

THE HIDDEN DANGERS OF NANOPARTICLES

Introduction



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Focus

This *News in Review* story is about nanoparticles, tiny bits of matter that behave in often unexpected ways. You will learn about some of the ways in which nanoparticles are being exploited by researchers and manufacturers. We also examine the possible risks to humans and the environment.

Further Research

For a timeline showing the evolution of nanotechnology, go to www.aolnews.com/nanotech/article/hold-timeline-16-key-moments-in-nanotech-evolution/19402102.

Nanoparticles are tiny bits of matter, detectable only with the use of a special instrument called a scanning tunnelling microscope. As a unit of measure *nano* represents one billionth. At the nano level, gold melts at room temperature; ceramics can be flexible; and rubber can conduct electricity.

Nanotechnology and nanoscience are not widely understood by the general public. A recent poll in the United States found that 80 per cent of consumers have either never heard of nanotechnology or have only a very basic understanding of what it's all about. But despite this lack of knowledge, we all have a great deal of experience with nanoparticles because they are found in many common products. These include cosmetics, sunscreens, clothing, digital cameras, and automotive parts.

In the scientific research community, however, nanotechnology is big news. The article "Nano facts vs. nano fiction" in *Canadian Chemical News* (November-December 2004) states: "Each chemist knows other chemists working diligently

on nanoscience-based applications that could lead to fast and inexpensive medical diagnosis, molecular computing, clean energy and environmental remediation, and new materials. These applications are all pieces of a projected trillion dollar industry."

Some scientists and researchers think we should be paying more attention to the implications of nanotechnology. Hundreds of new products are released every year, but, when it comes to one big question—can nanoparticles harm us—so far there is only one answer: we have no idea.

Some researchers are concerned because they are not sure whether nanoparticles can make their way into the human body or into the environment and actually cause harm. Some critics call them Frankenparticles—monsters created by men with good intentions that may well prove to be beyond our control.

For the moment, work with nanoparticles continues with very little supervision beyond the industries creating and using them.

To Consider

1. Many people have called for greater supervision of the nanotechnology sector by governments. Do you think that more government supervision would guarantee safety?
2. Is it hard for you to imagine how small something measuring one billionth must be?
3. How might nanoparticles have been "discovered" in the first place?

THE HIDDEN DANGERS OF NANOPARTICLES

Video Review

Quote

“Congratulations: the miracle of the future has arrived and it’s . . . stain-resistant pants?”
— Nicholas Varchaver,
Fortune, May 17, 2004

Focus for Viewing

Before you watch the video, consider the following: How much do you know about nanotechnology?

Then, as you watch the presentation, compare what you know with the facts and opinions in the video.

Viewing Questions

As you watch the video respond to the questions in the spaces provided.

1. How much higher are the levels of PCBs found in farmed salmon over those found in wild salmon?

2. How long ago were PCBs banned in Canada? _____

3. How many chemicals were found in the average child in the Canadian study referred to in this video story?

4. Where in nature are nanoparticles found?

5. Record a few of the manufactured products that contain nanoparticles.

6. How much smaller than skin cells are nanoparticles? _____

7. According to research at the University of Rochester, under what conditions are nanoparticles able to penetrate skin?

8. Where in the human body does recent research indicate inhaled particles might end up?

9. Have researchers established for certain that nanoparticles can harm human tissue?

10. What is “one of the biggest hurdles” that makes it hard for regulators to monitor nanoparticles?

11. What action does Peter Gruder suggest consumers should be taking?

12. What is the great fear that security experts have about nanoparticles?

Post-viewing Activity

1. Recent polls in the United States indicate that 80 per cent of Americans have heard little or nothing about nanoparticles. The case is likely similar in Canada and most other countries. Given this statistic, is it reasonable for Peter Gruder to expect Canadian consumers to take the lead in pressuring the government to better regulate nanoparticles? Explain.

2. Having watched the video, and having heard that there is no established proof that nanoparticles are safe to humans, are you comfortable with buying and using products that contain them? Why or why not?

3. Make a list of some of the products you use daily (e.g., cosmetics, electronics, clothing) that might contain nanoparticles. Compare your list with those of your classmates. You might like to follow up by checking the list provided by the Project on Emerging Technologies at www.nanotechproject.org/inventories/consumer/browse/products/.

THE HIDDEN DANGERS OF NANOPARTICLES

Nanoparticles

Did you know . . .

Nanoparticles exist in a wide variety of shapes, from soccer ball shapes to dots and wires. Size and shape are controlled by the researchers who are exploiting specific properties of the material they work with.

Further Research

For more on the STM, go to http://nobelprize.org/educational_games/physics/microscopes/scanning/index.html.

The most common definition of a nanoparticle is that it has one or more dimensions of 100 nanometres or less. A nanometre is one-billionth of a metre—about 1/100 000 the width of one human hair, or the length of 10 hydrogen atoms. A typical molecule might be made up of 100 atoms and measure one to 10 nanometres in diameter.

At this scale, something wonderful happens to particles of many materials. They typically develop physical behaviours very different from their existence in bulk. It is those particles that display physical changes on the nanoscale that are what most people think of when they speak of nanoparticles.

How do nanoparticles act?

The changes in the properties can include things like colour, material strength, magnetic behaviour, and the ability to conduct electricity or store heat.

Silver is a good example of a material that undergoes a dramatic change at the nanoscale. In its nanoparticle form, silver has antimicrobial properties that it lacks in its bulk form. Researchers have already taken advantage of this property to add nanoparticles of silver to bandages used to treat burn victims. Some companies are using them in the interiors of refrigerators and washing machines to kill bacteria.

Another interesting material is aluminum. Aluminum is a stable substance, but when it is reduced to particles 20-30 nanometres in size, it can explode.

As an object gets smaller, the ratio between its surface area and its volume increases. And, in general, the atoms on the surface of a material are more

reactive than those at the centre. In nanoparticles, almost all of the atoms and molecules in a substance are near the surface. So tiny particles consisting of a few atoms often display properties barely hinted at by a material in the form in which we normally encounter it.

Nanoparticles have been around forever. Some nanoparticles are the byproducts of combustion; others are the constituents of air pollution. Most scientists would say that only nanoparticles that are man-made should be considered part of nanotechnology.

How was nanotechnology developed?

Nanotechnology is the use of nanoparticles to create nanomaterials used in manufactured products. Researchers and developers use nanotechnology to exploit the unusual properties of these very small particles.

In 1981 researchers at IBM invented the scanning tunnelling microscope (STM). The STM meant that scientists could “see” atoms and molecules for the first time. Scientists don’t actually see them—their features are smaller than the wavelength of visible light. Instead, a conducting probe measures an electrical signal as electrons tunnel between the material and the stylus at the end of the probe.

How are new nanomaterials created?

There are two methods of creating new nanomaterials:

- From the top down, producing very small structures from larger pieces of material
- From the bottom up, adding atom to atom or molecule to molecule. This

is often referred to as self-assembly, because the atoms or molecules arrange themselves into the desired structure because of their natural properties.

Where are nanomaterials used?

Nanomaterials are being used in any number of consumer products ranging from coatings on windows to keep them clean, to fibres in clothing that form an invisible barrier to keep spills and dirt from penetrating fabric. Many moisturizers contain nanoparticles to help them penetrate deep into skin.

Nanoparticles are rapidly becoming an important part of medical research. Their use ranges from new methods of diagnosing disease to advanced methods of delivering medication.

Nanoparticles are also being used in environmentally significant research. They seem especially promising in helping in the development of new materials and ways of producing solar energy, and in efficient new water filtration methods that will be very important to developing countries.

Follow-up Activity

The Project on Emerging Technologies maintains an up-to-date list of products containing nanoparticles on its Web site at www.nanotechproject.org/inventories/consumer/browse/products/. There are now hundreds of products on the list. Many of these are cosmetic products that may be in your bathroom medicine cabinet. Check some of these products against the list to see if any are on it. What other kinds of products often appear on the list?

THE HIDDEN DANGERS OF NANOPARTICLES

The Concerns

Quote

"We absolutely know how [these materials] behave when they are larger. But when you engineer something that small, it changes all the fundamentals. Some are so new we don't even have adequate testing methods."
— Karluss Thomas of the non-profit Health & Environmental Sciences Institute (*Business Week Online*, February 24, 2005)

Nanotechnology and nonparticle research has increased dramatically in the last decade. At the same time, concern that the science is developing too rapidly is also on the increase.

Few are questioning the potential benefits of nanotechnology, but there are two main worries:

1. That we have little understanding of how nanoparticles really behave when introduced into the environment, and the range of their effects on life, especially human life
2. That no one—the corporations and research centres that create and use the particles in nanotechnology, or the governments that oversee new technology—is capable of monitoring the new science. Nor does there seem to be any serious attempt to provide the funds necessary to perform the research that would tell us exactly how safe they are.

The Questions

The list of unanswered questions is a lengthy one.

- Can nanoparticles, because of their tiny size, easily penetrate cells and produce unknown effects in plants and animals (including humans)?
- Are toxic nanoparticles like most other substances, where toxicity is related to quantity? In other words, are they dangerous in large doses, but reasonably safe in smaller ones? Can they accumulate over time in tissues and organs?
- What about the vulnerability of workers in factories that use nanoparticles? Are there safe limits that need to be monitored and enforced, just as there are with radiation levels?

- Are there potential detrimental effects of nanoparticles on the environment? Engineers who operate wastewater treatment systems have already raised the alarm that silver nanoparticles introduced into wastewater plants, due to their antimicrobial properties, might destabilize the systems. Are we creating new kinds of pollution?
- Many of these nanoparticles are totally new to science. What research is being done to establish their safety before they are used in manufacturing?
- Are women especially at risk? The numbers and types of nanoparticles now used in women's cosmetics are staggering.

What We Know

- As early as 1941—long before the term *nanoparticle* was used—researchers at Johns Hopkins Hospital established that nanoparticles in soot and smog could make their way to the brain.
- We are already dealing with many natural nanoparticles on a daily basis, such as the carbon particles in car exhaust or those of magnesium oxide in welding fumes.
- Studies on the effects of carbon-60 (a dome-shaped fullerene molecule) added to the water in which large-mouth bass are kept show that they are able to penetrate the brain, central nervous system, and the livers of those fish.
- Carbon nanotubes, used to strengthen a variety of materials such as automobile panels, are usually thought of as graphite. But a carbon nanotube also has a structure that resembles asbestos—one of the most dangerous minerals known to humans.

Quote

"Nanotechnology, like any new discovery, offers both risks and rewards. There will undoubtedly be some need to control its exploitation to [minimize] the risks, but there are also strong arguments for allowing the unfettered pursuit of knowledge: without it, innovation cannot flourish." — *The Economist*, January 1, 2005

- Many nanoparticles readily form clumps and behave differently when they clump and when they act individually.
- Laboratory research has shown that some nanoparticles have the ability to damage the hearts, aortas, and lungs of animals. The smaller the particle, the greater the chance of damage to the lungs.
- Female Chinese workers in a paint factory exposed to nanoparticles developed serious lung problems.
- Lab-grown human skin and liver cells have been killed by exposure to nanoparticles.

What to Do

Many environmental organizations, as well as several scientists, have called for at least a slowing-down of research into new nanoparticles until we have answered the major questions about their safety. Many argue that governments need to establish new ways of

overseeing the industry. Currently, most governments believe that this oversight can take place using existing legislation, especially food and drug laws.

Canada has received much acclaim for taking a different approach. In an Interim Policy Statement (November 23, 2009), Health Canada established a working definition of nanomaterials that includes all manufactured nanoparticles—and asserted its control over their regulation. A consultation process is currently taking place, and Health Canada expects to refine its policies and increase the information it provides on nanomaterials and their regulation by the end of 2010.

In addition to government oversight, more research needs to be done in ensuring that nanomaterials are made safely, handled safely, and made to be safe. For example, protective coatings are often used to make particles like buckyballs—used in both solar cells and cancer drugs—non-toxic. We need to be sure that this method is indeed effective in all uses.

For Discussion

Questions have been raised about the social impact of nanotechnology. With a partner or in a small group discuss a couple of these questions.

1. What happens to personal privacy when we can be implanted with tiny sensors that keep track of the minutiae of our lives?
2. What happens when the patents for products of benefit to developing countries are controlled by corporations in the developed world?
3. Who should be developing "answers" to these questions?
4. Can you think of other social issues raised by the rapid development of nanotechnology? Are there easy solutions to these issues or to the two mentioned above?

THE HIDDEN DANGERS OF NANOPARTICLES

Voices in Support

Just as the rapid development of nanotechnology has its critics, it also has many supporters. These supporters argue that nanotechnology is simply a natural development in the history of research and technology.

“Advances in information technology have been going on for 100 and some years and it’s all been about miniaturization. We were publishing papers at IBM on nano-structured materials in the 1970s. None of us in this field feel that there’s anything fundamentally new here. It’s the logical culmination of the long-term historical trends in miniaturization of many technologies.” — Tom Theis, director of physical sciences at IBM Research (*Fortune*, May 17, 2004)

Supporters also argue that although we’ve only recently been able to “see them” nanoparticles have most certainly always been around. If they’ve always been around, and we’ve always been exposed to them, it could be argued that we would know if they are toxic to humans.

“. . . humans evolved in the presence of nanoparticles. There is certainly reason to be careful. But our environment is filled with nanoparticles. We just didn’t know it until we had tools that could see them.” — R. Stanley Williams, director of information and the quantum systems laboratory at HP Labs in Palo Alto, California (*Computerworld*, September 29, 2008)

Much of the work with nanomaterials is acknowledged to be done very safely. One of the leading proponents of the use of nanotechnology to make foods safer

has been Kraft Foods, the force behind the NanoteK Consortium.

“Kraft Foods has been extremely careful in selecting its projects. We work with materials that are already in nature. For instance, the materials that researchers are using to develop flavor-encapsulating nanoparticles are derived from natural ingredients that break down in the body. Using degradable and biocompatible polymers to fabricate bin sensors for food packaging could also address potential health and safety issues.” — Manuel Marquez, head of NanoteK Consortium, researchers in nanotechnology (*Science News*, September 25, 2004)

Many researchers expect nanotechnology to have a major positive impact on health and medicine.

“In five to 10 years a flurry of new imaging agents—injected into the body to seek out and latch on to defective proteins in tumor cells, brain plaque in Alzheimer’s patients, molecular flaws causing rheumatoid arthritis or small blood clots hidden in the brains of people who are about to have a stroke—may emerge. These ‘molecular beacons,’ as one researcher calls them, would work with MRIs and CT scans to better pinpoint the presence of disease.” — *Forbes Global*, September 19, 2005

“Researchers are working on customized treatments, such as nanoparticles built to match the unique genetic profile of a patient’s cancer cells—and programmed to seek out and destroy them. Hundreds of these therapies are in the works. Most will fail. But if even a handful succeed, they could change medicine.” — Stephen

Baker and Adam Aston (*Business Week*, February 14, 2005)

Observers also point out that many different toxic materials are already used safely in industrial processes.

“Many researchers who acknowledge the potential dangers of nanoparticles point out that industry safely uses countless toxic and dangerous substances. The important thing is dose. There should be little problem if industry keeps worker exposures low.” — Anthony Seaton, emeritus professor at the University of Aberdeen in Scotland (*Science News*, March 19, 2005)

And the very toxicity of some nanoparticles can be valuable.

“... toxic nanoparticles will have their uses. Scientists are already trying to wrap them in harmless coatings so they can be used to fight diseases or destroy cancerous cells. The tailored delivery of a toxic nanomaterial to treat cancer would be far preferable to existing methods that flood a patient’s entire body with toxins. The ability of nanoparticles to cross the blood-brain barrier may also

turn out to be useful because at present it is very difficult to get drugs across that barrier.” — *The Economist*, January 1, 2005

“I have no concerns, but I do have great hopes. I think the beneficial effect of nanometre structures on health is likely to be revolutionary. But I’m also very much aware of the potential toxicological impacts of nanoparticles. My view on this, which is shared by most of my colleagues, is that with testing and an appropriate degree of regulation we’ll be able to reap the benefits with very little in the way of a downside. That would be my hope—getting it right is our responsibility.” — Don Eigler, physicist at IBM’s Almaden Research Center in San Jose, California (*New Scientist*, October 14, 2009)

“If you look at the development of other technologies, we are way ahead of the curve. We are actually trying to evaluate the risk, exposure, and health and safety issues before there are observed problems, rather than after.” — Kevin D. Ausman, a chemist at Rice University in Texas (*Science News*, May 6, 2006)

For Discussion

What happens if the experts turn out to be wrong in their assessment of the safety of nanotechnology? What will be the likely reaction to one negative experience by the public, the media, and governments?

THE HIDDEN DANGERS OF NANOPARTICLES

Case Study: Sunscreen

Quote

“The era of intentional nanotech-based consumer products is generally considered to have begun in the sun: Nanoscale zinc oxide flakes developed by Nanophase Technologies make invisible sunscreens possible. The tiny nanoflakes reflect harmful ultraviolet rays. But unlike larger flakes, they are too small to scatter visible light—and therefore don’t appear white, like a lifeguard’s nose.” — Carol Levin (*PC Magazine*, July 2004)

Sunscreens made with nanoparticles have been used for years. They make a thick solid-coloured lotion that covers the skin and prevents sunlight from penetrating. Some scientists are concerned that the nanoparticles might separate from the lotion and get into the body. If they were to pass through the dead skin layer, they could enter the circulatory system and migrate to other parts of the body. The atoms might then “create free radicals and undergo oxidation reactions, literally pulling cells apart in a fashion similar to the way alcohol consumption and cigarette smoking destroy cells” (*Business Week*, February 24, 2005).

So far no one has been able to determine if the particles do separate from the lotion. But recent research does indicate that nanoparticles can penetrate the skin. Sally Tinkle, from the National Institute of Environmental Health Sciences in the United States, has found that under certain conditions—if the skin is stretched a certain way or rubbed with enough force—nanoparticles can move below its top, dead layer. If the skin has cuts and abrasions or has been damaged in some other way, particles can get through to the layers underneath.

What happens once these particles reach the bloodstream is unclear. Some studies have found that smaller particles are cleared faster than larger ones and so are safer, but others suggest that once inside the body, nanoparticles travel through the blood, lodge in the lungs and brain, and accumulate over time, with effects that are still poorly understood.

Industry spokespeople argue that modern sunscreen with nanoparticles is safe. “John Bailey, executive vice president for science at the Cosmetic,

Toiletry, and Fragrance Association, an industry trade group in Washington, D.C., points out that sunscreens using titanium dioxide and zinc oxide nanoparticles have been used ‘safely and effectively by consumers for decades’ and have been reviewed and approved by the FDA [Federal Drug Administration]” (*Technology Review*, March-April 2007).

Meanwhile, some organizations continue to sound the alarm about nano-sized zinc oxide and titanium dioxide used in sunscreen. Friends of the Earth claims that recent research has shown them to be photoactive, “producing free radicals and causing DNA damage to skin cells when exposed to UV light” (*Natural Life*, March-April 2008).

The Consumer Reports Tests

In July 2007, *Consumer Reports* published an evaluation of 19 different sunscreens. Eight of them listed titanium dioxide and/or zinc oxide as a component. Of the eight, only one disclosed the use of nanotechnology on its label. The results of the testing were interesting indeed. All eight of the sunscreens listing the two compounds turned out to contain nanoparticles.

Consumer Reports expressed its concern: “Lab studies indicate that both of those nanoingredients create free radicals that damage the DNA of cells and possibly cause other harm as well. And even low exposure to nanoparticles of titanium dioxide can damage the lungs of animals if inhaled.”

The editors went on to note that the nanoparticles would only pose a health risk if they were able to penetrate the outer layers of dead skin, which studies indicate they normally won’t do. “But it’s not known whether skin damaged

by acne, eczema, sunburn, or nicks from shaving is more vulnerable to penetration . . . And studies of other nanoparticles show they can penetrate the outer skin layers through the hair follicles or when the skin is repeatedly stretched.”

Consumer Reports concluded: “Until there’s adequate safety assessment, people who wish to avoid exposure to those nanoingredients could choose

sunscreens that don’t list titanium dioxide or zinc oxide on their label.”

Especially good news for those wishing to avoid nanoparticles was that the magazine found no correlation between the presence of the two compounds and the effectiveness of the tested sunscreens. In fact, their top-scoring brand contained neither titanium dioxide nor zinc oxide.

Follow-up Activities

1. What brand of sunscreen do you normally use? Check the label to see if it contains titanium dioxide or zinc oxide. If it does, does this concern you? Why or why not?
2. Go to your local drugstore and survey the available sunscreens. How many of them contain either of the two compounds? Are they among the most popular brands?
3. As a result of some of the concerns expressed in this section, are you more likely to avoid certain sunscreens in the future? Or are you inclined to accept the argument that regulatory approval confirms that, at least in this case, nanomaterials in sunscreen are safe?

THE HIDDEN DANGERS OF NANOPARTICLES

Activity: Taking a Position

Further Research

Learn more about nanoparticles by visiting <http://nanoparticles.org>.

It's time to stand up and be counted. Should Canada allow manufacturers to continue to introduce nanoparticles into their products? Or should a moratorium on the use of nanoparticles be declared until researchers can determine if they are truly safe to use. Perhaps you prefer to propose a position somewhere between these two extremes.

1. Clearly (and briefly) state your position here:

2. Determine how you will make your position known and prepare your product. You might decide to:

- Prepare a speech to your classmates detailing your views
- Create a poster celebrating the virtues or decrying the dangers of nanotechnology
- Design a pamphlet explaining your position
- Prepare a short submission to Health Canada suggesting the policy they should adopt toward the regulation (or non-regulation) of nanoparticles
- Write a brief public awareness television or radio commercial on the benefits or dangers of nanoparticles
- Or choose another way of getting your message across

Be brief and to the point, but give your audience enough information so that they understand the issue. You may use any of the information provided in this guide or the video.

Planning Notes:
