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# Nanotech Raises Worker-Safety Questions



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RENO, Nev. -- To tour the gleaming offices of Altair Nanotechnologies Inc. is to see why the U.S. Commerce Department calls nanotech "the next industrial revolution" -- a revolution not of smelters and smokestacks but of precision-engineered carbon "buckyballs" one-ten-thousandth the size of the head of a pin and microscopic nanospheres that can pack the power of a car battery in a napkin-thin wafer. What could be more 21st-century?

But pass through heavy doors into the heart of Altair's manufacturing area and the future looks a lot like the past.

Men in grease-stained blue coats navigate catwalks atop hulking, two-story-tall spray-drying machines. Forklift drivers steer 55-gallon drums of chemicals from one area to another. Other workers attend to noisy milling operations, their face masks gathering a thin film of pale dust as they empty buckets of freshly made powders to be used in nanotech batteries and premium paints.

As the U.S. economy strides into the age of nanotechnology, thousands of workers like these are participants in a seat-of-the-pants occupational health experiment.

No state or federal worker-protection rules address the specific risks of nanomaterials, even though many laboratory and animal studies have shown that nano-size particles -- those on the order of a millionth of a millimeter -- spur peculiar biological reactions and can be far more toxic than larger granules of the same chemicals.

Regulators say they need more data before setting standards. But of the $1.2 billion the government has proposed spending on its National Nanotechnology Initiative in 2007 -- a research funding program to help jump-start the promising sector -- only about two-tenths of 1 percent is earmarked to study workplace safety issues.

The Occupational Safety and Health Administration does have a general "nuisance standard" for airborne particles, "but that standard is not going to be very useful for nanomaterials," said John M. Balbus, a physician and health program director for Environmental Defense, a watchdog group. Just three weeks in a workplace with that level of engineered nanospecks would be equivalent to the exposure that caused animals to choke to death in experiments in 2004, Balbus said.

Then again, government scientists admit, the science is so young that they do not even know what they should be focusing on: Is it the number of particles a person is exposed to that matters most? Is it their chemical composition or size? Or, as recent research suggests, is it the total surface

area of each intricately etched nanoparticle -- a complex spatial dimension that instruments can barely measure?

"We have very little data to make any kind of informed societal decisions about how to deal with nanomaterials in the workplace," said Paul Schulte, the director of education and information at the National Institute for Occupational Safety and Health (NIOSH).

That is why a swarm of NIOSH scientists recently spent the better part of a week at Altair with nearly a ton of equipment for measuring worker exposures to nanoparticles.

Altair was not in trouble -- far from it. The inspection was at the invitation of the company's chief executive, Alan Gotcher. Unlike many of his corporate peers, who have kept their heads down amid a flurry of questions about what, exactly, they are making and how they are assuring worker safety, Gotcher thinks the industry should share what it knows about nanotech manufacturing methods and safety strategies.

"We need to be responsible and we have to be proactive, and if we've got products that have problems, we've got to do something about it," Gotcher said. "On the flip side, we should not let fear of the unknown cause an overreaction."

Occupational settings have often served as bellwethers of toxic trouble. A spate of skin cancers in radiologists 100 years ago revealed the link between X-rays and cancer. "Mad hatters," who worked with mercury-exposed felt, demonstrated that metal's neurotoxic effects. And the link between asbestos and lung disease first came to light in workers handling the fibrous mineral.

Engineered nanomaterials, including geometric spheres smaller than viruses and hollow tubes just a few atoms in diameter, have just begun to be incorporated in a wide range of products, from sunscreens and clothing to aircraft parts. Early studies suggest many are likely to be innocuous. People are exposed to naturally occurring nanoparticles all the time, industry boosters note, including nanospecks of salt blowing in from the ocean.

But with their complex, chemically reactive surfaces, engineered nanoparticles act differently than natural ones. That can be helpful, allowing them to ferry drug molecules to cells that need them or conduct electricity through materials that would otherwise be resistant. At the same time, animal studies show they can also clog airways, trigger intense immune-system reactions and toast living cells.

Time will tell how much of a health risk various nanomaterials pose. But experts agree that workers producing them face the greatest danger because they are exposed to the free-floating motes directly, before they have been integrated into finished products. And although only a fraction of the estimated 210,000 workers involved in nanomanufacturing are being exposed directly to free particles, the industry is growing fast, according to Lux Research in New York. By 2014, Lux predicts, the value of goods made with new nanotechnologies will be $2.6 trillion -- 200 times as much as in 2004.

"We don't want to be sitting around 20 years from now saying, 'Gee, I wish we had looked into this,' " said Charles Geraci, a NIOSH branch chief who was part of the team visiting Altair.

For starters, that means figuring out how to measure worker exposures. A central goal of the NIOSH visit was to compare readouts from the agency's cumbersome and expensive instruments with those from cheaper, handheld devices, to see if the latter can suffice.

"We want to know if you can do this without a $75,000 piece of equipment and 6 PhDs," said NIOSH scientist Mark Hoover.

That is important, because most nanotech companies are small start-ups with limited resources, said David Rejeski, director of the Project on Emerging Nanotechnologies at the Woodrow Wilson International Center for Scholars.

"A lot of these companies are powder and metallurgy companies that used to make products at the micron [1,000-nanometer] scale and have found there's money to be made at the nano scale," he said.

That certainly describes Altair's earthy roots. Among other products, it makes nanoparticles of lithium and titanium dioxide from minerals dug from the ground.

In his office, Gotcher held up a vial of brilliant white powder. "This is pigment-grade titanium dioxide, made from dirt," he said, noting that the "dirt" cost him $60 a ton and the powder goes for $2,000 a ton.

The process of getting from dirt to riches involves creating droplets bearing microscopic amounts of the desired chemical and spraying them into the air in huge tanks; evaporating the droplets, which leaves behind tiny spherical crusts; shrinking them in kilns that reach nearly 2,000 degrees Fahrenheit; and milling them to break free the naturally formed nanocrystals.

At Altair, it was not difficult to identify at least some of the major points of risky exposure. In some areas, workers pour powders from bin to bin, or lift lids off 55-gallon containers, releasing visible puffs of white dust into the air.

"This is an area where we have some concern about exposure," said Gotcher, the CEO, with a mix of candor and discomfort.

Coming to a kiln where powders get baked in an unenclosed area, Gotcher grimaced again. "I don't like this," he said, "but we're monitoring it and we'll see."

To quantify those and other less obvious exposures, the NIOSH team rolled in carts loaded with advanced air sampling machines the size of large desktop computers, which tally the number, size and in some cases surface areas of airborne particles as they get trapped on a series of increasingly fine-grained filters. Some employees were fitted with wearable devices that sampled the air directly in front of their faces. A variety of handheld and portable devices were also deployed.

"We'll collect enough data here to keep us busy for a few months," Geraci said.

In line with NIOSH recommendations, Altair employees wear gloves and gas-mask-like respirators in dusty areas, but little is known about the reliability of those protections. Preliminary studies on latex gloves suggest outright holes, or pores, large enough to allow nanoparticles through may be rare. But definitive studies have yet to be funded.

Similarly, a few studies have suggested that high-quality respirators can trap 95 percent of nanoparticles. But "whether 95 percent efficiency is good enough or not is still open to discussion," said Hung Min Chein of the Industrial Technology Research Institute in Chutung, Taiwan, who is studying the issue.

Nanoparticles pose other workplace risks. They can be hundreds of times more combustible than common, micron-size particles, raising the possibility of explosion. Some behave like little ball bearings and can cause slips and falls, prosaic events that already account for one in seven workplace deaths.

It is not too late to get nano workplace safety right, said Andrew Maynard of the Wilson Center. But the spending trends are discouraging, he warned.

Government and private sources are expected to invest about $4 billion in nanotech this year. Less than 10 percent of that is focused on potential risks -- with most of that going to general toxicology and environmental impact studies. Only NIOSH is focused specifically on nanotech workplace issues -- a task it has had to accomplish with about $3 million a year it cobbles together from its general budget.

Worse than the funding crunch is the lack of overarching strategy, Maynard and others said. Research so far has produced a patchwork of results that largely reflect individual investigators' interests. Many experts want to see a national or even international plan that would rank the most pressing health and safety questions and allocate money to get them answered.

E. Clayton Teague, director of the National Nanotechnology Coordinating Office, which advises the White House on nanotech policy, said last month that the government is close to completing a two-year multi-agency effort to define those priorities. By summer, he said, recommendations should be released to guide the nation's nanotech research for the next five years.