Nanotechnology: Truth & Consequences

Exciting? Dangerous? Experts wrestle with this unparalleled enigma

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The reason nanomaterials are exciting is the reason they are dangerous. They offer hope to the hopeless but could destroy as well as create. While some companies are approaching nanotechnology with extreme caution, others are focused on rushing product to market. Top experts are calling for additional research, responsible development and government action

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What's It All About? 10 Key Points

Touted as a greater invention than sliced bread in national headlines and scientific journals, nanotechnology is an emerging science featuring nanomaterials &#151 engineered particles developed by working at the molecular level to create substances that are 80,000 times smaller than a human hair. Why all the hoopla around this engineering buzzword? In a nutshell, nanotechnology has the potential to clean up environmental messes, cure cancer and form the best darn paints and coatings, baseball bats and countless other products ever known to mankind. However, the essence of what makes nanomaterials so special &#151 they possess very different characteristics than their standard-sized counterparts &#151 is what is causing concern about their impact on the environment and human health. For this reason, the government recently funded research programs that focus on the implications of nanomaterials and nanotechnology, rather than just the applications.

Until the results are in, experts suggest taking a "responsible development" approach.

Ingenious Technology

Nanotechnology is the science of transforming nanomaterials, which are engineered by working at the molecular level, atom by atom, to create particles that range in size from one to 100 nanometers (a nanometer is 80,000 times smaller than a human hair) into a working technology that has the potential to do just about anything from treating serious illnesses to transforming environmental cleanup to improving a myriad of consumer goods such as computers and golf balls.
What makes the technology so ingenious is that nanomaterials and nanoparticles, which possess properties that demonstrate different characteristics from the same materials on a larger scale, can be added to composite materials or chemicals to strengthen or alter the mechanical properties of these other materials. In essence, they are a platform technology for bigger and better and very promising technologies. For instance, according to Kristen Kulinowski, director of the International Council on Nanotechnology and director of external affairs with the Center for Biological and Environmental Nanotechnology (CBEN) at Rice University in Houston, TX, researchers at CBEN are employing functional nanoparticles as a possible cure for cancer. "The application involves a nanoshell, which is a core shell structure where the core is silica and the shell is gold. Because of the way the nanoshells are structured, they have unique electromagnetic properties that enable them to absorb light in the infrared spectrum," she explains. "When the particles are injected into the body, they find their way to cancerous tissue via small gaps in the vasculature that supplies the tumors. The tumors themselves aren't robust because they grow so rapidly, so the nanoparticles can leak out and collect in the cancerous tissue. Or, we may be able to put something on the shell to target the known antibodies. Then, an infrared light is shined outside the body. The tissue doesn't absorb the light, but the nanotubes do. The light is converted into heat that is transferred to the cancerous tissue to which the nanoparticles are attached. This raises the temperature of the cancerous cells beyond the point of viability, essentially cooking cancer but leaving healthy tissue and cells unharmed because the nanotubes don't collect near healthy tissue." Kulinowski describes this application as quintessential nanotechnology in the sense that it is less than 100 nanometers. "The materials are capable of doing things that larger particles of the same material can't do &#151 namely absorbing infrared light and fitting into the gaps in the veins," she explains. "And it is an application that benefits human health." The environment may also benefit from nanotechnology. "This emerging field has the potential to transform environmental protection," says George Gray, assistant administrator for EPA's Office of Research and Development. "Researchers are now testing iron nanoparticles that could clean up pollutants in large areas of groundwater cheaper and more effectively than any existing techniques." CBEN is working on a similar project in which palladium and gold nanoparticles are put into polluted groundwater to serve as photo catalysts. "They take UV light from the sun and use it to speed up the breakdown of pollutants," says Kulinowski. "This application allows environmental scientists and engineers to take advantage of the large surface areas of nanoparticles and their ability to photo-catalyze at the

nanoscale." While these applications and a multitude of other promising ones make some scientists eager to use nanotechnology to engineer solutions for all sorts of serious issues, caution is mandatory. "It is the ability of nanoparticles to demonstrate different behaviors from the same chemicals at a larger scale or larger dimension that is both the promise and the potential peril of nanotechnology," warns Kulinowski. Dr. Nigel Walker, staff scientist at the National Institute of Environmental Health Sciences and the leader of the National Toxicology Program's Nanotechnology Safety Initiative, says nanomaterials have a very different way of interacting with biological systems. "We need to determine whether there is a negative side &#151 whether these unique nanoscale properties have a negative impact on biological systems as well. Do they increase accessibility to certain places in the body that aren't accessible at a higher size? Do they interact with biological molecules in a different way because they have electrical chemical properties and surface reactivity features that are unique to nanoscale materials? Could they be potentially dangerous to biological systems in the human body and the environment?" Right now, the answer to Walker's questions is maybe. "While no one has really demonstrated a known hazard to a person to my knowledge, the potential for damage to human and environmental health exists," says Kulinowski. There has been an increasing number of studies done on cells in culture, bacteria, rodents and lower level organisms that show that nanoparticles may be detrimental. One study demonstrated that if nanoparticles are injected into the lungs of rats, they cause scaring and inflammation and can agglomerate and block the airways of the animals, causing them to suffocate. Another study has shown that nanoparticles placed into cells in culture become almost like free radicals, punching holes in the membrane of cells, making them no longer viable.

Environmental studies have also revealed a possible dark side. There are some questions about their ability to translocate into the environment. In other words, if nanoparticles are put in one place, do they have the ability to absorb organic pollutants onto their surfaces and transport themselves and those pollutants somewhere else unexpectedly? Yet another study demonstrates the possibility of harmful effects on the organisms at the very bottom of the food chain, perhaps killing an essential part of nature's very complex food chain. "These and other studies like them have provided a growing body of literature that suggests that we might not want to have lots of unbound engineered nanoparticles dispersed into the world without care," says Kulinowski. Walker agrees. "We need to be looking at the possible ramifications at the same time the technology is being developed," he says. "There's certainly a lot of promise here but no one knows the potential downside or possible implications. The point being you don't want another situation like asbestos or PCBs, where the technology gets ahead of itself and doesn't take into consideration the potential human and environmental effects that could occur if the technology gets to the point where there's an application of the materials without any kind of study about how it might impact things."

Focus on Implications

For this reason, the EPA and other government agencies are beginning to

commission studies related to the implications as well as the applications of nanotechnology. "EPA wants to see Americans benefit from this exciting new technology while ensuring that human health and the environment are protected," says Gray. "Therefore, EPA has awarded 14 grants totaling $5 million to universities to investigate potential health and environmental effects of manufactured nanomaterials. By performing research on potential adverse affects, EPA is doing what is right for both human and environmental health and technological processes."
In addition to the grants, which were awarded through EPA's Science to Achieve Results (STAR) research grants program in partnership with the National Science Foundation and the National Institute for Occupational Safety and Health, the agency is calling its Toxic Substances Control Act into play. The program reviews and assesses new chemicals prior to their entry into commerce. And the EPA is working with a range of other agencies, stakeholders and businesses to develop a stewardship program that will allow the EPA to gain a better understanding of the benefits and risks associated with nanomaterials. While the voluntary program would ask participants to expose any ill effects they may find &#151 even if it means millions of research dollars have been spent to develop an application that ultimately can't be brought to fruition &#151 it is receiving chemical industry support. "We strongly support the EPA's stewardship program and we are trying to encourage EPA to get it into motion," says Bill Gulledge, managing director of the Nanotechnology Panel at the American Chemistry Council. "We believe eventually that the information that the EPA gathers from a stewardship program will help lay the groundwork for future applications."

Responsible Development

As Gulledge implies, there seems to be no stopping the development of nanotechnology. However, policy makers, the EPA and scientists are calling for responsible development. "The term 'responsible development' embodies what the EPA is trying to put together in its stewardship program," says Walker. "It is a dialogue between nanotechnology developers and the scientists and agencies that would deal with any problems that might be found. Such dialogue includes discussions about product safety, workplace safety and toxicology assessments of materials that are nearing commercialization."
He adds: "Big companies that have invested a lot are well in tune with 'responsible development' and 'product stewardship' because they realize that if they put out a product that turns out to be hazardous and they haven't evaluated it, their liability is huge." However, the trend toward open dialogue has not necessarily trickled down to smaller companies that are rushing to get product to the marketplace. Walker cautions against this. "Chemical engineers who are used to dealing with chemistry may not understand toxicology," he says. "It is in their best interest to be in touch with regulatory authorities in the early stages of development to determine if they are going down a road that is potentially hazardous and may have some problems. They don't want to produce anything that the EPA may eventually regulate or ban." For this reason, the steps the government takes toward guided development, which Walker says includes ethical, legal and environmental implications while nanoproducts are developed rather than after they are

developed, is important. "It is much easier to guide the development than to clean something up after the fact," he says. For the time being, experts suggest that chemical engineers working with nanotechnology proceed with caution. "I don't see a day where we will be able to say that all nanomaterials are safe. It is too broad an area and development is moving too quickly," concludes Walker. "But on the flip side, we can't let the studies with detrimental results lead us to believe that nanotechnology and nanomaterials are bad because a small handful of studies don't reflect the full range of nanoscale materials out there. For this reason, it is important to follow the government's lead and adopt responsible development guidelines. It will allow us to find the promise and avoid the pitfalls of nanotechnology."

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