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Nanomaterial Health Effects Part 3: Conclusion—Hazardous Issues and the Precautionary Principle

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ABSTRACT

This is the third and final paper in a series about nanomaterials and their potential health effects. There has been an incident of apparent respiratory health effects in Germany in consumers using a "nano" cleaning product. Other recently proposed consumer products seem to carry potential health and/or ecological hazards. In light of rapidly evolving nanotechnology the "precautionary principle" in environmental health science is reviewed. Hopefully a balance can be reached that allows the realization of societal benefits from the development and implementation of nanotechnology while preventing its unquestioned use in ways that damage ecology and human health.

INTRODUCTION

This is the third and final paper in a series of *Wisconsin Medical Journal* articles about nanotechnology health effects. The first paper[1] described the background and current knowledge on nanomaterials health assessment. The second paper[2] discussed uncertainties in the health risk assessment and recommendations for the future, with emphasis on the potential for nanomaterials to be used in the food industry. Nanotechnologies involve the manipulation and creation of materials and devices at the nanometer scale. "Nanomaterials" have properties that make them attractive for a variety of applications, including high strength, conductivity, durability, and reactivity. Hundreds of products containing nanomaterials are already on the market, including paints, sunscreens, sporting goods, textiles, and components of computers, cell phones, and other electronics. Biomedical and pharmaceutical researchers are developing novel nanomaterials and "nanobio" devices for a variety of medical applications including cancer chemotherapy.[3,4] Because of their small size, nanomaterials have very high surface-to-volume ratios, which makes them potentially more reactive—and potentially more toxic—than larger materials made of the same chemicals. Relatively few toxicology and epidemiology studies have been done on engineered nanomaterials, so significant uncertainties and data gaps face public health risk assessors.

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"MAGIC NANO" INCIDENT

On April 6, 2006, the *Washington Post*[5] reported that the Federal Institute for Risk Assessment in Berlin, Germany had recorded what appeared to be the first epidemic of health problems from a nanotechnology product. At least 90 people reported severe respiratory problems over a 1-week period at the end of March 2006, including 6 people who were hospitalized with pulmonary edema.[6] All had used "Magic Nano," a bathroom cleaning product. The symptoms cleared up for most within 18 hours, but some had persistent breathing problems for several days. "Magic Nano" went on sale as a bathroom cleaner in Germany on March 27. It was pulled from the market in 3 days because of the respiratory epidemic in users. The product was a spray meant to be used on glass and ceramic surfaces to repel dirt and water. Apparently the spray contained very tiny silicate particles suspended in fluid. When applied to a surface these particles block the minute surface crevices, reducing the possibility of bacteria, dirt, and moisture to cling to it.[7] The manufacturer reported no health problems reported from consumers who had used the same product dispensed in a pump bottle instead of as a spray. This implies that the size of the aerosol used to deliver the product was at fault. Aerosol spray can reduce the size of the product, mak-

ing the small particles airborne for longer periods of time and thus easier to breathe into the lungs. The company, Kleinmann GmbH (a subsidiary of Illinois Tool Works), described the constituents of the product in general: silica and silicone nanoparticles, ethanol, water, and other ingredients. It is not clear whether the respiratory distress cases were actually due to the "nano" constituents or some other aspect of the product. It is not even clear if the product actually contained "nano" materials or if the name "nano" was used as an advertising ploy.[8] Either way this was a wakeup call to the nanoindustry for more caution in marketing products that had not received adequate toxicological testing.

THE PRECAUTIONARY PRINCIPLE

The Precautionary Principle has been discussed in the context of environmental risk assessments since the 1960s. Its roots come from the inherent uncertainty in the science base underlying all environmental decision-making. In Germany in the 1960s, the legal principle of *Vorsorgeprinzip*, emphasizing precaution when it comes to environmental decision-making, was discussed in the context of acid rain and North Sea fishing.[9] In 1992, the Rio Convention on global climate change declared: "In order to protect the environment, precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full-scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[10]

On January 23-25, 1998, a conference was held at the Johnson Institute's Wingspread facility in Racine, Wis, which resulted in 4 principles of precaution when it comes to decisions concerning the environment:

1. There is a duty to attempt to take action to prevent harm, even in the face of uncertainty.
2. The burden of proof of harmlessness rests with the proponents of the new activity, technology, process, or chemical.
3. Before using a new potentially hazardous activity, technology, process, or chemical, a full range of alternatives needs to be explored.
4. Decisions must be open and informed and democratic and must include all affected parties.[11]

There has been considerable controversy in the risk assessment scientific community concerning the implementation of the philosophy of the precautionary principle in environmental health science decision-making. In particular, critics claimed that it could stifle future scientific and technical discovery.[12] The key dilemma regarding precaution in the environmental health risk assessment process is how careful to be as a society in the face of scientific uncertainty. Some argue that current bureaucratic and regulatory procedures are already precautionary; for instance safety factors are built into the risk assessment equations.[13] In addition, it has been said that the precautionary principle is not sound science because it is basically anti-science in that it advocates a policy position without enough scientific justification (because there is such uncertainty).[14]

More Worrisome Nano Developments

Certain potential uses of nanotechnology could be medically important to therapy, such as more accurate delivery of cancer chemotherapy drugs to wipe out cancer cells. However, there are several other new nanotechnology applications that seem of more questionable utility that also carry perhaps more inherent risk. One of these is using nanosilver in new types of washing machines.[15] Silver ions—silver atoms stripped of an electron—are being designed into a new type of washing machine as essentially a substitute for detergent and water. Silver ions are antibacterial. Even though the manufacturers have promised there will be little release into the environment, the idea of antibacterial silver ions being released into the environment is worrisome from an ecological perspective.

Another controversial discovery is "cloaking" carbon nanotubes as a way to make them non-toxic and thus useable in medicine. The hopeful vision of carbon nanotubes is that they could detect individual enzymes in cells and/or be excellent for delivery of cancer chemotherapy drugs to specific cellular components. The problem, up until the recent discovery of cloaking, is that bare nanotubes trigger the death of cells they touch. University of California-Berkeley researchers have developed mucin polymers to attach to the carbon nanotubes to make them non-toxic; however, the coating could wear off when the nanotubes leave the body.[16] Adequate consideration has not been given to the dissemination of the carbon nanotubes in the ecological environment once they have been eliminated from the body and the polymer wears off. There are multiple proposed uses of silver nanoparticles in antibacterial soaps, hand sanitizers, hospital curtain, sportswear (to prevent odor), refrigerators, brooms, and food containers, which could pose ecological risk because of their antibacterial properties.

Nanotechnology with Precaution

Nanotechnology is a potentially risky technology from an environmental health and ecological point of view in that it uses novel properties of substances made ex-

University of Wisconsin-Madison's Nanotechnology in Society Project

Scholars with the University of Wisconsin's Center for Nanotechnology in Society* are establishing a network of toxicologists, epidemiologists, environmental engineers, health and safety experts, and social scientists to examine the environmental and health effects of engineered nanomaterials. The objectives of this network are to bring interdisciplinary expertise to bear on key questions and data gaps in the evaluation and assessment of new and emerging nanotechnologies and to provide insights relevant to developments in local, state, and federal policy. See http://www.lafollette.wisc.edu/research/Nano/ for more information about the Center for Nanotechnology in Society.

* The Center for Nanotechnology in Society at the University of Wisconsin-Madison is a component of the Center for Nanotechnology in Society, a national center of excellence for research on the societal implications of nanotechnology led by Arizona State University. The Center is funded by the National Science Foundation and affiliated with the Nanoscale Science and Engineering Center.

tremely small. At this point, at least, there is considerable scientific uncertainty as to the environmental risk assessment for most nanotechnologies. There have been scientific reviews that try to get as much health and ecological information as possible by analogy from the potential parallels between what is known about small particles in the ambient air and asbestos fibers and other "known" environmental entities and these novel new nanomaterials.[1,2,6] However that is not a substitute for systematic in vivo and in vitro toxicology and epidemiology studies, including potential effects on the workers who manufacture these substances.

The Precautionary Principle is not an absolute idea, but does argue for evidence to be provided by the advocate for a potentially risky environmental activity before that activity is allowed to proceed. It is difficult for experts or consumers to make informed decisions unless more information is given to environmental regulatory and public health agencies before the product is put up for sale to the general public. There is a compromise that needs to be developed between an industry's ability to be innovative and develop new products while keeping their proprietary formulations to themselves and the public's right to know the safety of the products they are buying. It is to the benefit of both producers and consumers to work out how better decisions can be made in an open, informed, democratic way, without stifling invention and creativity in technology.

Uncertainty is the key concept in trying to find our way through the difficult task of balancing new nanoproducts, advancing science, and protecting the public health. Kriebel et al[17] present a cogent analysis of the linkage between science and policy and the precautionary principle. They emphasize the uncertainties that exist in all the disciplines involved, including the risk assessment, the scientific discovery, and the policy domains. The uncertainty in all areas involved calls for compromises by the different disciplines in order to achieve a proper balance between scientific innovation and the potential risks and benefits to society and the environment. Grandjean,[18] in a review of the Precautionary Principle from a public health point of view, emphasizes its role in primary prevention of health and environmental harm. He questions the current risk assessment paradigm as being too lax in regard to prevention of threats to human health and the environment.

The field of precautionary policy is advancing. Dekay et al[19] offer a decision analysis framework for implementing precautionary policies while balancing costs, benefits, and event disagreements between advocacy parties in the process. Both sides (nanotechnologists and environmental health practitioners) are trying to find common ground to allow nanotechnologic advance while protecting the public health. Bernard Goldstein, one of the leaders of the field of environmental health, in 2 editorials in leading public health journals[20,21] calls for risk-benefit analysis in a risk assessment framework that also includes properly functioning public health surveillance and legal tort systems. He points out that public health regulators have made mistakes in the past by not being precautionary, and calls for multidisciplinary analysis and communication between the disciplines to achieve good decisions. John Graham,[22] a leading advocate for using the formal tools of risk assessment, including cost-benefit analysis and risk-equity analysis, also believes that properly incorporating precautionary analysis into the risk framework would be advantageous both from an innovation and environmental protection point of view. The end product of doing more thorough precautionary analysis before allowing the dissemination of new nanomaterials would be rational decision-making, where the benefits of certain materials would be judged to outweigh their potential risks, and where the sale of others would not be allowed. Thus, a nanomaterial that is used to deliver a chemotherapy for cancer would be judged differently than a cleaning product for furniture. The field of environmental health risk assessment needs to continue to develop its theoretical and practical basis to allow for more informed decisions to protect society from potentially harmful pollutants while allowing the advancement of scientific invention.

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