Nanotechnology and Health Maintenance

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ABSTRACT

We have all heard about the marvelous advances being made in the use of nanomaterials in imaging, cancer therapy and controlled release pharmaceuticals. What is less well known is the role of nanotechnology in prevention – from filtration and purification of air and water to the preparation of surfaces that are resistant to the growth of bacteria, mold and algae. This paper reviews some of the lesser-known but still vitally important roles that nanotechnology can play in keeping us well.

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INTRODUCTION

Nanotechnology refers to technologies in which matter is manipulated on the atomic and molecular level to create new materials and processes. It is not just the study of the very small; it is the practical application of that knowledge. Mother Nature can serve as a model for having many materials and processes that functions at the nanoscale (1); small molecular building blocks are joined together to produce nanostructures with defined geometries and functions. It became evident that Nature's bottom-up approach can be emulated to produce new materials with nanosized dimensions and engineered properties.

Nanotechnology is emerging as a powerful complement to biotechnology and health care fields. It is an area that promises better drug and gene delivery systems (2, 3, 4), more sensitive and selective biosensors (5, 6, 7) and more efficient diagnosis and treatment of diseases like cancer through tumor destruction via heating (8). Nanotechnologies also have the potential to improve diagnostics by creating new ways of imaging through fluorescent biological labels (9,10). Useful summaries of the opportunities in Nanomedicine can be found in the 2006 NNI Nanobiotechnology Report (11) and recent reviews of EC studies in this area (12,13).

In the health maintenance area, nanotechnology applications evolve rapidly, from cleaning up contaminated soil and water, to infection prevention for significant improvements in public health.

Nanotube membranes and iron nanoparticles have been shown to be efficient for water filtration (12) and in the removal of arsenic from drinking water (13, 14). A. Srivastava *et al.*, report the manufacturing of macroscopic hollow cylinders that contain radially aligned carbon nanotubes (12). The efficiency of these membranes was demonstrated in elimination of heavy hydrocarbons from petroleum and filtration of bacterial and virus contaminants from water. Recent research (13) has suggested that as a remediation technique, nanoscale iron particles are effective for the transformation of a large variety of environmental contaminants, and in addition are inexpensive and have low toxicity. Zinc oxide nanoparticles have a double role, both as sensor and in encouraging the degradation of organic pollutants in the environment (15); the contaminants are sensed by change in visible emission signal and in the same time are degraded via photocatalytic oxidation, to form more benign environmentally compounds.

A healthy environment in residential, commercial and public buildings including hospitals is crucial to public health. Biological contaminants include bacteria, molds, mildew, fungi, and viruses. Contaminated air handling systems easily become breeding grounds for bacteria, mold, fungi, mildew, and other sources of biological contaminants and can distribute these contaminants throughout the local environment.

Molds that produce airborne toxins (*Stachybotrys*, *Aspergillus* and *Penicillium*) can cause serious symptoms, such as breathing difficulties, memory and hearing loss, dizziness, and flu-like symptoms. Often removal from exposure, medication, diet, and other treatment protocols are necessary. But there are indications that other health problems may remain permanently, such as brain damage and weakened immune systems. Besides the health problems, the presence of mold is of great economic and aesthetic significance. The financial effects of mold can be very large; American insurers shed a $30 billion liability by trimming mold coverage on business and homeowner policies in the last couple of years.

In the clinical environment, microbial biofilms on surfaces cost the nation billions of dollars yearly in equipment damage, product contamination, energy losses and medical infections.

Nanotechnology is proving to be of great importance in preventing infections and diseases associated to inhaling fungal and bacterial contaminants.

Here we present two examples of how nanotechnology can help in maintaining a clean and safe environment.

MOLD-FREE SURFACES

Molds are fungi which can form on construction materials in less than 2 days if the right combination of temperature and humidity is present. Mold spores are omnipresent and a food source such as cellulose can be found in all construction materials listed above.

It has been suggested that in housing and public buildings, "mold is the new lead"; it is the leading health exposure issue associated with buildings. There are concerns as diverse as military housing in Hawaii and Washington State and schools in New England. Recently there was a strong emphasis on mold remediation, especially following the 2005 hurricane season, but there has been relatively little emphasis on mold prevention. Many homes, schools, hospitals and government buildings suffer mold damage even without the additional effects of hurricane damage. Mold is not only a cosmetic problem but a health hazard as prolonged exposure can lead to sensitization, asthma, and allergy related issues. It is also an increasing burden for homeowners when houses are sold.

Although a range of approved inhibitors can be used in construction materials, much of the inhibitors capability is lost during processing, application and initial exposure and requires a high concentration to be applied. The ideal situation is to have a latent inhibitor present which is only released when moisture is present, and then in a concentration only sufficient to inhibit the mold formation. Mold resistant materials are available but are only used sporadically as they tend to be significantly more expensive than conventional building materials and are not specified in building codes or federal purchasing requirements.

Nanotechnology allows us to encapsulate EPA approved latent inhibitors economically within natural clay-based systems with the same chemistry as kaolin to achieve a controlled release as required. This allows the effective use of mold resistant agents at very low concentrations

Liquid inhibitors are incorporated in the approximately 30 nm lumen of the mineral nanotube (Figure 1) and analytical as well as biological testing confirms that the controlled release of these materials is highly effective (Figure 2).

Figure 1. Halloysite clay nanotubes (200nm diameter)

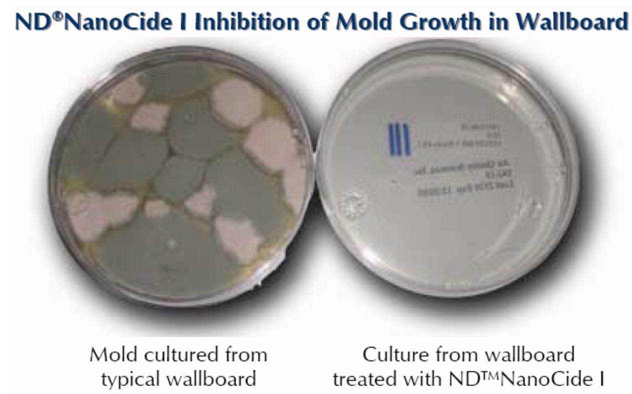

Figure 2. Inhibition of mold by wallboard paper treated with controlled release mold inhibitor.

BACTERIA-FREE SURFACES

The increasing demand for hygienic living conditions leads to a great need of antimicrobial materials that do not allow microbes to attach, survive and proliferate on surfaces. Such materials lower the risk of transmitting diseases and poisoning the environment.

Everyone knows what silver is. It is the white, shiny metal used to make jewelry, cutlery, and coins. But besides all its beauty, ordinary metallic silver has long enjoyed a reputation for antimicrobial properties. In ancient Greece and Rome, those who could afford it often stored their perishable liquids in silver containers, because the metal helped retard the growth of microorganisms that spoil food and cause disease. Prior to the development of refrigeration, it was once common to drop a silver coin into a container of milk to retard spoilage.

Silver exhibits a broad range of antimicrobial activity against gram-positive and negative bacteria, yeast and molds (17). Silver nanoparticles constitute a reservoir for the antimicrobial effect. In the presence of moisture, metallic silver oxidizes, which results in the release of the silver ions. Silver ions are the species that are responsible for fungi and bacteria growth inhibition. Because silver oxidation is a slow reaction, the size of silver particles is critical to achieve fungi growth inhibition. The smaller the particle size, the higher surface area, and the greater the area available for oxidation. Particles with diameter less than 100 nm (see Figure 3) are required to have the surface area necessary to allow a continuous release of silver ions.

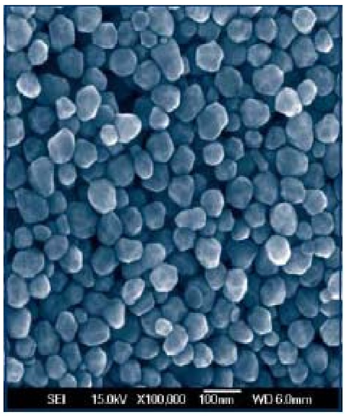

Figure 3. 80nm silver nanoparticles

The main advantages of silver nanoparticles over organic biocides are: i) silver is not volatile, it does not degrade in time, ii) it has no offensive odor and iii) it has long term efficacy.

Silver has been proved to be effective against *Staphyloccocus aureus*, a bacterium which is the leading source for hospital-related infections, and *Escherichia Coli*, a bacterium responsible for urinary catheter associated infections (see Figure 4).

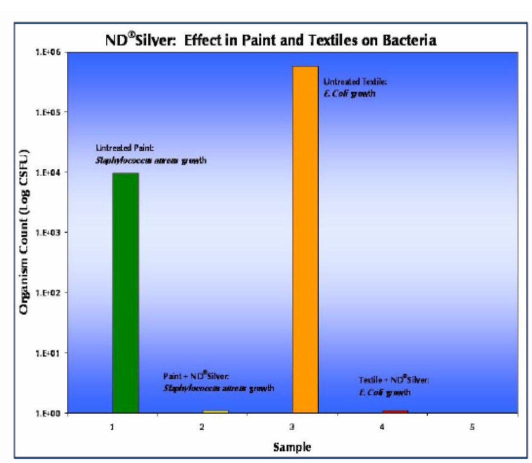

Figure 4. The antibacterial effectiveness of adding nano silver to paint and textiles

CONCLUSIONS

We have really only skimmed the surface here of the potential which includes soil resistant, self-cleaning surfaces which show bacteria, mold and algal resistance; biofilm prevention in water treatment and industrial processes; water treatment to selectively remove organic and inorganic contaminants and even the catalytic removal of airborne particulates and contaminants from combustion in transportation and other sources.

Because of the diversity of chemistries and applications we can expect to see a wide variety of nano-enabled products coming to market over the next few years helping to make our environment cleaner and safer.

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