WHITE PAPER

Weighing the Benefits and Risks of Nanotechnology

Nanotechnology through the Ages

There is a famous artifact at the British Museum known as The Lycurgus Cup. Fashioned from gold and silver nanoparticles mixed with glass by Roman craftsmen in the 4th century, its shifting colors of green to red reflect one of the earliest known examples of nanotechnology at work. It is far from unique. From the gold chloride nanoparticles that give the stained glass windows of Europe's medieval cathedrals their magnificent hue to the carbon nanotubes behind the razor-sharp edges of the legendary Damascus swords of the 13th century, manmade nanotechnology has played a significant role in human history for thousands of years.[1]

The Scale of Things

It was not until the 20th century that scientists could actually see inorganic nanoparticles (NPs) for the first time. Thanks to electron and atomic force microscopy, mass and infrared spectrometry, and other advanced technologies, scientists and engineers can now not only detect nanoparticles and study their interactions, they can essentially manipulate them to build entirely new nanoparticles.[2]

To fully appreciate what that means requires a clear definition and a better sense of scale. In short, nanomaterials are chemical structures with at least one dimension of 1 to 100 nanometers (one-billionth of a meter).[3] For comparison's sake, a strand of human hair is 80,000 nanometers wide and a single grain of rice measures 5 million nanometers long. If a nanoparticle was the size of a baseball, a typical red cell would be about the size of the entire stadium.

Yes, nanomaterials are infinitesimal, but do not let their size fool you. Their surface area actually increases at the nanoparticle scale to infuse these miniature building blocks with unique magnetic, mechanical, structural, optical, and electrical properties that are different from the same chemical at a larger size. Some scientists believe that these properties, known as quantum mechanical effects, hold the promise of revolutionary discoveries yet to come. Others are concerned they may unleash a flood tide of human and environmental health issues.[5]

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The Potential for Good and Bad

Some nanotechnology wonders, and at least one possible nightmarish discovery, are already upon us. Touching all of the physical sciences, molecular engineers and scientists are able to build nanostructures from "Buckyballs" to nanotubes to leverage the quantum effects that occur when matter is organized at nanoscale.[6] Those results now play an important role in advancing technology, manufacturing, medicine, and consumer products, all without much in the way of regulatory barriers.[7] Engineered nanomaterials are currently employed in the fight against cancer and other diseases, such as Ebola.[8] They are also used in a host of industrial and consumer products, from flash memory chips and stronger materials for the automotive industry to anti-bacterial clothing, kitchenware, and toothpaste. Nanoparticles are even finding their way into the foods we eat to keep them looking and tasting fresh.[9]

While the initial benefits of nanotechnology are undeniable, there are mounting concerns over the potential dangers nanomaterials may pose to human and environmental health. Especially in an unregulated environment that one bioethicist describes as the "Wild West,"[10] some scientists worry that the media might misinterpret an aspect of nanomaterial research and trigger a public outcry against the technology in general, much like what has happened with GMO products.[11]

The Silver Nanoparticle Debate

In many respects, the proverbial "smoking gun" may well have already surfaced in the form of silver nanoparticles. A traditional remedy against infections, silver's alleged curative powers are now marketed as nanoparticle additives to a host of consumer antimicrobial products from socks that fight odors to stuffed animals for children that fend off germs.[12] At the same time, research studies show conclusively the toxicity of nanosilver on cells. The latest is a report from the Max Planck Institute in Germany. It concludes that silver nanoparticles are highly toxic once inside cells.[13] How they actually get there is provoking another heated debate. Ingesting colloidal silver as a medicinal is certainly one possibility. Absorption through the skin is another popular, if persistent, myth, along with a variety of other plausible and fanciful theories.[14]

Whatever the cause, an increasing number of scientists wonder if modern society is promoting the virtues of nanosilver without fully appreciating its potential risks to human and environmental health.[15] Still others argue that poor testing standards by nanotoxicology labs have led to misleading information. Worse still, the press has been quick to link such findings to the use of silver nanoparticles in general. For all of the wrong reasons, they argue, silver nanoparticles have become the red herrings of a potential nanotechnology scare fueled more by hearsay than hard science.[16]

The Guiding Hand of Government

The French Agency for Food, Environmental, and Occupational Health and Safety (ANSES) recently admitted as much. Despite all of "the research that has been carried out to examine the potential health and environmental effects of silver nanoparticles, ... [it] is still insufficient to allow the health risks to be assessed," ANSES reported. In light of its findings, ANSES is currently recommending "that the use of silver nanoparticles (production, processing, and utilization) be limited to applications whose advantages have been clearly demonstrated, and whose benefits to human health outweigh the risks for the environment."[17]

The EU, meanwhile, enacted legislation in late 2014 requiring food manufacturers to list all nanomaterials used in ingredients of what are classified as "novel foods." The full impact of that law will not be realized until 2016, when manufacturers need to meet health and safety requirements for all of their nanomaterial additives or pull these novel foods off the market.[18]

In the U.S., the Environmental Protection Agency (EPA) also recently issued its current thoughts on silver nanoparticles. It came in the form of a 23-page response to a seven-year-old petition from a number of activist groups requesting federal regulation of nanosilver.

In brief, the EPA noted that it would now require companies using nanosilver for antimicrobial purposes to register their products as pesticides, even if there is no pesticide claim made. It mandates that all new products containing nanosilver to control microbes will be subject to a battery of tests to review their health and safety impacts before they are made available to the public. Much like the French, however, the EPA refused to take actions against all nanosilver products currently on the market, as requested by the petitioners. The reason? There is a lack of factual evidence proving that silver nanoparticles are solely used because of their antimicrobial properties, which would place them under EPA regulation as pesticides.[19]

The U.S. Food and Drug Administration (FDA), meanwhile, does not even have regulatory definitions for "nanotechnology," "nanomaterial," or "nanoscale." Until recently, the FDA says that it considered these as engineering terms.[20] That position is slowly changing.

In June 2014, the FDA updated its final guidance for the nanotechnology industry. While it took no categorical stand on the safety or danger of nanotechnology, it made clear that the FDA would be proactive in making its future decisions about nanomaterials on a case-by-case basis. For the nanotechnology industry, that means more documented research and third-party oversight are needed. According to the FDA's own guidance, manufacturers "should consider potential implications for regulatory status, safety, effectiveness, or public health impact that may arise with the application of nanotechnology in FDA-regulated products."[21]

The FDA also put manufacturers on notice that any significant product changes that introduce intentionally manipulated nanomaterials would be subject to additional safety and regulatory screenings of foods intended for animal and/or human consumption.[22] As strong as these guidelines appear, the FDA echoed the EPA and ANSES in calling for more research on the physical, chemical, and biological effects of nanomaterials on both human health and the environment.

Characterizing Nanoparticles

There is a growing body of evidence showing that there are significant differences between some nanomaterials and their non-nanoscale counterparts. What those differences portend raises many new questions about their potential to cause harm to human health and the environment. For decades, the bulk of nanotechnology research has been left to various business sectors with little in the way of shared scientific methodology or regulatory oversight. While that process has led to some astonishing advances in our ability to manipulate the basic building blocks of life, some scientists, environmentalists, and regulators wonder if we have overlooked the risks.[23]

Government agencies are now taking the first significant steps to develop the proper scientific methodologies needed to analyze the unique properties and effects of nanomaterials during their production, while they are in use, and what happens to them when they are recycled or discarded. According to the EPA and other agencies, those testing methods need to evaluate the chemical makeup of nanosubstances to identify and depict their composition down to the elemental level.[24]

For inorganic nanomaterials, among the most advanced analytical instruments for precise nanoparticle characterization, structure analysis, counting, and sizing is the award-winning PerkinElmer NexION® ICP-MS single particle analyzer.[25] In tandem with PerkinElmer's Syngistix™ Nano Application Module software interface, this dedicated system accurately characterizes nanoparticles with a data-acquisition speed that is 10 times faster than any other SP-ICP-MS system, so nothing is missed.

As a global leader in nanomaterial analysis, PerkinElmer also offers an array of analytical instrumentation that provides rapid, clear analysis of even the most challenging organic, carbonaceous, and hybrid nanomaterials. These include among others:

- The LAMBDA™ 1050+ UV/Vis/NIR spectrometer, with its wide range of accessories, is the instrument of choice for many applications from detecting carbon nanotube defects and impurities to analyzing nanoparticles in cosmetics.
- PerkinElmer's TG-IR-GC/MS evolved gas analysis system, combining a TGA or STA analyzer with an FT-IR spectrometer and a GC/MS, lets you uncover results and insights not otherwise possible through individual techniques. This hyphenated system is ideal for testing carbonaceous and hybrid nanomaterials, QA/QC applications, and polymer analysis.

As new oversight methods are developed to deal with current and future generations of nanomaterials, scientists, engineers, and government regulatory agencies will continue to rely on the analytical instrumentation and expertise of PerkinElmer instruments where sound science has been making a difference in our world for over 75 years.

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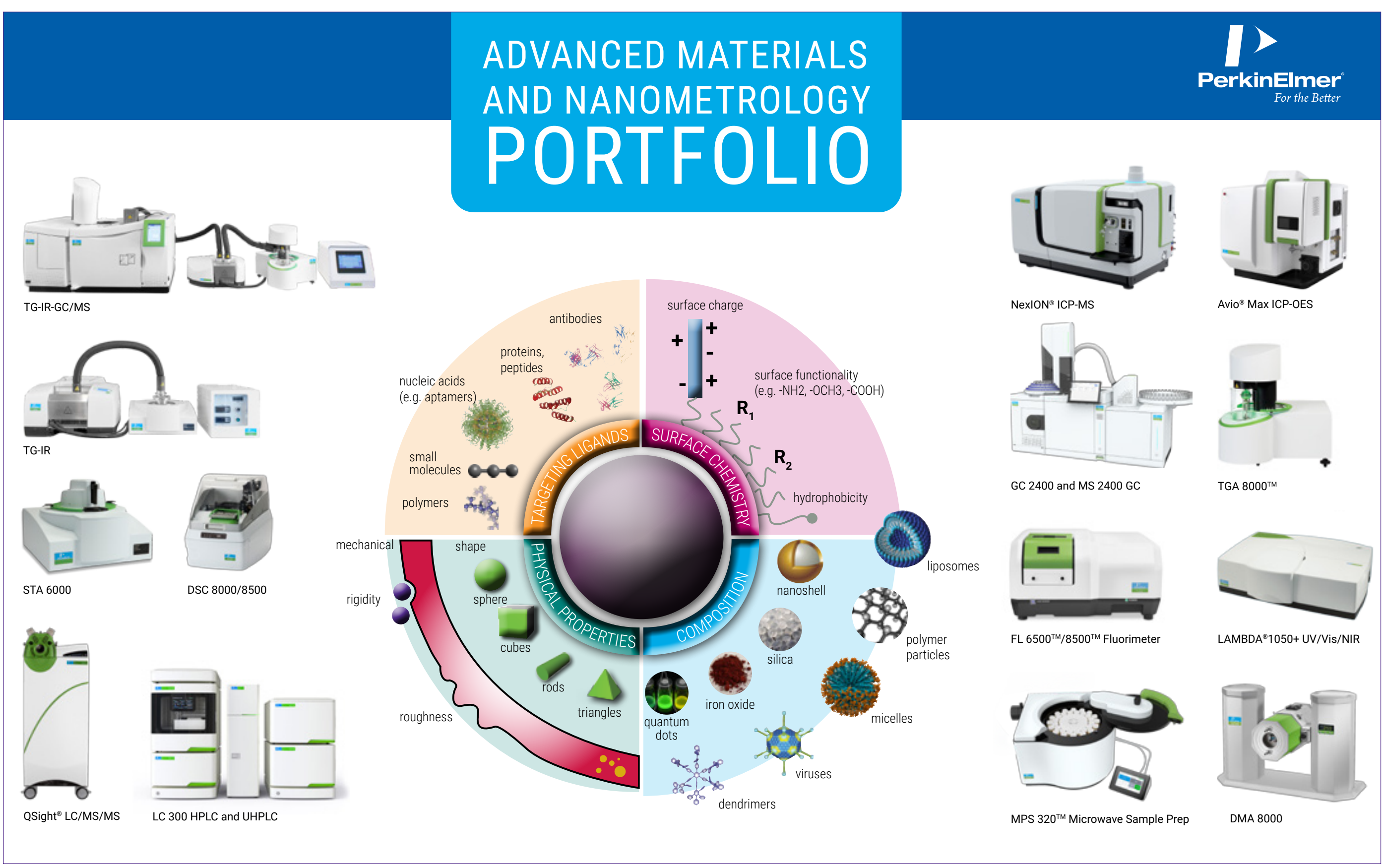

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