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Our Silver-Coated Future

NANOTECHNOLOGY, FAST BECOMING A THREE-TRILLION-DOLLAR INDUSTRY, IS ABOUT TO REVOLUTIONIZE OUR WORLD. UNFORTUNATELY, HARDLY ANYONE IS STOPPING TO ASK WHETHER IT'S SAFE. >>>>>

FOR AN industry that trades in the very, very small, projections about the potential scope of nanotechnology are gigantic. Estimates are that the industry will grow at a staggering pace in its first decade, reaching close to \$3 trillion globally by 2014. The National Nanotechnology Initiative, created by President Bill Clinton in 2000, has called it “the next industrial revolution.” Enthusiasts say that nanotechnology may someday enable scientists to build objects from the atom up, leading to entirely new replacement parts for failing bodies and minds. It may enable engineers to make things that never existed before, creating nanosize “carpenters” that can be programmed to construct anything, atom by atom—including themselves. Or it may make things disappear, with nanowires that get draped around an object in a way that makes the whole package invisible to the naked eye.

As difficult as it is to comprehend how huge is the promise of nanotechnology, it’s just as hard to wrap your head around just how tiny “nano” is. A nanometer is defined as one billionth of a meter, but what does that mean? The analogies are mind-boggling but not necessarily enlightening. Hearing how small things are when you’re working at the nano level doesn’t help you visualize anything, exactly; all it does is make you sit back and say, “Wow.” If you think of a meter as the earth, goes one analogy, then a nanometer would be a marble. If you think of a meter as the distance from the earth to the sun, then a nanometer would be the length of a football field. A nanometer is one hundred-thousandth the width of a human hair. Or it is, in a particularly kinetic description, the length that a man’s beard will grow in the time it takes him to lift a razor to his face.

“Things get complex down there, in terms of the physics and the chemistry,” says Andrew Maynard, chief science adviser for the Project on Emerging Nanotechnologies, established in 2005 at the Woodrow Wilson International Center for Scholars in Washington, D.C., in partnership with the Pew Charitable Trust. “When you have small blocks of stuff, they behave differently than when you have large blocks of stuff.”

At the nano level, some compounds shift from inert to active, from electrical insulators to conductors, from fragile to tough. They can become stronger, lighter, more resilient. These transformed properties are what account for the infinite potential applications of nanoparticles, defined as anything less than about 100 nanometers in diameter.

The field is a textbook example of exponential growth. According to Lux Research, an emerging-technologies research and advisory firm based in New York that has tracked the industry since 2001, the total value of all products worldwide that incorporated nanotechnology was \$13 billion in 2004. That figure grew to \$32 billion in 2005 and to \$50 billion in 2006, and Lux Research projects it will reach \$2.6 trillion by 2014.

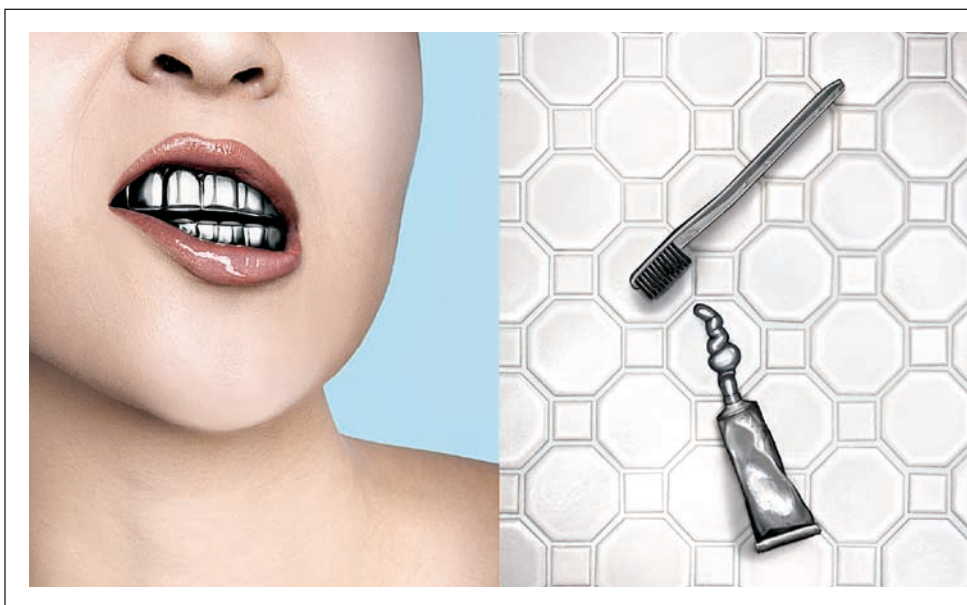
Nanotechnology holds great potential for improving our lives. It might benefit the environment, for instance, by reducing our dependence on oil through the creation of a new power grid based on carbon nanotubes—which can carry up to 1,000 times as much electricity as copper wiring without throwing off heat—and solar energy farms that use thin, cheap, flexible nano-engineered solar panels.

Nanostructures offer better options for rechargeable batteries, for instance, including the ones to be used in the next generation of hy-

brid cars. One such battery, made with nanostructured lithium-iron-phosphate electrodes, is smaller and lighter, less environmentally toxic, and can hold more energy, take a charge more quickly, and maintain a charge longer than conventional lithium batteries, according to Michael Holman, a senior analyst with Lux Research. “It’s not the compound itself that’s nanoscale, but the surface of the material,” Holman says. The surface of the battery electrode contains nanosize bumps and ridges, “which make the surface area much higher, allowing the electrons to flow in and out of it more quickly.”

In the medical field, nanotechnology is expected to lead to dozens of innovations: new methods of cancer treatment that deliver chemotherapy directly to the tumor, earlier cancer detection using nanowires that can spot derangements in just a few protein cells, new methods of blood vessel grafting during heart surgery using nanogluce formed from nanospheres of silica coated in gold.

In cancer treatment, one application involves gold nanoshells: gold-coated glass spheres no more than 100 nanometers in diameter. These nanoshells enter tumors by slipping through tiny gaps



in blood vessels that feed the malignancy. Once enough nanoshells accumulate in the tumor, scientists shine a near-infrared laser through the skin, heating up the gold particles and burning away the cancer. This technique, developed at the University of Texas Health Science Center, has worked in animal experiments and is about to be used in humans.

However, the real impact of nanotechnology, at least in the short term, will not be at the dramatic level of cancer cures or a new energy grid. For now, the technology will have to prove itself in the more mundane arena of commerce: washing machines that fight germs, antiseptic computer keyboards and kitchen utensils, windshields that repel the rain, sunscreens that rub on easily and block the full spectrum of ultraviolet rays. Nanoparticles are being put into stain-resistant clothing (Haggar NanoTex pants with NANO-PEL), superlight tennis rackets (Wilson nCode), antiwrinkle face creams (Lancôme Rénergie Microlift), sunscreens (Blue Lizard), computer peripherals (IOGEAR), and a wall paint made by an Australian company, Nanovations, that says the paint can “achieve better energy ratings for buildings, better indoor air quality and fewer allergy-related illnesses.”

BUT BEFORE we hurtle off toward a nano-utopia, we need to step back and ask ourselves whether this is a direction in which we really want to go.

When an industry grows this quickly, there may be neither the time nor the inclination to ask some tough questions about possible risks. First of all, there are the health and environmental hazards. Would nanotechnology bring unacceptable risks to workers making these materials or consumers who use the final products? Would it affect air or water quality near where the nanomaterials are dispersed? Very little is known about nanotoxicology, which might be very different from the toxicology of the same materials at normal scale (see “Smaller Is Weirder,” page 28).

Then there are the social, even existential, consequences. If the hype about nanotechnology contains even a smattering of truth, the technique could shake up our most basic assumptions about our place in the universe, turning us from its residents to the architects of its most fundamental elements. Might that act

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of hubris somehow subvert us as a species?

As nanotechnology explodes, and as federal agencies wrangle over whose responsibility it is to deal with an essentially unregulated industry, it's all the more crucial to take stock of the emerging field as soon as possible.

“This is not a technology we want to say no to out of hand,” says Jennifer Sass, a senior scientist at the Natural Resources Defense Council (NRDC). “I think this is a technology that is potentially transformative, but we want to use it in a way to take advantage of that while reducing the risk.”

Maynard sees this moment as a crossroads for nanotechnology. “What concerns me,” he says, “is that if we're not smart about this we'll get something wrong, which would cause unnecessary damage to the environment or to people and would undermine the potential of all nanotechnology.”

Nowhere is the tension between real and perceived risk—not to mention the tension between the mundane and the transformative—more apparent than with nanosilver. Nanosilver offers an important early test case for two reasons: It is now used in more consumer

products than any other nanomaterial, and it is principally designed for use in products that come into direct contact with the human body. Since late 2005, the Project on Emerging Nanotechnologies has been compiling an inventory of products that contain nanomaterials. In the first two years the list more than doubled, to more than 500 products as of the summer of 2007. Of these, nearly 100 contain nanosilver, almost always because of its antimicrobial action.

In its ordinary form, silver is a metallic element with brilliant luster, great malleability, and the ability to conduct both heat and electricity. Its most common use is in photography, as silver halides and silver nitrate on photographic paper, and it has also long been used to make jewelry, coins, and tableware. Its luminosity has inspired songsmiths and poets; Emily Dickinson, for one, described the ocean as “an everywhere of silver.”

Silver can also, in its regular form, kill bacteria, fungi, and other infectious microorganisms. (So can other metals, such as mercury and lead, but they, unlike silver, are almost as toxic to the human host as they are to microbes.) When silver is converted to nanosilver, this germ-killing quality is amplified, probably because of a change in surface-to-mass ratio. Silver's antimicrobial action is due to the release of positively charged silver ions on the surface, says Maynard, and “you get higher performance from the same mass of material” at the nanoscale. In addition, nanosilver can be incorporated into plastics, fabrics, and other consumer items more easily than can larger silver particles.

Nanosilver is added to socks and shoe liners to combat foot odor, to bandages to promote healing, to the insides of refrigerators and food storage containers to retard spoilage. It may soon be applied to artificial joints and other implants to reduce the risk of infection. Already there are nanosilver coatings or infusions in computer keyboards, computer mice, nail clippers, dog food bowls, spatulas, back support pillows, pay phones, air purifiers, handrails, ATM buttons—anywhere one set of hands might come into indirect contact with another set.

“But do we really need to put antimicrobial coatings on a computer mouse?” asks Maynard. “I mean, how many infections are really transmitted by someone using a mouse that has germs on it?”

Just before the 2006 flu season, the government of Hong Kong put nanosilver coatings on the handrails and grab-poles in the city's subway system to help prevent the spread of avian flu. The uncertainty over the health consequences of such an action was driven home in photographs of workers applying the nanosilver. As they sprayed on the nanomaterial—applied, remember, to protect the public's health—they were covered head to toe in protective hazmat suits. Granted, nanosilver might be more toxic in aerosol form than it is after it dries, but that's the point—no one knows for sure. The image of workers spraying stuff on handrails while wearing protective gear and face-masks was, to say the least, disconcerting—and no one can say whether the nanosilver coating will remain intact once it dries, or whether it will be rubbed off and dispersed after contact with thousands of commuters' hands.

And if hazmat suits are required for workers to apply nanosilver to handrails, what is nanosilver doing in Theramed S.O.S. Sensitive toothpaste? Or in a baby bottle made by the Korean company Baby Dream? Or in another child care product from Korea, NANOVER Wet Wipes, which the manufacturer says are “soft like cotton, protect babies' frail skin”?

Silver has a long history of use in humans, and it has generally been found to be safe. In the days before antibiotics, silver was used

as a curative; as long ago as the fourth century B.C., the Greek physician Hippocrates recommended as an ulcer treatment “the flowers of silver alone, in the finest powder.”

Because of its germ-killing power, silver has taken on an almost mystical aura. According to folklore, silver repels vampires, and a silver bullet is the only way to kill a werewolf. Housewives in the early 1900s would drop a silver dollar into a bottle of milk, hoping to keep the milk fresh longer. And many doctors still routinely administer eyedrops of silver nitrate to newborns to prevent blindness that could result from an infant’s exposure to gonorrhea, chlamydia, or other microorganisms living in the birth canal.

The alternative-medicine community has latched on to silver as an antimicrobial too. Silver is sold in health food stores as colloidal silver, a liquid mixture of silver and water. A suspiciously broad range of claims has been made for colloidal silver, from healing wounds to treating skin cancer. Similarly extravagant claims are being made for nanosilver, as on the Web site of one distributor, Spirit of Ma’at of Sedona, Arizona, which states that its nanosilver supplement “protects against colds, flu, and hundreds of diseases (even anthrax).” The only health risk known to be associated with such supplements is an unsightly (though benign) condition known as argyria, in which the skin is permanently stained blue. (A Libertarian candidate in last year’s U.S. Senate race in Montana, Stan Jones, who started using a homemade colloidal silver concoction in 1999, was famous for his ashen blue-gray skin.)

But might exposure to nanoscale particles of silver have more pernicious side-effects? It’s hard to say, because few studies have been done specifically on nanosilver. Despite this uncertainty, consumer products with nanosilver keep being introduced. And without any requirements for premarket safety testing, manufacturers have no incentive to conduct such tests on their own.

At the moment, the health risks of nanosilver are conjectural, based on what little is known about how other nanoparticles behave. But this is an imperfect system, since we can’t be sure whether one nanoparticle’s tendency to penetrate individual human cells predicts how a different nanoparticle—even a slightly different size or shape of the same basic nanomaterial—will behave.

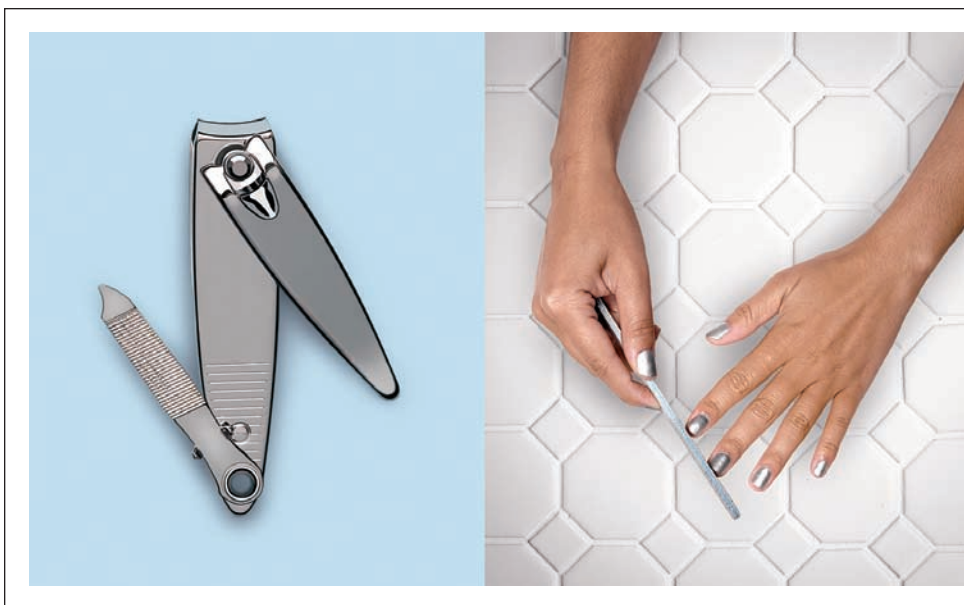
What we know at this point is merely suggestive, but in some cases worrisome. One study of cells in culture, for instance, showed that when human lung tissue is exposed to carbon nanotubes, the lung cells see these not as foreign agents but as a biological substrate on which to build other tissue. Rather than mounting an immune response to attack the nanotubes as invaders, the lung cells start building layers of collagen around them. No one can say how likely it is in real life for carbon nanotubes to be inhaled; for most current uses, such as lightweight bicycle parts or tennis rackets, they are fixed in a matrix. But there is a chance that they might be inhaled during manufacture or as the product degrades, either through normal wear and tear or after it’s disposed of. If they get into people’s lungs, will carbon nanotubes act *in vivo* the way they do in cell culture, and become a scaffolding for new layers of collagen that could block the airways?

Similar questions about the safety of nanoparticles arise from animal models showing that they can get into the bloodstream

through the skin and then travel to vital organs, including the brain. As with airborne exposure, the likelihood of skin exposure to carbon nanotubes is still an unknown, but once again early research indicates that there could be some health effects. Toxicologist Günter Oberdörster of the University of Rochester, working with rodents, found that carbon nanoparticles were small enough to enter the brain by way of the olfactory nerve, circumventing the blood-brain barrier, the usually impermeable membrane that protects the brain from foreign agents.

The main thing that is known about the toxicology of nanoparticles is how much remains to be discovered. Nanoparticles, says Maynard, “can penetrate into cells in ways that larger particles cannot, or migrate to places in the body large particles cannot get to.”

Another worrisome finding is a possible link between nanoparticles and the more rapid formation of protein fibrils, a material found in neurons that, when it accumulates, can lead to the buildup of a brain toxin called amyloid. Chemists from several European universities, led by Sara Linse of University College Dublin, exposed a laboratory



preparation of purified protein to four types of nanoparticle, including carbon nanotubes and so-called quantum dots (crystals just 5 or 10 nanometers in diameter that are used in the semiconductor industry to measure electric current down to the level of the electron). All four types of nanoparticle accelerated the abnormal development of the protein into amyloid fibrils. The reason for the concern is that amyloid has been implicated in a variety of neurological diseases, including Alzheimer’s and Parkinson’s.

As with most studies in nanotoxicology, the Linse study is preliminary; it was conducted *in vitro*, not in an animal or a human, and it remains to be seen whether the findings will be replicated *in vivo*. But it does point out the complexity of the emerging field of nanotoxicology.

“One of the most important messages of this work for chemists,” wrote Vicki Colvin and Kristen Kulinowski of Rice University in last May’s *Proceedings of the National Academy of Sciences*, “is that when NP’s [nanoparticles] enter the biological world they become very different materials.” According to Colvin and Kulinowski, “The small sizes of NP’s convey the potential to

access many biological compartments, where they are met with a smorgasbord of possible binding partners from the complex and concentrated soup of biomolecules.”

IN TERMS of environmental consequences, if nanosilver is anything like ordinary silver, we might be in for some trouble. As with the potential human health risks, the environmental dangers can only be guessed at by analogy—in this case, to the known impact of normal-scale silver on aquatic organisms. According to Samuel Luoma, a senior research scientist at the U.S. Geological Survey in Menlo Park, California, silver is a powerful environmental toxin, second only to mercury in the damage to invertebrates that even trace amounts can do. It kills microorganisms indiscriminately and can wipe out the beneficial ones as well as the pathogenic ones. In addition, it has a direct effect on the reproductive capabilities of certain aquatic invertebrates, and possibly fish as well.

Through most of the 1980s, says Luoma, silver pollution from a photo-processing plant led to widespread sterility among the *Macoma*

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balthica clams in South San Francisco Bay near Palo Alto. Clams are an important part of the bay-bottom food web, he says, and the population recovered only when new regulations limited the amount of silver in the bay. The photo-processing plant was eventually closed.

The lesson learned was a crucial one: It took a very low concentration of silver, less than one part per billion, to destroy the reproductive organs of virtually all adult *M. balthica* living within a certain distance of the silver source, and to spread silver contamination throughout the South Bay.

“No one outfall [the sewage pipe that carries wastewater from a treatment plant] could have effects everywhere in San Francisco Bay,” Luoma says. “The risk with nanosilver from consumer products is that it would come from all outfalls that serve urban customers. What we need to know is how much silver would be released from many households. Would it be comparable to the mass from photo processing?”

Silver might have been especially toxic in San Francisco Bay because the bay is salt water. Unlike many other environmental toxins, silver seems to be more dangerous in salt water than in fresh. In freshwater, silver combines with chloride and forms a solid that sinks to the bot-

tom, becoming less bioavailable (that is, less capable of absorption by the body). But in salt water, with a preponderance of chloride atoms, more silver chloride remains in solution, binding to particulate matter. This puts more of it into the food chain and therefore makes it more likely to do damage to marine organisms.

No other metal has this property of behaving one way in freshwater and another way in salt water. This presents a regulatory problem that’s unique to silver, especially at the nano scale. According to Luoma, most toxicity testing is done in freshwater. “But a silver nanoparticle could look innocuous in freshwater and be extremely toxic in sea water,” he says. How significant is this? Nobody really knows—but Luoma is concerned. It’s reasonable, he says, to expect that nanosilver will shed from treated fabrics and from the linings of washing machines and food containers and make its way into rivers and streams, eventually ending up in the ocean.

There is also some evidence that excessive use of silver as an antimicrobial can lead to silver resistance in bacteria, in much the same way that excessive use of antibiotics can lead to the development of antibiotic-resistant organisms. In 1968, for instance, a burn patient in Maryland was treated with bandages infused with silver nitrate; his burns became infected by the common bacteria *E. coli*, which developed resistance to silver. If *E. coli* could do it, could other, potentially more dangerous microbes do the same thing? And if it happened with normal-scale silver, would it be more or less likely to happen with nanosilver? At the very least, nanosilver complicates the picture, since it allows silver to be used in so many more products. “If we use it too widely,” Maynard says, “we may be giving away our best weapon.”

Are we foolish to forge ahead in developing nanosilver products without full toxicology information? Perhaps. Luoma, who lives in Silicon Valley, says that the frenzy surrounding nanotechnology, the rush to be first at any cost, reminds him of the heedless gold-rush mentality of the dot-com era. A lot of nano-promises might fail to materialize, as happened with so many brilliant Internet startup ideas. The crucial difference is that the dot-com boom did no harm to the environment or to human health while the Darwinian struggle for survival played itself out. Nanotechnology might.

HERE’S HOW one product made from nanosilver, a set of kitchen utensils available in the United States, is being promoted by its manufacturer, Nano Care Technology of Hong Kong: “People always use traditional ways such as sterilizer to kill bacteria and germs but the result is not satisfied [sic], because many bacteria and viruses survive or relive [sic] very quickly.” But the company’s nanosilver kitchen utensils may do the job permanently, its Web site continues, and “can prevent people from the following diseases: duodenitis caused by spirillums, virosis hepatitis, dysentery caused by salmonella and food poisoning caused by golden staphylococcus.”

The Korean appliance manufacturer Daewoo makes similar claims for its products treated with nanosilver (currently distributed only in Europe), which include a washing machine, refrigerator, and vacuum cleaner. It’s clear from the Daewoo Web site that the company is using nanosilver for its antimicrobial properties: “After splitting the particles of silver known to have superior deodorant and antibiotic power by 1/1,000,000 mm, we have applied it to major parts of [the] refrigerator in order to restrain the growth and increase of a wide variety of bacteria and eliminate odor particles.” Not only is nanosilver a disinfectant and deodorant, the company writes, in an

English-language translation so elliptical as to make the true meaning unclear. It also “maintains balance of hormone [sic] within our body and intercepts electromagnetic waves significantly.”

At the moment, claims like Nano Care’s and Daewoo’s exist in a regulatory limbo. No single agency has jurisdiction over nanomaterials (the same applies to many materials of conventional size); it depends largely on how a product is used or where it is in its life cycle. During its manufacture, a nanoparticle might fall under the jurisdiction of the Occupational Safety and Health Administration, which deals with workplace exposure. After that, if it is to be ingested or used in a drug or a medical device, it might be regulated by the Food and Drug Administration. Once it’s discarded, it might fall under the purview of the Environmental Protection Agency (EPA), charged with minimizing air- and water-borne toxins.

Federal agencies have been turning their backs on regulating nanotechnology, according to a report issued in May by the Wilson Center, largely because they are not convinced it warrants anything beyond the regulations already in place for standard-scale chemicals. But this might be a dangerous assumption, writes J. Clarence Davies, a senior fellow at Resources for the Future, a nonpartisan research center, in “EPA and Nanotechnology: Oversight for the 21st Century.” According to Davies, “The relationship between science and regulation is complex” and filled with uncertainties. The best course is therefore “striking a balance between the harm that could be done by proceeding with an innovation and the harm that could be done by not proceeding.”

Nanosilver is something of a jurisdictional oddity. Initially the EPA decided that a nanosilver-releasing Samsung washing machine was a device, like a flyswatter, and not a pesticide. But after public pressure from several interest groups, including NRDC, the agency reversed itself. It placed nanosilver—an antimicrobial agent—under the authority of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) rather than the Toxic Substance Control Act (TSCA), under which most other chemicals are regulated. FIFRA requires manufacturers to submit toxicity data before a product can be approved for sale and gives EPA broad authority to prohibit or limit the sale of pesticides.

“There is something surreal about asking whether washing machines or food-storage containers are pesticides,” notes Davies in his report, “and it is a type of problem not envisioned by the drafters of the FIFRA statute.” His reading of the act is that what matters in classifying an ingredient as a pesticide is not so much what the manufacturer says it does as what the ingredient has been put there to do. “It’s less a matter of claim than intent,” he says. “And in my opinion, it’s pretty easy to show that the silver isn’t doing anything in the products we’re talking about other than acting as a pesticide.”

After EPA’s initial FIFRA decision, however, the agency decided to regulate only specific nanosilver products—those that make explicit claims of antibacterial action. The result has been that several manufacturers have changed their claims from “kills germs” to less obvious formulations, such as “specially patented” or “stays fresh longer.”

In early 2006, for instance, The Sharper Image was saying that its FresherLonger food-storage containers were “infused with naturally antibacterial silver nanoparticles.” The company’s Web site at the time featured photographs of strawberries and grapes stored for eight days

Smaller Is Weirder

THE CHANGES IN PHYSICAL PROPERTIES THAT MAKE nanomaterials so useful can also alter their toxicity profiles. Vicki Colvin, a chemist at Rice University, says that the usual way to assess toxicity, by measuring a toxin’s mass, won’t work at the nano level. Nanomaterials have a much higher surface-to-mass ratio, and while this makes them good for such purposes as water filtering, it also could cause them to interact with body cells that their tiny size allows them to infiltrate.

The implications of such characteristics for health and for the environment remain unclear. “One problem with nanomaterials is that how toxic they are depends on a lot of things,” says Jennifer Sass of NRDC. “It depends on surface coatings, whether the nanoparticles are functionalized, whether they agglomerate”—in other words, whether they are modified in ways that make them more easily absorbed by the body and whether they tend to clump together into bigger-than-nanoscale clusters. These variables make it difficult to issue blanket safety standards for nanoparticles.

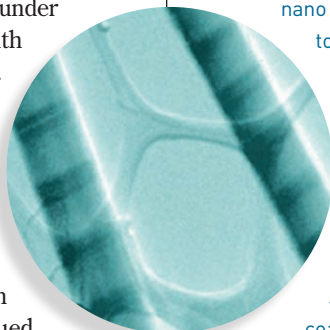
In late 2006, Andrew Maynard of the Project on Emerging Nanotechnologies in Washington, D.C., along with 13 colleagues, pointed out in a commentary in *Nature* the unique challenges of nanotoxicology. “We have known for many years that inhaled dusts cause disease, and that their harmfulness depends on both what they are made of and their physical nature,” they wrote. With asbestos, for instance, the material’s likelihood of causing respiratory problems is directly related to its size and shape: “Thin, long fibers of the material can lead to lung disease if inhaled, but grind the fibers down to shorter particles with the same chemical makeup and the harmfulness is significantly reduced.” Sometimes it’s more dangerous for particles to be small, sometimes it’s less dangerous. While the toxicological profile of a nanoparticle might depend on its size, Maynard and his colleagues wrote, it might also depend on other factors, such as “surface area, surface chemistry, solubility and possibly shape.”

And it’s not just the characteristics of a nanomaterial that might be relevant but also its provenance. For instance, there are four different processes for manufacturing nanotubes (above), five different purification methods, and 10 different surface coatings, not to mention 20 different structural types, ranging in length from 5 to 300 nanometers. In all, calculates J. Clarence Davies in the recent report “EPA and Nanotechnology,” there are 50,000 different versions of single-walled carbon nanotubes. Of these 50,000, “each version may have different chemical, physical, and biological properties.”

Nanotoxicology is filled with uncertainties. Even though a growing number of toxicity studies show that nanoparticles behave differently from larger particles, different does not necessarily mean more dangerous. “Unknown risks do not translate to high risks in every case,” Maynard says. “There are many nanomaterials where the materials are likely to be relatively safe.”

So if the mind reels trying to conceptualize the smallness of nanoscale, it has almost as much trouble trying to comprehend the vastness of the task of getting a handle on the health and safety ramifications of nanotechnology.

—RMH



in FresherLonger, compared with fruit stored for the same period in a conventional container. The conventionally stored fruit had grown “furry,” the company wrote, and the FresherLonger fruit looked almost as good as new. The difference? “The silver nanoparticle miracle,” according to Web site archives from April 2006. “In tests comparing FresherLonger to conventional containers, the 24-hour growth of bacteria inside FresherLonger containers was reduced by over 98 percent because of the silver nanoparticles!”

Berries stayed fresh, according to the 2006 Web site, because “patent-pending antimicrobial silver nanoparticles infused into the containers reduce growth of mold and fungus. . . . Silver in microscopic particle form is a safe, medically proven antibacterial agent. That is why silver nanoparticles are infused into the polypropylene containers of the FresherLonger system.”

By May 2007, the text and the fruit photos were gone from the Web site, replaced with a bland description of the product as a “specially treated” polypropylene container that “helps to retard spoilage.” Nothing nano is even mentioned. All that is specified is a “patent pending” airtight seal, and the fact that the containers are durable, dishwasher safe, and translucent, so you can see what’s stored inside.



A SAFER RIDE? In the Hong Kong subway, mass transit and public health officials pose for the media as a worker sprays handrails with nanosilver.

The Sharper Image also makes slippers with nanosilver, but while they were once called “Contour-Foam Silver Slippers”—a name that had a kind of Wizard of Oz ring to it—today the slippers are described simply as “Contour-Foam.” The company’s Web site in April 2006 said they were made with “viscoelastic foam insoles infused with microscopic particles of silver that is naturally antibacterial and reduces growth of odor-causing bacteria.” The Web site today makes no mention of silver, nor of bacteria fighting.

A company spokesman declined to comment when asked to explain The Sharper Image’s marketing decisions. But Patrick Lin, director of the Nanoethics Group, in San Luis Obispo, California, offers one possible explanation: Manufacturers are trying to have their cake and eat it too. “The manufacturers say that nanosilver is the key ingredient to kill bacteria in your laundry,” he wrote in an e-mail follow-up to a telephone interview, “but in the same breath, they say (at least implicitly) that nanosilver won’t have any

significant impact after [it is] released into the water system. Well, which is it—is nanosilver an effective killer or not?”

THE NEW science of nanotechnology is poised precariously between two vistas. In one direction, scientific researchers and industry scramble to capitalize on the technique’s alluring potential; in the other, regulatory agencies and environmental groups debate ways of keeping risks to a minimum. Complicating the tasks in both directions, the exploitation and the regulation, is something that can be thought of as Nano’s Paradox: The qualities that make nanoparticles a potential threat to health and the environment are the very same qualities that offer a wonderful opportunity to improve that same health and environment.

Despite the uncertainty, even nanotechnology’s critics stop short of calling for a moratorium. “Testing can be done on individual nano materials and products,” Davies writes in “EPA and Nanotechnology,” “and judgments on limiting production or marketing should be based on the results of these tests.”

But just because testing can be done does not mean it will be

done. Nor does it mean that scientists are even sure exactly how toxicology testing for nanoparticles should proceed. And the political process of imposing new regulations grinds slowly—much more slowly than the field of nanotechnology is growing. This is why Maynard, for one, urges that we think in terms of “oversight” rather than regulation. “If you’re looking at developing best practices for handling nanomaterials,” he says, “you can be far faster than you can with new legislation leading to regulation. So there are ways of dealing with challenges in the near future that don’t necessarily mean resorting to regulation.”

When Maynard refers to oversight, he means whatever works to monitor and manage the impact of nanotechnology. Government regulation is just one tool for this kind

of management; others, he says, include stewardship programs developed by industry, voluntary programs pushed by government, and guidance on safe practices in manufacture and disposal.

To Davies, who was one of the original architects of the EPA back in 1970, nanotechnology offers a chance to rethink the government’s creaky regulatory apparatus altogether. He urges an overhaul of the EPA; a joint government-industry research institute on nanotoxicology; an interagency regulatory coordinating group, coupled with oversight committees in the House and Senate, focused on nanotechnology; and an annual appropriation of \$50 million specifically for EPA research into the potential risk of nanomaterials to individual health and the environment (\$38 million is currently spent on this by the federal government as a whole). Agency officials did not respond to repeated requests for comment on Davies’s proposals.

“From a scientific perspective the field is incredibly exciting,” says Sass of NRDC. “From a regulatory perspective, I sympathize—it’s a quagmire. But the real problem is from the economic perspective. Nanotechnologies are already out there in the marketplace, and we can’t keep putting this stuff in products until we know more.”