Nanotechnology Annotated Bibliography

Topics Covered:

Nanotechnology General
Nanotechnology Applications
    General
    Environmental
Nanotechnology Implications
Use of the Precautionary Principle in Nanotechnology
Attitudes about Nanotechnology

Nano General:

DeFrancesco, Laura "Little Science, Big Bucks: Governments around the world are investing in nanotechnology in the hopes that applications in the biotechnology and chemical industry will help turn faltering economies around." Nature Biotechnology Vol. 21, No. 10, October 2003

Worldwide investment in nanotechnology by government organizations has increased roughly sevenfold in the past six years. Currently, biotechnology research gets 10% or less of global government nanotechnology funds, but venture money is preferentially going to nanobiotechnology over other kinds of nanotechnology. Groups winning government grants are top-notch universities who collaborate effectively. Communication can present a challenge. Some estimates show that the US spending in nanotechnology lags behind that of Japan when private spending is included. Based on buying power, China beats all others in their commitment to nanotechnology. This has paid off in increased numbers of publications on nanotechnology; in the past few years, publications coming from China have been second only to the US. The Bush administration places high priority on nanotechnology, placing it second on R&D priorities to combating terrorism. With such support from government grants and small startups, nanobiotechnology will continue to grow in the US. Mihail Rocco, chair of the Nanoscale Science, Engineering and Technology subcommittee at the NNI expects that as early as next year, 25% of NNI funding will go to nanobiotechnology, and that by 2015 at least half of all pharmaceuticals will be based on nanotechnology.

"The Works," KUOW November 9, 2004 http://www.kuow.org/program_theworks.asp?Archive=11-09

John Moe interviews Glen Fleshman, science reporter for the Seattle Times. References K. Eric Drexler as the man who created term nanotechnology. Bothell company called Numera (?) working on nano fiber-optics. Respirocite replicates red blood cells – can process more oxygen than red blood cells, more efficiently, so could be used for people who have trouble breathing and

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are on oxygen, work in oxygen low environments, or even under water. Reference to cancer fighting nano-bots. Will these little devices have any autonomy – artificial intelligence? Logic says no because technology is built with specific purpose. Even Drexler has recanted his idea of "Grey Goo" created by replicating nano-bots. That doesn't mean that nanotech can't be used for evil – it could have destructive properties but would take tens of billions of dollars and advancements in science not avail. now. Prominent debate now between Drexler and Richard Smalley is – is it possible that small robots will ever exist? Smalley says no because we can't be precise enough on that small of a level. Current developments are in manufacturing nanotech, not robotic nanotech. Work includes private, government and academic development. Likely there will be patent fights on nanotech because it's hard to define and assign patents now. Nano.gov is government site focused on nano developments.

Nano Applications:

General:

Baraton, Marie-Isabelle and Merhai, Lhadi "Advances in air quality monitoring via nanotechnology," Journal of Nanoparticle Research 6(1), Feb 2004, pp 107-117.

Urban air pollution has serious consequences on public health. More accurate tracking of air pollution through air quality monitoring is necessary. Current air quality monitoring stations (AQM) are expensive and bulky. The research reviews two European projects to provide alternate and complimentary mobile air quality microstations utilizing nanotechnology.

Two projects funded by the European Commission worked on improving semiconductor gas sensor characteristics using nanosized semiconducting particles for CO, NO, NO_2 and ozone detection. Results showed that nano-particles based semiconductor sensors exhibit higher sensitivities to air pollutants, lower detection thresholds (enabling detection of smaller amounts of pollutants), and lower operating temperatures. Long-term evaluation of chemical and electrical stability of produced sensors is ongoing.

Eckert, Jeff "Advanced Technologies – Oscillator Senses Viruses." Nuts & Volts January 2005 pp 84

Researchers have developed a method to look for viruses, DNA, Proteins and toxic organic chemicals. Oscillation of a matter like a knife or paddle depends on the mass of the handle. Using this principle, nanosized silicon paddles can weigh virus particles and other small matter. Researchers believe the device will ultimately be sensitive enough to sense one virus. The current device measures down to six viruses.

European Microbicides Project – EMPRO

35 Principle Investigators from institutions in Europe and Africa. One microbicidal product uses glyconanoparticles to block the entry of HIV at mucosal sites. Glyconanoparticles are multivalent systems, based on nanotechnology, that mimic the presentation of carbohydrate on a cellular surface and can be used to block carbohydrate-protein interactions.

Mantone, Joe "Shrinking technology; Nanotechnology holds the promise of spectacular medical advances, including a cure for cancer, but critics warn of dire consequences." Modern Healthcare Vol 33 Issue 49, Dec. 8, 2003 pp 32.

Rice University's Center for Biological and Environmental Nanotechnology in Houston was awarded a five-year federal grant in 2001 of $2.5M per year. They are examining how to produce nanostructured membranes to improve such environmental technologies as water filters and

pollution control devices. The Rice center is also examining hazards nanosized technologies could pose for public health and the environment. (See also entry under Implications)

National Science Foundation (NSF) Press Release "Carbon Nanotubes Yeild a New Class of Biological Sensors: Glucose sensor provides real-time readouts without the need to draw blood samples," NSF PR 04-154, December 13, 2004

Scientists at the University of Illinois, funded by the NSF, have discovered a method of monitoring blood glucose levels without taking blood samples. A carbon nanotube is inserted on a fingertip. Reactions after illumination with an infrared laser directly corresponds to blood glucose levels. This application would be particularly beneficial for diabetes patients.

Starpharma, Ltd. (starpharma.com) – an Australian based nanotech firm

"Starpharma is creating value from dendrimer-based nanotechnology through:

- The development of high-value dendrimer nanodrugs to address unmet market needs
- Partnering with pharmaceutical companies to create new opportunities and solutions to problems with the application of dendrimer nanotechnology
- Extending our core skills and know-how through licensing and partnering with others
- Parallel investment in non-pharmaceutical applications of dendrimer nanotechnology"

Starpharma developed "VivaGel" a dendrimer-based microbicide to prevent transmission of HIV and other STDs. Funding support for VivaGel comes from the topical microbicide team within NIH. VivaGel is unique in the microbicide market in that it is the only one that targets other STDs in addition to HIV using a defined, single molecular entity. Starpharma is also working on dendrimers to protect against other public health threats including adenovirus, chlamydia, cholera, dengue, ebola, hepatitis B, herpes, human papilloma virus, influenza viruses, malaria, West Nile virus and yellow fever virus, among others.

Medicine without frontiers The Economist, Sept 15, 2005

The article gives a brief biography of Leroy Hood, president and founder of the Institute for Systems Biology, in the context of his new project to develop a nanosensor device capable of making measurements and analysis from blood protein. A device such as this could be used to help doctors prescribe drugs tailored to a patient's individual health needs, both to reverse disease and prevent onset. Dr. Hood is past chair of UW's Department of Molecular Biotechnology in 1992, but left in 2000 when the department was not given enough funding to account for growth. Dr. Hood is also co-founder of NanoSystems Biology Alliance and is the chair of the Scientific Advisory Board for Seattle's Nanostring Technologies

Environmental Applications:

Krane, Jim, AP Technical Writer "Nanotechnology May Aid Environment," Yahoo News, Sept 8, 2002

As nanotechnology advances, the first products are likely to emerge in medicine. Mihail Rocco, NSF's senior advisor on nanotechnology, says that filter systems for drinking water, waste, natural gas pipelines, and smokestacks can be designed at the molecular level to remove even the most minuscule of impurities. This means cleaner drinking water, cleaner burning products and less smog-creating impurities. Nanoparticles are also being examined for use as sensors to monitor air and water for presence of toxins, environmental pollutants and potentially chemical or biological weapons.

Stuart, Candace, "A soak cycle at Inframat, and pollutants come out in the wash," Small Times, June 2, 2004

A handful of companies and research labs are working to provide nanotechnology based solutions for water remediation in domestic and international markets. In the 1980's, millions of villagers in Bangladesh were exposed to unhealthy levels of arsenic in drinking water. This exposure continues to impair the health of people in Bangladesh, India and South Asian nations. The U.S. Geological Survey found high concentrations of arsenic in water in parts of Texas, California, Massachusetts and other states. Inframat Corp and Pacific Northwest National Laboratory are working on filtration systems to take arsenic, mercury and other health hazards out of water. Potential solutions would involve significant cost savings and a reduction in disposal costs compared to other methods.

Water Remediation, General:

Brown, David, "Impact of Safe Water, Sanitation on World's Poor; Efforts go Beyond Better Health, Experts Say," Washington Post Nov 22, 2004 pg A12

Access to safe water and basic sanitation were among the "Millennium Development Goals" adopted in 2000 by 189 heads of state from around the world. They pledged that by 2015 they would reduce by half the proportion of people living without safe water and basic sanitation. 1990 was set as the baseline year. Early reports show that progress is on track to meet safe water goals by 2015, but sanitation goals may fall short. China and India together account for the most people without safe water or improved sanitation. Among regions, Africa is worst off. Although clean water and toilets have many benefits, some are not entirely health related. People's health is linked to other factors including personal habits, food cleaning and storage, education and income. However, access to high *amounts* of water has proven beneficial. Bringing water sources to residences reduces diarrhea by 44% whereas installing a public pipe where water must be transported to houses decreases diarrhea by only 6%. Responsibility for water supply and transportation falls primarily on women and girls in a community. With increased access to close water comes greater self-esteem, less harassment of women and better school attendance by girls.

Population Services International, "Haiti: Saving Children's Lives Through Clean Water," Nov 19, 2004 http://www.psi.org/news/1104b.html

Diarrhea is a major killer of children under five in Haiti, responsible for 41% of all deaths in children under five in rural areas. It's the leading cause of death in children aged 1-11 months and second leading cause of death for children aged 12-59 months. The Safe Drinking Alliance was launched involving 3 non-profits (Population Services International, The Johns Hopkins University Bloomberg School of Public Health's Center for Communication Programs (CCP) and CARE) and Proctor & Gamble. P&G developed a new water purification product, PUR, for use in Haiti. The product will be sold at prices affordable to needy Haitians through commercial and non-profit channels. In addition, CCP will promote public health messages to prevent diarrhea such as water treatment and hand washing. Point of use water treatment approaches such as this have shown a reduction of 30-50% in diarrhea disease.

Nano Implications:

Colvin, Vicki L. "The potential environmental impact of engineered nanomaterials," Nature Biotechnology Vol 21 (10), October 2003, pp 1166-1170

Author's commentary on environmental impact of engineered nanomaterials. Recognition in intro that there an absence of a developed literature base on the subject.

Nanoparticle exposure is growing with growth in field of development and research. In the US, material safety data sheets (MSDS) for nanomaterials often are identical to those for bulk materials – no increase in restrictions/safety relevant to unique properties of nanostructures. Occupational exposure risks include respiration, dermal absorption or oral ingestion. Consumer exposure risks include dermal absorption through products already on the market (cosmetics, sunscreens). Current studies argue that inhalation of nanomaterials is unlikely to be as pulmonarily toxic as other occupational ultrafine particulates because it is difficult to generate isolated and respirable nanoparticles. Existing literature also rules out direct skin absorption of micronized titania (>40nm diameter) used in sunscreens. Greater exposure risks include long-term effects of nanomaterials on the ecosystem through water and soil.

Carbon nanostructures are the only class of engineered nanomaterials that have received focused toxicological study. In vivo, certain forms of C60 are phototoxic. Animal studies of fullerenes have found minimal dermal and oral toxicity, but more acute toxicity after intravenous administration. Two studies have reported lung damage caused by nanotubes in rats and mice.

The article concludes that "currently, nanomaterials exposures and health effects are unlikely to pose any substantial risk to public health given the most prevalent exposure routes and the limited scope of their use. However, as the quantity and types of engineered nanomaterials used in society increases, the potential for unintended environmental consequences will also increase."

Donaldson, K et al. "Nanotoxicology" Occupational and Environmental Medicine Issue 61, 2004 pp 727-728.

This editorial written by researchers in the UK, Netherlands and Germany, calls for the development of a new disciplinary field called nanotoxicology. The article sites various research that points to potential harmful characteristics of nanoparticles, and the lack of further research considering nanoparticles' interactions with fluids, cells and organs.

ETC Group "No Small Matter! Nanotech Particles Penetrate Living Cells and Accumulate in Animal Organs." ETC Communiqué May/June 2002 Issue 76

The report details issues, implications and policies of nanotechnology. Despite findings at a mid-March 2002 fact finding meeting of the EPA that nanoparticals can bioaccumulate, no regulatory body is dedicated to overseeing nanotechnology. Nanotechnology has been pegged to become the world's largest industrial revolution, currently including more than 450 nanotech enterprises globally. Drs. Jennifer West and Mark Wiesner at Ricer University's Center for Biological and Environmental Nanotechnology (CBEN) warn of potential bioaccumulation and adverse health affects. Because nanomaterials have different properties than larger sized particles of the same material, we don't know what accumulated amounts of any human-made nanomaterial will do in our lungs, livers or groundwater, even if we do know how larger particles of the same material behave.

Fullerenes and nanotubes were discovered in 1985 and 1991 respectively, and until recently, could not be manufactured at will. The shape and size of these carbon forms present two potential problems: Nanotubes' shape is similar to asbestos fibers. While they currently tend to clump together rather than act like a single fiber, an intensive area of research is to find a way to de-clump them, potentially increasing their ability to damage respiratory systems. Second, nanoparticles' size lets them slip past the body's immune system. This can be beneficial for drug delivery, but could be hazardous in other applications. Virtually no one is tracking the potentially negative impacts of nanotechnology in present-day products, although there is some focus on future applications.

Feder, Barnaby J. "Research Shows Hazards in Tiny Particles" The New York Times New York, NY, Apr 14, 2003 p C.8

A review of research on nanoscale materials suggests that tiny particles are often toxic because of their size and are likely to pose health hazards, especially to workers making them. Dr. Vyvyan Howard at the University of Liverpool examined results from 27 studies published since 1984. Her findings suggested that the type of particle seems to be less related to how hazardous it is than its size. Nanoparticles are much smaller than human cells, and are easily ingested, inhaled or absorbed through the skin.

Feder, Barnaby J. "As Uses Grow, Tiny Materials' Safety Is Hard to Pin Down." The New York Times New York, NY, Nov 3, 2003 p. C.1

Pinpointing the potential environmental and health impacts of nanotechnology could take years. First stages of research are generating more questions than answers. At DuPont in 2002, researchers injected nanotubes into the lungs of rats. The animals began unexpectedly gasping for breath, and 15% of them quickly died. Yet all the surviving animals seemed completely normal within 24 hours after exposure. Lungs are not the only concern – research shows that nanoparticles deposited in the nose can make their way directly into the brain. They can also change shape as they move from liquid solutions to the air.

Today's products use tiny amounts of nanoparticles, causing many in the field to say there's no reason yet for them to investigate potential environmental impacts. Nanotech advocates say they support faster and broader environmental research, but paying for it hasn't been a priority for businesses or the government. Don't ask, don't tell is the operating mode for much of the nanotech industry when it comes to where discarded products end up. Even with testing, researchers caution that establishing toxicity is only part of it. Determining risk requires determining likely exposure too.

Feder, Barnaby J. "Study Raises Concerns About Carbon Particles." The New York Times New York, NY, Mar 29, 2004 p C.5

Buckyballs can cause extensive brain damage in fish, according to research presented at a national meeting of the American Chemical Society. Eva Oberdorster, and environmental toxicologist at Southern Methodist University, said they also altered the behavior of genes in liver cells in fish. David Warheit, a DuPont researcher, said that how nanoparticles are coated and how quickly they clump together may be more important factors in toxicity than their size.

Freedman, Michael "Nanofear" Forbes Sept 6, 2004 Vol 174 Issue 4, p. 168

The article introduces Pat Mooney's ETC Group's focus on nanotechnology. ETC's goal is to "spread the word of risks and persuade regulators to declare a moratorium on new nanotechnology research until there is an established protocol for safety and a public discussion on the impact of technology." Mooney's report "The Big Down," suggested a release of nanomaterials could cause all sorts of health and environmental problems and compared some nanoproducsts to asbestos. Impacts of Mooney's research may be more widely felt in Europe where consumers are more prone to panic. Large companies, nevertheless, are feeling impacts. Nantero uses nanotechnology to build memory chips and lost a potential funding partner a few years ago, potentially due to groundless environmental hazard worries. DuPont uses Ecos, and environmental consulting firm run by former Greenpeace members.

Goldman, Lynn and Coussens, Christine, Editors "Implications of Nanotechnology for Environmental Health Research" Roundtable on Environmental Health Sciences, Research and Medicine. Institute of Medicine Report. National Academy of Sciences, 2005

The purpose of the Roundtable is to foster dialogue and discussion across institutions and sectors to illuminate issues, not to make recommendations or to solve issues. This meeting focused on nanotechnology and surrounding environmental health issues. In general, the need for open communication was discussed, as was the need for a research agenda to ensure that the right questions are being addressed and efforts are coordinated. Members agreed that the public is an important part of the process. Meeting discussion was segmented to five chapters: Preparing for Nanotechnology: Health, Policy and Emerging Issues; The Promise of Nanotechnology; Nanotechnology: Expanding Scientific Understanding; Nanotechnology: Government Involvement; and Next Steps.

Preparing for Nanotechnology: this chapter defines nanoparticles are particles in the size range of 0.1nm to 500nm and focuses on engineered nanoparticles as opposed to natural or incidental particles. There are 4 basic categories of nanoscale materials on the market: metal oxides such as zinc oxide, naturally occurring nanoclays that are used to strengthen materials such as containers for liquid and tennis balls, nanotubes that are used in coatings to minimize static electricity and quantum dots that are used in exploratory medical diagnostics and self assembly of nanoelectronic structures. Political implications include the fact that most government regulatory frameworks were made 30-40 years ago prior to nanodevelopment. Because people do not always trust government, the actual issue is not regulation per se, but enforcement of regulation that would apply to nano development. This might include a transnational corporation to encourage responsible development of nanotechnology across national borders, recognition of the popular narratives of nanotechnology in society including books, movies and video games, and voluntary agreements with industry on responsible use of nanotechnology, bringing together universities, NGOs and industry to develop principles and best practices.

The Promise of Nanotechnology: Nanotechnology products are already on the market including in sunscreen and cosmetics, sporting equipment, clothing, telecommunication infrastructure and fuel cells. Potential environmental applications include sensors, treatment, remediation and green nanotech manufacturing and engineering. Applications are either reactive or proactive. Reactive applications include sensors. Current research at the University of Arkansas is working on sensors that could be used to monitor shellfish populations for toxin exposure, replacing costly and time consuming methods currently being used. Other applications include detection of microbial

pathogens in drinking water. Treatment and remediation of environmental issues are also being developed; Barbara Karn of the EPA proposes that nanotechnology will make possible great advances in our ability to clean up the environment. Proactive applications include the green manufacturing (use of nanotech to reduce pollution at the source and efficient production of nanomaterials themselves) and green energy including such as solar and fuel cells.

Mantone, Joe "Shrinking technology; Nanotechnology holds the promise of spectacular medical advances, including a cure for cancer, but critics warn of dire consequences." Modern Healthcare Vol 33 Issue 49, Dec. 8, 2003 pp 32.

Rice University – Kristen Kulinowski, Executive Director for the Rice University's Center for Biological and Environmental Nanotechnology in Houston – holds a five-year federal grant beginning 2001 to examine how to produce nanostructured membranes to improve water filters and pollution-control devices (applications). The Rice center is also examining hazards of nanosized technologies on public health and the environment.

Rice researchers found that some nanosized particles have a tendency to clump, which could block respiratory passages and cause vascular complications.

Some groups fear environmental consequences of nanotechnology and advise regulations on studies. "Currently, there are no nanotechnology-specific regulations… oversight agencies such as the Food and Drug Administration will handle the innovations on a case-by-case basis." Greenpeace published a report in July that says nanoproducts in the marketplace could be dangerous and states "these materials should be considered hazardous until shown otherwise."

Pethokoukis, James M. "Devil in the Details? (new concerns about nanotechnology, as reflected in Michael Crichton's new book, 'Prey')" U.S. News and World Report Jan 27, 2003 p. 44

Michael Crichton's new techo-thriller, Prey, raises concerns about possible health effects of nanotech's tiny particles and weapons potential. While nanotech has drawn billions in funding, so brushing off public concern could b a PR mistake similar to that suffered in the 90's regarding genetically modified crops. Several groups worry that nanotechnology has a downside: "Nanotech has broad public-health implications" says Carolyn Raffensperger of the Science and Environmental Health Network in Ames, Iowa. Mark Modzelewski, head of the NanoBusiness Alliance, is putting out reports, lobbying Congress and cultivating media contacts because "You have to be engaged and make people feel safe about a technology as radical as this." Glen Reynolds, a University of Tennessee law professor specializing in technology says that "nanotech companies and labs need to agree on guidelines to address safety concerns and fears that nanomachines could escape." Ultimately, supporters hope the controversy is nothing but growing pains for the industry.

Seaton, Anthony and Donaldson, Kenneth. "Nanoscience, nanotoxicology, and the need to think small." The Lancet March 12, 2005, Vol 365, Iss 9463, pp923-924

The authors argue that while few nanotechnologies pose a direct threat to humanity or the environment, there are foreseeable hazards resulting from nanoparticles and nanotubes. Because nanoparticles and nanotubes share characteristics of other materials proven to cause inflammation, changes in blood coagulability and increased risk of heart attack, they authors hypothesize that inhaled nanoparticles are likely to cause the same damage. The authors suggest

that documented effects of air pollution nanoparticles and asbestos may be early warnings for the use of engineered nanoparticles and nanotubes.

Service, Robert F. "Is nanotechnology dangerous?" Science Nov 24, 2000, Vol 290, Iss 5496 pp. 1526-1527

The conclusion of the article is that, no, nanotechnology is not dangerous. However, nanotechnology is likely to face social issues including public acceptance down the road. In order to combat potential social issues and resistance, researchers need to involve outsiders in the development process.

Service, Robert F. "Nanotechnology Grows Up. Is the field moving so fast that it's destined to repeat the mistakes of earlier technological revolutions?" Science June 18, 2004, Vol 304 pp. 1732-1734

Futuristic visions of nanotechnology are far reaching, but nanotechnology is already among us. Public and private funding worldwide is increasing exponentially. Currently 775 companies and organizations in the US alone are engaging in nanotechnology including Fortune 500 firms such as General Electric, Lucent, Philips, Intel and Merck. Companies have already released 130 different nano-based products into the market. Concerns about safety are supported by research: Eva Oberdörster told nanoscience researchers at the American Chemical Society meeting in March of 2004 that buckeyballs could damage cell membranes in the brains of fish. Fears of nanotechnology have been popularized by the "grey goo" scenario, however, most nanoscientists agree that a more plausible threat is that nanoparticles released from coatings or other products will create a new type of chemical pollution. Most observers agree that it's too early to start regulating nanoparticles. Some, such as ETC's Pat Mooney and Greenpeace's Douglas Parr advise a more cautionary approach, even calling for a moratorium on the release of new products until health standards have been created.

Government support for research into environmental and safety concerns is growing with the field, but some would argue not enough. Mihail Roco, head of the NNI, says that NNI has funded studies of the social, ethical and environmental implications of nanotechnology since NNI's inception. Currently, 11% of NNI's budget is spent on environmental studies, but that includes funding for health and environmental applications for nanotechnology. DuPont also currently funds toxicology work on nanomaterials. Environmental researchers draw on the large body of past research and current models for studying the toxicity of ultrafine particles. Predictive models, currently used to assess a new substance's safety by comparing it with well-studied materials in the same chemical family, may falter when applied to nanotechnology because the small size causes a change in properties. Some fear a public backlash similar to that experienced with genetically modified foods. Experts suggest strategies to help reduce potential for environmental harm and increase public acceptance of materials including: 1) companies should let consumers know upfront which products contain nanoparticles, educating them on benefits but ultimately letting them make the choice. 2) Scientists should not dismiss public concerns as uniformed or unrealistic, but rather engage them in discussion and address concerns. 3) NNI must continue to back studies on environmental and other impacts of nanotechnology and disseminate them widely. Being open from the beginning and providing as much information as possible helps prevent public perception that something is wrong.

Service, Robert F. "EPA Ponders Voluntary Nanotechnology Regulations" Science July 1, 2005 Vol 309 pp. 36

Sissell, Kara "Studies question health effects of nanotechnology." Chemical Week Vol 166, issue 12 April 7, 2004 p. 12

The article relates that many studies have shown negative health effects of nanotechnology. A recent study at Southern Methodist University found that exposure to fullerenes can cause brain damage in fish. Researchers at DuPont in 2003 found carbon nanotubes can damage lungs if inhaled. Congress's NNI has earmarked an undetermined amount of funding for research into health and environmental effects of nanoparticles, yet Senator Ron Wyden, a sponsor of the law stated that there is "currently too little known about the adverse health and environmental impacts of nanoparticles to regulate them."

White, Michelle J. "Asbestos and the Future of Mass Torts," Journal of Economic Perspectives Vol 18, No. 2 Spring 2004 pp. 183-204

This article explores asbestos regulations and litigation in the United States as a case study for future regulation and litigation of potential environmental health hazards. It has interesting potential implications for the possible risks imposed by nanotechnology in that nanotech seems the only likely personal injury case resembling the asbestos saga closely enough to be replicated in the future. Key to the asbestos cases:

1. were failure of regulation to prevent exposure and protect workers
2. mass cover-up of asbestos manufacturers following discovery of health hazards
3. multiple defendants (over 8,400 by the end of 2002)
4. multiple plaintiffs (over 730,000 by the end of 2002)
5. lengthy latency period following exposure prior to onset of disease
6. lack of employer liability to cover employee illness through worker's comp.
7. relaxing of legal standards particular to asbestos cases

These factors together fed into and maintained the massive asbestos litigation that is infamous in the United States. No other mass tort has achieved the same scale.

Related to nanotechnology, it seems likely that many of the same factors will be present. Many firms will use nanotechnology in many products creating the likelihood of multiple defendants. Current regulation appears to be lagging behind growth of the nanotechnology industry, and will only become more difficult to impose as the industry grows and gains profitability. It is likely that effects of nanotechnology won't be identify for years to come following prolonged exposure to products, and given the delay in onset of symptoms, it is unlikely that exposure will be precisely tied to negative health effects. The time lapse and indirect effect on health could lead to relaxing of law similar to that seen with asbestos cases.

Witchalls, Clint "The Next Asbestos? There may be more to sunscreen than meets the eyes. Scientists are taking a closer look at nanoparticles." Newsweek International Edition. New York. July 21, 2003 p 49

Shrinking zinc oxide and titanium dioxide down to nanosize particles lets them keep their sun reflective properties but no longer makes them scatter light. This way, sunscreens can use these effective materials without the white goo of past products. However, Nanoparticles are tiny enough to sneak past the body's immune system. If a pregnant mother puts on sunscreen, does it get

thorugh to the fetus? Vyvyan Howard at the University of Liverpool in England says "I'm not sure anyone knows." A 1997 Oxford University study showed that nanoscale titanium dioxide from sunscreens damaged DNAin skin cells. A NASA study in March of 2002 concluded that carbon nanotubes were more toxic than quartz dust but a conflicting study by DuPont, which makes nanotubes, found them to be less toxic than quartz dust.

Olden, Kenneth; Colvin, Vicki; Rejeski, David; Harris, Myron; Karn, Barbara; Warheit, David; et al "Technology and Environmental Health: Implication on Nanotechnology." Institute of Medicine, Public Discussion. May 27, 2004

This public discussion featured guest speakers from a variety of disciplines and agencies. Many speaker power points are available for download online at http://ww.iom.edu/subpage.asp?id=19612 Among topics discussed:

Barbara Karn, Ph.D. – EPA

Nanotechnology and Environment: the New Future in Remediation

- Water purification and filtration (Wan Y. Shih, Drexel University)
  - Drinking water purification on large scale
  - Bio-terrorism prevention/protection
- Groundwater remediation and pollutant removal/purification (Weixian Zhang, Lehigh)
- Green manufacturing – limit toxic air and water pollution. "Nanostructured catalysts will lead to cleaner, less expensive, more environmentally friendly petroleum refining; better batteries and fuel cells."

David Warheit, Ph.D. – Haskell Lab, DuPont

Potential for Bio-uptake and Bioaccumulation of Nanotechnoloy Particles

- Nanoparticles are more toxic (inflammogenic, tumorigenic) than fine-sized particles of identical composition. DuPont research of nanotubes injected into the lungs of rats – 15% died quickly but the surviving rats seemed completely normal within 24 hours. Concept generally based on 3 particle-types: Titanium Dioxide particles, Carbon Black particles, Diesel Particles. Pulmonary fibrosis?

Eva Oberdoesrster, Ph.D. – Methodist University

The Central Nervous System as a Target: The good and the bad

- Bioaccumulation in body (Yamago S, Tokuyama H, Nakamura E, Kikuchi K, Kananishi S, Sueki K, Nakahara H, Enomoto S, Ambe F. 1995. In vivo biological behavior of a water-miscible fullerene: 14C labeling, absorption, distribution, excretion and acute toxicity. Chem Biol. 2:385-389.)

Precautionary Principle Lit Review

Gilbert, Steven G. "Public Health and the Precautionary Principle." Northwest Public Health, Spring/Summer 2005, University of Washington Scholl of Public Health and Community Medicine, p 4.

The precautionary principle consists of four concepts:

1. taking preventive action in the face of uncertainty
2. shifting the burden of proof or responsibility to the proponents of an activity
3. exploring alternatives to potentially harmful actions
4. increasing public participation in decision making.

In contrast to a risk assessment, the precautionary principle asks what actions can we take to prevent harm from occurring, rather than how much harm can we tolerate.

Phoenix, Chris and Treder, Mike. "Applying the Precautionary Principle to Nanotechnology." Center for Responsible Nanotechnology web site 8/1/2005. http://crnano.org/precautionary.htm

The Center for Responsible Nanotechnology does not believe a prohibition of advanced nanotechnology (the kind that might contribute to self-replicating mechanisms) would be feasible. Molecular manufacturing also promises many benefits both making it more difficult to enforce any prohibition and making it difficult to ignore – nanotechnology based manufacturing could produce less pollution than traditional methods. The Center's position is that the strict form of the precautionary principle is not an appropriate test for nanotechnology because it does not allow consideration of the risks of inaction. Inaction with regards to nanotechnology poses these risks:

1. no solution found for pressing problems
2. development and use of molecular manufacturing by less responsible people
3. lack of understanding of the technology leaving the world ill-equipped to deal with irresponsible use.

However, the Center feels that the active form of the Precautionary Principle would be appropriate for guiding development of molecular manufacturing policy. The Center promotes responsible development of nanotechnology precisely because nanotechnology is risky and the only realistic alternative to responsible development is irresponsible development.

Attitudes about Nano:

Cobb, Michael D. and Macoubrie, Jane. "Public perceptions about nanotechnology: Risks, benefits and trust." Journal of Nanoparticle Research. 2004, Vol 6 pp 395-405.
http://www.springerlink.com/media/n2v6e3wxvr4knw1kvrt0/contributions/q/1/0/2/q1026n34273r6662.pdf

This article reports on a 2004 random dialed telephone survey of 1536 adults living in the continental US to assess reported levels of benefits, risks, trust and knowledge about nanotechnology. The study, the first to conduct a random sample of the US population, found significant differences in several responses. Overall, more than 80% of respondents indicated they had heard "little" or "nothing" about nanotechnology. Only 16% had "heard some" or heard "a lot." When asked to answer 3 true/false questions about nanotechnology to more accurately gauge knowledge, respondents could only answer one question correctly, on average.

Despite knowing little about the subject, 40% of respondents predicted that benefits would outweigh the risks of nanotechnology. 38% thought benefits and risks would be about equal. 22% thought risks would outweigh the benefits. Greater knowledge is associated with more positive perceptions of risks and benefits. Respondents who were "high" on knowledge were much more likely to predict that benefits would exceed risks – 50% of high knowledge respondents predicted that benefits would outweigh risks while just 34% of low knowledge respondents made the same prediction. Respondents were overwhelmingly likely to chose "new ways to detect and treat human diseases" as the most important benefit and least likely to choose "cheaper, better consumer products" as the most important benefit from among a list of 6 potential benefits. Given 6 potential risks, respondents were most likely to choose "losing personal privacy" and least likely to choose "uncontrollable spread of nanobots" as the most important potential risk – though the risk responses were more evenly distributed than the benefit responses.

Eighty percent of respondents claimed to not feel worried about nanotechnology and over 70% claimed to feel somewhat or very hopeful about nanotechnology. Less knowledge about nanotechnology was associated with less hopefulness while 44% of high knowledge respondents claimed to be "very hopeful."

Over 60% of respondents said they had "not much" trust in business leaders to minimize risks of nanotechnology. Fewer than 5% of respondents claimed to have "a lot" of trust in business leaders to minimize risks.

Having read or heard discussion about Michael Crichton's novel *Prey* was found to increase perception about benefits outweighing risks and decrease perception that risk would outweigh benefits. 63% of those who knew of *Prey* thought benefits would outweigh risks compared to 38% who had not heard of the novel. 13% of those who were familiar with *Prey* thought risks would outweigh benefits, compared to 23% who were unfamiliar with *Prey*. The investigators hypothesized that perhaps demographics associated with people who had read/discussed *Prey* produced these results as opposed to the novel on its own.

Demographic variables of race and education had effect on perceived risk. White respondents and more educated respondents were more likely to report benefits outweighing the risks. Additionally, the more respondents say they had heard about nanotechnology, the more they reported benefits outweighing risks. Interestingly, it is how much respondents say they have heard about nano, not their specific knowledge on the subject, that influences responses.

Macoubrie, Jane "Informed Public Perceptions of Nanotechnology and Trust in Government." Project on Emerging Nanotechnologies. Woodrow Wilson International Center for Scholars and Pew Charitable Trusts. September 2005

This report summarizes a study conducted May through June of 2005 funded by the National Science Foundation on public's perception of government, nanotechnology and regulation. This study occurred after and in response to questions raised by the 2004 "Public Perceptions of Nanotechnology study.

117 participants from 3 U.S. sites were asked questions relating to nanotechnology and trust in government regulation. They were then given information on nanotechnology and the role several governmental agencies in regulating technology and development. A post test was administered including some additional questions relating to industry self-regulation, ways the government could increase public trust, and ways industry could increase public trust. Subjects then participated in group discussions and individual opportunities to share information.

In aggregate, after receiving information about nanotechnology and the role of government in regulating it, 71% of respondents thought the benefits of nanotechnology would either outweigh the risks or be about equal to the risks (41% and 30%). Most responders had little initial awareness of nanotechnology prior to the survey. After receiving information, 50% of participants were mostly or quite positive in attitude about nanotechnology. 76% thought a ban on nanotechnology would be "overreacting."

Goldman, Lynn and Coussens, Christine – editors. “Implications of Nanotechnology for Environmental Health Research. Roundtable on Environmental Health Sciences, Research and Medicine.” Institute of Medicine, The National Academies of Science, The National Academies Press, Washington D.C. 2005

The purpose of the roundtable was “to foster dialogue and discussion across sectors and institutes, and to illuminate issues, not resolve them.” Early reports questioned the safety of nanotechnology products on the market for health and the environment. The report argues that the role of the environmental scientists is to create a framework so that as new technologies are being developed, scientists and policy makers are better prepared to put policies in place to safeguard environmental health and inform the public of any risks. The need for open communication was discussed in great detail and a research agenda will be developed to ensure that the right questions are being asked and that the research effort is coordinated. The public were identified as an important part of the process. Issues discussed included: Preparing for emerging issues, the promise of nanotechnology, expanding scientific understanding and government involvement.

Karn, Barbara et al. “Nanotechnology and the Environment: Applications and Implications.” American Chemical Society, Washington D.C., 2004

This symposium’s thrust was to bring together nanotechnology research that contributed to enhanced environmental protection toward human activities, in addition to helping define the problems and processes that might occur in the natural environment. The symposium was organized around two themes: the applications of nanotechnology to the environment and implications of nanotechnology on the environment. Topics discussed for environmental applications included treatment and remediation of existing pollutants, nanocatalysts for more selective and efficient reactions, nanotechnology-enabled green energy, metrology to measure these small materials, nanotechnology-enabled sensors for substances of environmental interest, and environmentally benign manufacturing of nanomaterials. Environmental implications included toxicolology and biointeractions of nanomaterials and nanoparticle geochemistry in water and air.

Oberdörster, Günter et al. “Nanotoxicology: An Emerging Discipline Evolving from Studies of Ultrafine Particles.” Environmental Health Perspectives, Vol 113, No 7, July 2005 pp 823-839.

This article summarizes present knowledge of ultrafine particles and applies that knowledge to nanoparticles.