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Perception of Risks and Nanotechnology

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Abstract. There is no scientific evidence to support the notion that nanoparticles and nanotubes – basic components of nanotechnology-based products – pose risks to human health and the environment. Yet, there already have been considerable discussions in the mass media and the U.S. Senate about the potential hazards of nanoparticles and nanotubes, on how they possibly interact with living organisms and non-living systems, and further disseminate in the human body and the environment. For now, though, the lack of genuine scientific data on the potential hazards of nanotechnology on human health and the environment has misled the discussions: debate about the risks of nanotechnology today truly amounts to the *perceived* risks of nanotechnology – since the technical, scientifically estimated risks remain at bay. This paper argues that the perceived risks of nanotechnology are likely to overestimate and overrate the risk of nanotechnology. Contrary to what the nanotechnology community, policy makers, and funding agencies might be inclined to believe, the soon-to-be-released reports on nanomaterials toxicology will not necessarily put an end to public controversies over the potential risks and benefits of nanotechnology.

1. Assessing the Risks and Benefits of Nanotechnology

For scientists studying nanotechnology, defining risk-benefit trade-offs generally means weighing the risks and benefits of nanoparticles, fullerenes, nanotubes, nanowires and the like compared to those associated with materials that are currently in use. A case in point is the application of nanoshells to treat cancer. Nanoshells, made of silicate or silver core nanoparticles surrounded by a gold coating, have unique optical properties (Jackson & Halas 2001, Lal *et al.* 2002). The hope is that chemically modified nanoshells could identify, bind and – unlike traditional chemotherapy – selectively destroy cancer cells. The results could be a significant reduction of chemotherapy side-effects and a higher survival rate by early detection of cancer cells.

Recently though, some concerns about the potential hazards of nanoparticles and nanotubes for human health and the environment have been raised in the media (Brumfiel 2003, Dagani 2003, Feder 2003a, Feder 2003b, Nature Editorial 2003, Service 2003, Stuart 2003, Witchalls 2003). The focal point of these discussions is the size of these nanomaterials – typically one billionth of a meter, that is to say approximately 70 times smaller than a red blood cell in size and close to a DNA molecule in diameter. There is concern that these dimensions might allow them to penetrate the skin and possibly even elude the immune system to reach the brain. From an environmental standpoint, issues such as the pace and strength with which nanomaterials may bind to organisms and non-living species in water, soil, and air, as well as their stability over time and potential bioaccumulation in the food chain, are being discussed, too.

2. What is Known, What is Not

As of Fall 2003, no peer-reviewed scientific article has concluded that nanoparticles and nanotubes are dangerous for human health and the environment. At present, the only two studies published on the hazards of nanomaterials did not find carbon nanotubes to be toxic. More specifically, these initial studies concluded that fullerene soot with a high content of carbon nanotubes does not induce pulmonary dysfunction or show any signs of health hazards related to skin irritation or allergic risks (Hucszko *et al.* 2001, Hucszko & Lange 2001). Still, there is no consensus among scientists whether nanomaterials are risk-free.

More toxicology studies are currently being carried out at the Johnson Space Center, at the Dupont Haskell Laboratory for Health and Environmental Sciences, and elsewhere. The preliminary results of these investigations were presented at the 2003 American Chemical Society's annual meeting, but are not yet published in peer-reviewed journals. Additional toxicology studies are also expected to be carried out as a result of the July 2003 call for proposals by the U.S. Environmental Protection Agency (EPA). It dedicates $4 million to the study of the impacts of manufactured nanomaterials on human health and the environment.

To summarize, any health and environmental hazards from nanomaterials remain unidentified for now. Interestingly, insights from controversies over genetically modified – GM – crops reveal that the perception of risks can quickly overtake reality in the court of public opinion, and dominate public acceptance for years to come even when data suggests that the fear is overblown. In fact, a close look at the GM crop story suggests that at the heart of the debacle was public perception of risks, not scientific facts.

3. A Digest of the GM Corn Debacle

Genetically modified corn with Bt – *Bacillus thuringiensis* – bacteria was seen as a seductive option that provides an alternative to spraying crops with pesticides. In the US, corn generates over $17 billion per year and over $4 billion in exports. One of the problems in growing corn is that it can be attacked by insect pests. Among them, the European corn borer is the worst enemy. Bt corn was engineered to produce toxins with pesticidal properties that selectively kill European borers but that are inoffensive to other insects, animals, birds, humans and the environment.

As a result of a series of risk assessment studies, the EPA approved marketing of the first genetically modified crop in 1995. The controversy over Bt corn was triggered four years later, when Cornell entomologists published a scientific correspondence in *Nature* with the provocative title "Transgenic pollen harms monarch larvae". The study suggested that Bt corn pollen may harm the beautiful and already endangered monarch butterfly (Losey *et al.* 1999). The day after its publication, on May 20 1999, both the U.S. and European mass media covered the story with sensational headlines: "Biotech vs. 'Bambi' of insects? Gene-Altered Corn May Kill Monarch" (*Washington Post*); "Engineered corn kills butterflies, study says" (*USA today*); "Pollen from GM maize shown to kill butterflies" (*The Guardian*). Opponents of bioengineering were quick to point out that scientists might not be able to anticipate the negative consequences of introducing engineered plants into the environment.

The controversy had devastating consequences for the GM crop industry. Monsanto, the world's leading Bt corn producer, experienced a 10% drop in the value of its stock; while Gerber Products, a baby food producer, announced under public pressure that it would not use GM ingredients. While there were definite concerns in the US, the study only served to intensify Europe's fear and disgust with GM crops. The EU chose to suspend the approval of Bt corn in 1999 – though there is only a small population of monarch butterflies in Europe – fearing that native moths and butterflies may be endangered. Soon after, the EU called for a moratorium on GM foods.

In November 1999, a consortium made of Bt corn producers – namely Monsanto, Novartis and Dupont – and the US Department of Agriculture hosted a conference on the impact of GM crops on the environment. After investing $150,000 in nine research projects commissioned to academic institutions, the scientific community failed to reach a consensus on Bt corn hazards, but acknowledged that there is some level of risk that needed to be further understood. A month later, in December 1999, the EPA held hearings on GM foods. In the spring of 2000, in response to a petition by activist groups, the EPA undertook additional risk assessment studies that concluded, "EPA is confident in Bt crops".

Meanwhile, Bt corn producers and the Department of Agriculture spent an additional $200,000 on research projects. The results, published in October 2001 in the Proceedings of the National Academy of Sciences concluded that Bt corn presents little risk to monarch larvae (Hellmich *et al.* 2001, Oberhauser *et al.* 2001, Pleasants *et al.* 2001, Sears *et al.* 2001, Stanley-Horn *et al.* 2001, Zangerl *et al.* 2001). The US EPA then extended registration of Bt corn for seven years. After maintaining its moratorium on the farming and import of genetically modified foods and grains for several years, the EU partially lifted the moratorium in July 2003 by establishing a rule that would allow the marketing of GM foods on the condition that all food with more than 0.9% GM ingredients be labeled.

The GM corn debacle suggests that the mere allusion to Bt corn risks to the monarch butterfly, amplified by the media, profoundly altered the trajectory of some genetic engineering applications and considerably damaged the financial wherewithal of major companies. Intriguingly, the initial negative perceptions of the unknown risks were not subsequently overcome by the agreed upon evidence that Bt corn is harmless. Promoters of nanotechnology hope that such a scenario will not be repeated. The question that deserves to be looked at with scrutiny is this: what factors are most important in affecting these perceptions of risk?

4. Perception, Judgment, and Reaction to Risk

To many, the monarch butterfly is a vivid symbolic image of nature's fragile beauty. The association of this vivid image with a catastrophic event, namely the potential extinction of the monarch butterfly by involuntary exposure to Bt corn pollen, stigmatized Bt corn in the view of the public. This grave image that an endangered and beautiful species could be wiped out due to human tinkering created strong negative feelings in the mind of the public. Had the story been about beetles or flies, the mass media, consumers groups and environmental groups probably would not have responded in the same way – essentially because the association of images with beetles and flies is considerably weaker and less positive than with the monarch butterfly.

What seems counter-intuitive is that the initial formulation "Bt corn = monarch butterfly killer" stuck to the public mind, even after the publication of convincing evidence for "does not do harm" eighteen months later in the Proceedings of the National Academy of Sciences. In fact, the industry, regulatory, and funding agencies probably hoped that failure to link Bt corn to undesirable consequences on the monarch butterfly would make public opinion tip towards public acceptance of GM crop. It did not. Instead, the initial framing that GM crops are bad remained persistent in the public's mind throughout the controversy. At best, it fed into public skepticism in the U.S.; and at worst, it fed into the public backlash against GM food in Europe.

These observations are consistent with what psychologists, behavioral and decision science researchers have described over the last two decades. In fact, psychologists Amos Tversky and Daniel Kahneman – recipients of the 2002 Nobel prize for economics– have long ago shown that presentation of information and formulations of risks causes significant shifts of preference in the choice between different options (Tversky & Kahneman 1981) – that is, such choice is sensitive to the way stories and problems are framed (for example, in terms of the probability of the outcomes expressed as loss of human lives or, on the contrary, as gain of human lives).

In other words, judgment about risk strongly depends on the way risks are presented (or framed) and communicated to the lay public. In the case of the Bt corn controversy, the mass-media have contributed to framing the debate around "Bt corn = monarch butterfly killer", insidiously stressing the negative consequences of Bt corn use over its potential benefits – limiting the spraying of pesticides – and putting the burden of proof on the scientific community and Bt corn producers.

Paul Slovic and coworkers demonstrated that initial public perceptions are in fact strong and difficult to overcome (Slovic 1987). The initial and controversial perception that Bt corn is bad, as framed by the mass media, was indeed resistant to change, even in the presence of subsequent agreed upon, contrary evidence. The persistence of the initial perception is reinforced also because risks stick to the public mind to a higher degree than the associated benefits (Starr 1969).

Along the same lines, Slovic concluded in a recent study on nuclear technology that negative trust-destroying events are more visible and carry greater weight than positive, trust-building events (Slovic 1999). For example, in the Bt corn story, the publication of the article in Nature entitled "Transgenic pollen harms monarch larvae" received much more attention from the media than the series of articles published in Proceedings of the National Academy of Sciences in early October 2001 whose titles were much more neutral in tone, as illustrated by these two examples: "Impact of corn pollen on monarch butterfly populations: A risk assessment" or "Assessing the impact of Cry1Ab-expressing corn pollen on monarch butterfly larvae in field studies" (Sears *et al.* 2001, Stanley-Horn *et al.* 2001).

5. Decision Process and Risk Overestimation

Though the mass media played an important role in framing public debate and shaping public opinion on Bt corn, individuals' characteristics are also decisive in perceiving risks. In the lay public mind's eye, the association of a vivid image with a catastrophic event that can potentially be a threat to future generations leads to risk overestimation. Other factors that distort risk judgment are the newness of a technology, its dreadful character, the lack of knowledge and lack of controllability of risks. Risk distribution – who shares the risks and the benefits – also play a significant role in the way non-technical persons comprehend risk. All these factors lead to the overestimation of risk (Slovic 1987). More recently, Sjöberg showed that risks created by interfering with the process of nature – that is, natural *vs.* unnatural risks – affect risk judgment (Sjöberg 2000).

In brief, risks are often misjudged. Contrary to what the scientific community is inclined to believe, reactions to risks are not exclusively guided by evidence collected in the scientific tradition. Instead, risk assessments are rooted in human values such as common sense, intuition, imagination, memory, and past experience. This may explain why scientists and staffers from regulatory and funding agencies tend to believe that open public debate over technology often distorts the truth about facts and claims, which eventually results in poor social decisions. But research in decision science clarifies these concerns. It shows that individual response to risk is likely to be conditioned by feelings like worry, anxiety and fear (Loewenstein *et al.* 2001).

Moreover, fear – and its perception – is big business. Marginal pressure groups such as environmentalists and consumer groups have a great impact on public debate because they feed on the fear factor of new technologies to raise funds, to increase their membership, and to become more visible. The media, too, benefit from the fear factor. Events that are novel, rare, vivid, and that generate tensions and negative feelings are far more newsworthy – thus leading to increased newspaper sales and higher advertisement revenues – than ordinary, mundane, and happy events. To some extent, funding and regulatory agencies also profit from the fear factor. In fact, the FDA, EPA, and OSHA justify part of their budgets by increasing the scope of hazards monitored in our food, drugs, the environment and our working place – even more so in the aftermath of 9/11 and the Iraq war.

Perceptions of risk and decision processes about new technology have been the topic of key articles published in *Science* (Tversky & Kahneman 1981, Slovic 1987, Starr 1969). But the troubling development of genetic engineering controversies over the last five years or so suggests that the scientific community, NSF, EPA and FDA among others have failed to take notice. So long as such studies are overlooked, tensions between the lay public and the scientific community are unlikely to fade away.

6. Perceptions of Risk and Nanotechnology: What to Watch For?

The perceived risks of nanotechnology are likely to overestimate the risk of nanotechnology. Some of the concerns expressed in the media by environmentalist groups, and by a handful of scientists as well, happen to be the trigger points that lead to risk overestimation. They catalyze the lack of familiarity with nanotechnology among the public, the uncertainty over equitable distribution of knowledge and equitable balance of the risks and benefits, the difficulty in predicting the potential hazards, and – last but not least – the association of nanotechnology with the public backlash against genetically modified foods. Along with these, dimensions like beliefs, conviction, morality (what is wrong, what is right), and ethics (what is good, what is bad) have so far received little attention from scholars in nanotechnology and deserve to be explored.

Collecting information on the perception of nanotechnology risk is as important as – or perhaps more important than – the mere collection of scientific data about the potential hazards of nanomaterials. So far, the burgeoning field of nanotechnology risk assessment has emphasized data collection and factual judgment based upon the utilitarian framework of technically calculated cost/benefit analysis rather than emphasizing the values of individuals that have long been known by decision theorists.

The failure to understand or acknowledge how non-technical persons perceive, assess and make decisions about risk may hamper the trajectory of nanotechnology as public policies and business practices are adopted. In conclusion, perceived risks are real. Perceived risks may very well constitute the tipping point that will decide whether nanotechnology succeeds.

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