al., 2014). The properties of particles such as reactivity, mobility, and shelf-life can vary depending on the manufacturing process or the vendor providing the particle (Liu et al., 2014).

In Situ Application of Nanoparticles

The method of application for nanoparticles is usually site-specific and is dependent on the type of geology found in the treatment zone and the form in which the nanoparticles will be injected. The most direct route of injection utilizes existing monitoring wells, piezometers, or injection wells. Recirculation is a technique that involves injecting nanoparticles in up gradient wells while down gradient wells extract groundwater. The extracted groundwater is mixed with additional nanoparticles and re-injected in the injection well. The wells keep the water in the aquifer in contact with the nZVI, and also prevent the larger agglomerated iron particles from settling out, allowing continuous contact with the contaminant.

Research is ongoing into methods of injection that will allow nanoparticles to better maintain their reactivity and increase their access to recalcitrant contaminants by achieving wider distribution in the subsurface. Creating nZVI on site reduces the amount of oxidation the iron undergoes, thereby reducing loss in reactivity. Researchers in green chemistry have successfully created nZVI in soil columns using a wide range of plant phenols, which, according to the researchers, allows greater access to the contaminant and creates less hazardous waste in the manufacturing process (Hart and Milstein, 2003).

Site-specific conditions such as the site location and layout, geologic conditions, concentration of contaminants, and types of contaminants may limit the effectiveness of nanoparticles. For example, the research conducted for this fact sheet documents only two sites that have used nanoparticles in fractured bedrock, although several pilot studies have been undertaken.

The pH of the subsurface may also limit the effectiveness of nanoparticles because the sorption strength, agglomeration, and mobility of the particles are all affected by the pH of the groundwater (Elliot, 2006). The ionic strength and types of cations in the groundwater, as well as the chemical and physical characteristics of the aquifer materials, also affect the agglomeration and movement of iron nanoparticles (Hart and Milstein, 2003).

Application of Nanotechnology in Food and Agriculture

The current global population is nearly 6 billion with 50% living in Asia. A large proportion of those living in developing countries face daily food shortages as a result of environmental impacts or political instability, while in the developed world there is a food surplus. For developing countries, the drive is to develop drought and pest resistant crops, which also maximize yield. In developed countries, the food industry is driven by consumer demand which is currently for fresher and healthier foodstuffs. This is big business, for example the food industry in the UK is booming with an annual growth rate of 5.2% and the demand for fresh food has increased by 10% in the last few years. The potential of nanotechnology to revolutionize the health care, textile, materials. Information and communication technology, and energy sectors has been well-publicised. In fact, several products enabled by nanotechnology are already in the market, such as antibacterial dressings, transparent sunscreen lotions, stain-resistant fabrics, scratch free paints for cars, and self-cleaning windows. The application of nanotechnology to the agricultural and food industries was first addressed by a United States Department of Agriculture roadmap published in September 2003. The prediction is that nanotechnology will transform the entire food industry, changing the way food is produced, processed, packaged, transported, and consumed. This short report will review the key aspects of these transformations, highlighting current research in the agri food industry and what future impacts these may have.

The EU's vision is of a "knowledge-based economy" and as part of this, it plans to maximize the potential of biotechnology for the benefit of EU economy, society and the environment. There are new challenges in this sector including a growing demand for healthy, safe food; an increasing risk of disease; and threats to agricultural and fishery production from changing weather patterns. However, creating a bio economy is a challenging and complex process involving the convergence of different branches of science. Nanotechnology has the potential to revolutionize the agricultural and food industry with new tools for the molecular treatment of diseases, rapid disease detection, enhancing the ability of plants to absorb nutrients etc., Smart sensors and smart delivery systems will help the agricultural industry combat viruses and other crop pathogens. In the near future nanostructured catalysts will be available which will increase the efficiency of pesticides and herbicides, allowing lower doses to be used. Nanotechnology will also protect the environment indirectly through the use of alternative (renewable) energy supplies, and filters or catalysts to reduce pollution and clean-up existing pollutants. An agricultural methodology widely used in the USA, Europe and Japan, which efficiently utilises modern technology for crop management, is called Controlled Environment Agriculture (CEA). CEA is an advanced and intensive form of hydroponically-based agriculture. Plants are grown within a controlled environment so that horticultural practices can be optimized. The computerized system monitors and regulates localised environments such as fields of crops. CEA technology, as it exists today, provides an excellent platform for the introduction of nanotechnology to agriculture. With many of the monitoring and control systems already in place, nano technological devices for CEA that provide "scouting" capabilities could tremendously improve the grower's ability to determine the best time of harvest for the crop, the vitality of the crop, and food security issues, such as microbial or chemical contamination.

The use of pesticides increased in the second half of the 20th century with DDT becoming one of the most effective and widespread throughout the world. However, many of these pesticides, including DDT were later found to be highly toxic, affecting human and animal health and as a result whole ecosystems. As a consequence, they were banned. To maintain crop yields, Integrated Pest Management systems, which mix traditional methods of crop rotation with biological pest control methods, are becoming popular and implemented in many countries, such as Tunisia and India.

In the future, nanoscale devices with novel properties could be used to make agricultural systems "smart". For example, devices could be used to identify plant health issues before these become visible to the farmer. Such devices may be capable of responding to different situations by taking appropriate remedial action. If not, they will alert the farmer to the problem. In this way, smart devices will act as both a preventive and an early warning system. Such devices could be used to deliver chemicals in a controlled and targeted manner in the same way as nano-medicine has implications for drug delivery in humans. Nanomedicine developments are now beginning to allow us to treat different diseases such as cancer in animals with high precision, and targeted delivery (to specific tissues and organs) has become highly successful.

Technologies such as encapsulation and controlled release methods, have revolutionised the use of pesticides and herbicides. Many companies make formulations which contain nanoparticles within the 100-250 nm size range that are able to dissolve in water more effectively than existing ones (thus increasing their activity). Other companies employ suspensions of nanoscale particles (nano-emulsions), which can be either water or oil-based and contain uniform suspensions of pesticidal or herbicidal nanoparticles in the range of 200-400 nm. These can be easily incorporated in various media such as gels, creams, liquids etc., and have multiple applications for preventative measures, treatment or preservation of the harvested product.

New research also aims to make plants use water, pesticides and fertilizers more efficiently, to reduce pollution and to make agriculture more environmentally friendly. Agriculture is the backbone of most developing countries, with more than 60% of the population reliant on it for their livelihood. As well as developing improved systems for monitoring environmental conditions and delivering nutrients or pesticides as appropriate, nanotechnology can improve our understanding of the biology of different crops and thus potentially enhance yields or nutritional values. In addition, it can offer routes to added value crops or environmental remediation.

Particle farming is one such example, which yields nanoparticles for industrial use by growing plants in defined soils. For example, research has shown that alfalfa plants grown in gold rich soil, absorb gold nanoparticles through their roots and accumulate these in their tissues. The gold nanoparticles can be mechanically separated from the plant tissue following harvest.

Nanotechnology can also be used to clean ground water. The US company Argonide is using 2 nm diameter aluminum oxide nano-fibres (Nano-Ceram) as a water purifier. Filters made from these fibres can remove viruses, bacteria and protozoan cysts from water. Similar projects are taking place elsewhere, particularly in developing countries such as India and South Africa. The German chemical group BASF's future business fund has devoted a significant proportion of its 105 million USD nanotechnology research fund to water purification techniques.

Research at Lehigh University in the US shows that an ultrafine, nanoscale powder made from iron can be used as an effective tool for cleaning up contaminated soil and groundwater- a trillion-dollar problem that encompasses more than 1000 still-untreated Superfund sites (uncontrolled or abandoned places where hazardous waste is located) in the United States, some 150,000 underground storage tank releases, and a huge number of landfills, abandoned mines, and industrial sites. The iron nanoparticles catalyse the oxidation and breakdown of organic contaminants such as trichloroethene, carbon tetrachloride, dioxins, and PCBs to simpler carbon compounds which are much less toxic. This could pave the way for a nano-aquaculture, which would be beneficial for a large number of farmers across the world. Other research at the Centre for Biological and Environmental Nanotechnology (CBEN) has shown that nanoscale iron oxide particles are extremely effective at binding and removing arsenic from groundwater (something which affects the water supply of millions of people in the developing world, and for which there is no effective existing solution).

It has been argued that nanotechnology holds the potential to eliminate the concept of waste and pollution (Fryxell et al., 2005). In a more modest vein it has been suggested that nanotechnology promises to drastically cut resource consumption and pollution, will strongly reduce prices for sustainable converters of energy such as solar cells and will make much improved recycling and detoxification technology possible. Nanotechnology has also been argued to allow for greater selectivity in chemical reactions, and to contribute to improved energy efficiency and to toxics reduction (Fryxell et al., 2005). However, the emergence of nanotechnology has also sparked debate about the hazards of ultrafine particles (Salata, 2004). This author now concentrates on hazards of nanoparticles as they are currently used in or contemplated for use in production and products and on the issue of what can be done to limit the associated risks.

Many current or prospective applications use fixed nanoparticles and are thus not inherently dispersive. A longstanding example thereof is the use of carbon black for printing and in the production of tires. Newer applications include coatings, textiles, ceramics, membranes, composite materials, glass products, prosthetic implants, anti-static packaging, cutting tools, industrial catalysts, and a variety of electric and electronic devices including displays, batteries and fuel cells. Other uses of nanoparticles are inherently dispersive or ‘free’ (Royal Society). These include drugs, personal care products such as cosmetics, quantum dots and some pilot applications in environmental remediation (Oberdorster, 2004). Apart from manufactured nanoparticles, there are also ultrafine particles that are generated in unintended ways. These include particles originating in the combustion of fuels, e.g. ultrafine particles emitted by diesel fueled cars (Oberdorster, 2004) in smelting processes of metals, heating of polymers (Wallace, 2004) or frying foods (Dreher, 2004) and are also called non-manufactured nanoparticles. Most of the manufactured nanoparticles currently used are made from metal oxides, silicon and carbon (Allen and Cullis, 2004). So far the majority of nanosized approved drug delivery systems are lipid, liposomal and poly ethylene glycol- based (Ahmed et al., 2016). Potential exposure to manufactured nanoparticles may increase dramatically in the future (Yetisen et al., 2016, Wong et al., 2016, Zhao et al., 2015, Firoozi et al., 2015, Altairnano, 2014, Cao and Zhang, 2006, Chen et al., 2005, Firoozi et al., 2016, Xu et al., 2011, Rao et al., 2015, Sirivitmaitrie et al., 2008).

CONCLUSION

Based on the review in this paper, Nanotechnology has the potential to be the key to a brand new world in the fields of food and agriculture, construction materials, mechanical, medicine and electrical engineering. Although replication of natural systems is one of the most promising areas of this technology, scientists are still trying to grasp their astonishing complexities. Furthermore, nanotechnology and nanomaterials is a swiftly growing area of research where new properties of materials on the nano-scale can be utilized for the benefit of industrial and a number of capable developments exist that can potentially modify the service life and life-cycle cost of construction infrastructure to make a new world in future.

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