Nanotechnology For Promise or Peril?: Learning From Dual-Use Technologies

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NANOTECHNOLOGY FOR PROMISE OR PERIL?: LEARNING FROM DUAL-USE TECHNOLOGIES

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Nanotechnology product development has surged in recent years, with over 800 nanotechnology-based consumer products available on the market, spanning a spectrum of products including tennis rackets, stain-resistant pants, cooking oil, sunscreens, pharmaceuticals, and electronics.[1] Nanotechnology involves science and engineering at the scale of 1–100 nanometers (nm) where nanoscale materials exhibit novel properties such as increased strength, enhanced optical features, antimicrobial properties, and superconductivity. While nanotechnology offers much promise, these novel properties and behaviors may also pose new risks. There is increasing concern of the toxicity of engineered nanomaterials and the effects on biological systems and the environment, which remain largely unknown.[2] There is also concern of the potential for misuse of nanotechnology for large-scale malicious acts; in fact, many scientists warn that engineered nanoparticles mimicking a deadly virus could create a global health threat if released into the public because of the current inability to detect specific nanoparticles in the air or water.

Despite emerging applications, consumer access to nanoproducts, and concerns about the potential dangerous uses of nanoscale materials, policy-makers are struggling to determine what oversight framework is most appropriate and effective to oversee nanotechnology research and downstream products. Using a comparative approach, this paper focuses on considerations for the development of oversight of a distinct risk of nanotechnology: not one resulting from consumer use of nanotechnology products, but rather the potential misuse in the laboratory to produce a nefarious application that threatens public health or the environment. In this context, dual-use technologies serve as a useful comparison as they can be used legitimately as well as improperly for dangerous uses such as bioterrorism. This paper advocates that there is a critical need to identify core issues encountered in the past with dual-use technologies in order to develop adequate preparation mechanisms for nanotechnology research with potential dual-use capabilities. This article will examine important considerations for preparation, monitoring and surveillance, detection, and response plans for past dual-use technologies to identify critical issues for potential misuse of nanotechnology. Based on the lessons from dual-use technologies, this article will conclude with basic recommendations for initial nanotechnology governance before legislative or administrative action can be effective.

I. POTENTIAL DUAL-USE OF NANOTECHNOLOGY

Nanotechnology has uses in many areas of society, including academia and industry, but arguably its most powerful and potentially dangerous use is with military research and applications. Nanoparticles have been found to have properties that are attractive for military uses; they can be more explosive than ordinary materials and due to their greater surface to mass ratio, they are more reactive.[3] From 2007 to 2009, the U.S. Department of Defense (DOD) had the greatest investment in the National Nanotechnology Initiative (NNI) budget for nanoscale science and engineering research and development of the 26 member agencies, with $450 million in 2007, $487 million estimated for 2008, and $431 proposed for 2009.[4] Based on these numbers, one can either conclude that the DOD either sees great military potential in nanotechnology or great risk to national security from possible acts of terrorism or military activities of other countries.

Due to the properties of nanotechnology and the lack of relevant research and oversight about the airborne transport of nanomaterials or its effect on the human body and the environment,[5] it is entirely probable that nanotechnology research—under either good or poor intentions—could lead to a large-scale adverse event that may severely damage public health, the environment, or both. Nanotechnology could be used to create resistance to current vaccines or medication, which could lead to a large-scale outbreak or epidemic for which there is inadequate preparation. Another possible use is the release of a dangerous substance into the environment utilizing enhanced nanoscale transport properties, which would be irreversibly damaging to soil and ecosystems given that the removal of nanoparticles from the environment may not be possible.[6] Real-life examples of this type of event could include releasing harmful nanoparticles similar to Anthrax into a highly populated area or releasing dangerous nanomaterials into a large water system. This paper will use the term "nanobioterrorism" when discussing a nefarious use of nanotechnology, because the primary terrorism concerns discussed will relate to the use of nanomaterials interacting with the human body, as well as nanomaterials mimicking biological systems as agents or viruses.[7]

II. NANOBIOTERRORISM: PREPARATION, DETECTION, SURVEILLANCE, AND RESPONSE

It is essential to create a framework of oversight to prevent dangerous use of nanotechnology within the context of terrorist attacks. International frameworks and policies for oversight and prohibition of chemical and bioweapons already exist through efforts such as the Chemical Weapons Convention and the Biological Weapons Convention that ban the use of such weapons.[8] The U.S. has passed its own legislation to protect the public from biological or chemical technologies used towards the development and use of weapons.[9] While some argue that nanobioterrorism would be within the context of existing frameworks of chemical or bioterrorism, this may not be appropriate due to the lack of information of behavior and properties at the nanoscale.

Initial governance of nanotechnology requires learning from past treatment of other dual-use technologies. The National Science Advisory Board for Biosecurity (NSABB) has broadly defined dual-use research as "the development of new technologies and the generation of information with the potential for benevolent and malevolent purposes."[10] This article details considerations that will be important in developing legal and regulatory frameworks regarding nano dual-use potential, including prevention measures, early surveillance and detection methods, and possible responses to a nanobioterrorist event. It will conclude with recommendations to address these elements of overseeing potential nanobioterrorism.

A. Preventive Measures for Nano Dual-Use

After September 11, 2001 and the 2001 Anthrax spore attacks, it is evident that terrorist attacks are a real concern and merit preventive measures and planning. Furthermore, with developments in nanotechnology, nanobioterrorist efforts will achieve results of greater magnitude, with materials at a smaller scale that are harder to detect. Since nanobioterrorism is not an unlikely occurrence in the near future, it is important to begin advance planning in order to prevent such attacks and reduce wide-scale repercussions.[11]

1. Model and Scenario Building

Models and scenario-building that simulate terrorist events can be a strong source of information-gathering to improve response capability. These models are important because they provide knowledge about the level of threat from biological weapons, and they allow estimations of the effectiveness of various responses. Models can be developed through engagement of relevant agencies[12] and conducting experiments to formulate a better prediction of how mass exposure to nanoparticles or bacteria/viruses will impact humans, as well as the environment.[13]

Unlike bioterrorism, simulating a nanobioterrorist attack would be very difficult due to the lack of research and nano-specific knowledge. However, these simulations could provide insight into the areas of potential weakness during response and where research is most needed in order to ultimately have an effective prevention and response plan.

2. Categorization of Risks

A complementary approach is to categorize the types of dual-use technologies that pose risks with information on their potential threat to human safety and national security. In preventive preparation for bioterrorism using biological agents and organisms, one approach is to mark and identify the source of the risk involved in different types of dual-use technology by assigning a unique code to each type and variant.[14] This organization of potentially dangerous elements offers knowledge in how to provide defense to these threats, as well as how to respond to the threats if they do occur. However, biological weapons are distinct from nanomaterials in that biological agents and microorganisms are well categorized presently and new strains can be identified as potentially harmful with minimal difficulty based on existing information.

3. Expert Review by the Department of Defense

The DOD has invested substantial funding into nanotechnology research, indicating that there will likely be military and national security applications. As much of the military research and development is classified information not available to the general public, there is a transparency issue regarding prevention planning which recreates a unique responsibility for the DOD. Thus, the DOD must implement a specialized framework for regulation, accountability, and response that involves objective experts privy to classified information and external to the actual research investigation. Such a system of expert review will identify military research that could inadvertently result in malevolent use as federal oversight frameworks are not equipped to deal with the subsequent impact given the secrecy surrounding its development.

Although this three-part comparative analysis is grounded in techniques applied to bioterrorism, the behavior of nanomaterials may be so unique that comparable efforts will be ineffective. They also highlight the need for more research and testing on toxicity and the effects of exposure to nanomaterials before relevant laws can be effectively designed. Current preventive preparation for a nanoterrorist attack will prove to be complex and mainly derived through historical analysis and comparison since current predictions of nanotechnologies may be incorrect or speculatory.

B. Early Surveillance and Detection

The uniqueness of nanotechnology derives from the fact that certain—and, often common—materials react in different ways at the nanoscale. The difference between surveillance of nanotechnology and biologics is due to a number of unique nano-characteristics, namely: optical, chemical, mechanical, thermal, and physical. Environmental and health surveillance and research surveillance are discussed below.

1. Environmental and Health Surveillance

Currently, there are no generally available tests to determine the presence of nanoparticles in air and water and consumer products. Additionally, with nanoparticle toxicity risk assessment and surveillance, it is not only important to detect the material, but also its form, surface area, size, and other qualities.[15] For example, the presence of a common element like carbon is not necessarily concerning in itself, but it could provide unique risks and toxicity concerns at the nanoscale because of the change in properties.

Nanobioterrorism also has a potential to create large-scale threats to human health through contaminated food, drugs, and biologics. These products may fall under Food and Drug Administration (FDA) enforcement authority as adulterated or misbranded; however, this may not be sufficient as contaminated nanoparticles may present a unique—and, potentially, more severe—risk to public health and safety.

2. Research Surveillance

Surveillance not only includes actual environmental testing of nanoparticles, but also surveying the laboratories that are working with nanotechnology research of dual-use capability. This surveillance recognizes that even researchers with positive intentions could be creating applications with malevolent uses if the products or information came to be within the possession of individuals with terrorist objectives.

In dual-use biotechnology research, the principal investigator is responsible for compliance with the National Institutes of Health guidelines in their research, as well ensuring that all reporting requirements occur within the appropriate time period.[16] Enforcing compliance with these guidelines ultimately uses the weight of federal funding, but also utilizes both local self-regulation and limited federal oversight. While reporting mechanisms may be useful for those that have positive research intentions, they will not necessarily catch the "bad actors" or companies that develop potentially dangerous products.[17] It is unlikely that companies will voluntarily choose to test environmental effects because it is costly, links a certain product to a negative effect, and there is little incentive to comply. A mandatory regulatory framework for laboratory research and development is needed to ensure responsible and consistent reporting and feedback loops to all agencies.

C. EMERGENCY RESPONSE

Advance preparation for emergency response is critical to reduce both immediate damage and long-lasting health and environmental effects from hazardous exposure to chemicals or biologics. Two of the major public health concerns involve either introduction of hazardous airborne nanoparticles or introduction of nano-manipulated viruses or bacteria that lead to comprised immune systems. Appropriate emergency response must both shield the population from the danger and protect those that have not yet been exposed. With an open air release or the release of a dangerous agent, it is difficult to know how many people will be affected and how quickly disease will set in.[18] This section will discuss infrastructure capacity and engagement of the public as useful efforts for emergency response to dual-use technologies.

It is necessary to create a system that has the public health and medical infrastructure to address sudden and large-scale demands on various systems.[19] Treatment may be unavailable due to the disruption in immunity or the lessened efficacy of available vaccines;[20] therefore there must be plans for basic needs in the case of quarantine and isolation in order to reduce further public health issues and to quell public fear during a time of crisis.[21] While systems already exist within the federal government for disaster response, coordination with preexisting local response plans is a necessity.[22] This planning requires coordination of responsibility allocation between the public and private sector.[23] It is likely that bioterrorism risks of large-scale demands on health care capacity and financial resources will also be true for nanotechnology because maximized damage and paralysis of society are typically the ultimate goals of terrorist acts. This process should involve governmental agencies and experts to create a coordinated plan for examining available data, creating a response plan, coordinating the response between the different actors, and communicating with the public.[24]

CONCLUSION

From current knowledge and research, nanotechnology will likely have dual-use applications and thus require special attention in risk assessment and response efforts. One of the valuable qualities of nanomaterials is their novel properties at the nanoscale, making them attractive for malevolent uses in nanobioterrorism. With this potential, it is critical to devise a comprehensive system of oversight and regulation to prevent nanobioterrorist attacks and minimize their potential impact. Until research on the possible harmful effects progresses, it is necessary to approach the development of this system through governance based on existing knowledge and frameworks for dual-use technology oversight.

This paper demonstrates the urgent need to anticipate and respond to malevolent uses of nanotechnology before enacting laws that may unduly restrict research and innovation. Serious questions arise with respect to whether new governance is necessary from known materials and whether new laws are required in existing products and biologics. The gaps identified in this paper indicate a number of weaknesses in our system of oversight of nanotechnology research and products. These weaknesses indicate specific and concrete risks that will continue unless the scientific community and the nanotechnology industry begin to invest increased time and energy into risk assessment and nanotoxicology studies, in addition to greater collaboration among actors, and increased public engagement and education. Although these are not easy tasks, it is necessary to address potential dangers as nanotechnology research will continue to bring risks that may ultimately require nano-specific legislation and government agency oversight.

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[1] PROJECT ON EMERGING TECH., CONSUMER PRODUCTS (2008), *available at* http://www.nanotechproject.org/inventories/consumer/.

[2] *See* Andrew D. Maynard et al., *Safe Handling of Nanotechnology*, 444 NATURE 267, 268–69 (2006) (suggesting that three out of the "five grand challenges" are "[d]evelop instruments to assess exposure to engineered nanomaterials in air and water, within the next 3–10 years;" "[d]evelop and validate methods to evaluate the toxicity of engineered nanomaterials, within the next 5–15 years;" and, "[d]evelop models for predicting the potential impact of engineered nanomaterials on the environment and human health, within the next 10 years").
[3] *See* J. CLARENCE DAVIES, NANOTECHNOLOGY OVERSIGHT: AN AGENDA FOR THE NEW ADMINISTRATION 3 (2008).
[4] NAT'L NANOTECHNOLOGY INITIATIVE, FY 2009 BUDGET & HIGHLIGHTS 2, *available at* http://www.nano.gov/NNI_FY09_budget_summary.pdf.
[5] *See* NANOSCALE SCI., ENGINEERING, AND TECH. SUBCOMM., NAT'L SCI. AND TECH. COUNCIL, ENVIRONMENTAL, HEALTH, AND SAFETY RESEARCH NEEDS FOR ENGINEERED NANOSCALE MATERIALS 29 (2006).
[6] *See* DAVIES, *supra* note 3, at 3.
[7] *See generally* Mihail Roco, *Nanotechnology: Convergence with Modern Biology and Medicine*, 14 CURRENT OPINION IN BIOTECHNOLOGY 337, 337 (2003) (defining nanobiotechnology as the application of nanoscale principles and techniques in order to understand and manipulate biosystems which uses biological principles and materials to form new systems and devices integrated from the nanoscale).
[8] *See* United Nations Office at Geneva, Disarmament: The Biological Weapons Convention, http://www.unog.ch/80256EE600585943/(httpPages)/04FBBDD6315AC720C1257180004B1B2F?OpenDocument (last visited Dec. 1, 2008) (describing the Biological Weapons Convention as a disarmament treaty banning biological and toxin weapons); United States Chemical Weapons Convention Website, http://www.cwc.gov/cwc_about.html (last visited Dec. 1, 2008) (describing the Chemical Weapons Convention as a treaty that prohibits the "development production, stockpiling, and use of chemical weapons"). *See generally* COMM'N ON R&D NEEDS FOR IMPROVING CIVILIAN MED. RESPONSE TO CHEM. & BIOLOGICAL TERRORISM INCIDENTS, INST. OF MED. & BOARD ON ENVTL. STUDIES & TOXICOLOGY, NAT'L RESEARCH COUNCIL, CHEMICAL AND BIOLOGICAL TERRORISM: RESEARCH AND DEVELOPMENT TO IMPROVE CIVILIAN MEDICAL RESPONSE 16 (1999).
[9] *See, e.g.*, Anti-Terrorism and Effective Death Penalty Act of 1996, Pub. L. No. 104-32, 110 Stat. 1214 (codified as amended in scattered sections of 8, 18, 22, 28, & 42 U.S.C.); Chemical and Biological Weapons Control and Warfare Elimination Act of 1991, Pub. L. No. 102-82, 105 Stat. 1245 (codified at 22 U.S.C. §§ 2798, 5601–5 (2006)); Biological Weapons Anti-Terrorism Act of 1989, Pub. L. No. 101-298, 104 Stat. 201 (codified as amended at 18 U.S.C. §§ 175–178 (2006)). *See generally* COMM'N ON R&D NEEDS FOR IMPROVING CIVILIAN MED. RESPONSE TO CHEM. & BIOLOGICAL TERRORISM INCIDENTS, *supra* note 8, at 16–17.
[10] NAT'L SCI. ADVISORY BOARD FOR BIOSECURITY, PROPOSED FRAMEWORK FOR THE OVERSIGHT OF DUAL USE LIFE SCIENCES RESEARCH: STRATEGIES FOR MINIMIZING THE POTENTIAL MISUSE OF RESEARCH INFORMATION 2 (2007), *available at* http://oba.od.nih.gov/biosecurity/pdf/Framework%20for%20transmittal%200807_Sept07.pdf. The NSABB further explains dual-use research by stating that information from life sciences research provides many benefits to society, national security, and the economy, "[y]et the very information and tools developed to better the health, welfare and safety of humankind can also be misused for harmful purposes. Information from legitimate life sciences research can be

misapplied to create dangerous pathogens for employment as weapons, bypass countermeasures or threaten in other ways the health and safety of humans, animals, plants, and the environment or to cause harmful consequences to materiel." *Id.* at 1–2. The NSABB points out that a "dual use research of concern" is "research that, based on current understanding, can be reasonably anticipated to provide knowledge, products, or technologies that could be directly misapplied by others to pose a threat to public health, agriculture, plants, animals, the environment, or materiel." OFFICE OF BIOTECH. ACTIVITIES, NAT'L INSTS. OF HEALTH, NSABB – FREQUENTLY ASKED QUESTIONS 2–3, *available at* http://oba.od.nih.gov/oba/faqs/oba_nsabb_faq.pdf (last visited Mar. 5, 2009).

[11] *See generally* PANEL ON BIOLOGICAL ISSUES, COMM. ON SCIENCE AND TECH. FOR COUNTERING TERRORISM, NAT'L RESEARCH COUNCIL, COUNTERING BIOTERRORISM: THE ROLE OF SCIENCE AND TECHNOLOGY 27 (2002) ("We can never create a perfect system to safeguard against terrorist use of a biological agent. But conscientious preparation—to the greatest extent that budgets and available methods allow—will reduce anxiety and greatly mitigate the consequences of an actual attack.").

[12] Possible agencies are: the National Institutes of Health, the Center for Disease Control, and the United States Department of Defense.

[13] *See* PANEL ON BIOLOGICAL ISSUES, *supra* note 11, at 28.

[14] *See id.* at 30–31.

[15] *See* Günter Oberdörster, Eva Oberdörster, & Jan Oberdörster, *Nanotoxicology: An Emerging Discipline Evolving From Studies of Ultrafine Particles*, 113 ENVTL. HEALTH PERSPECTIVES 823, 823–25 (2005).

[16] *See* COMM. ON RESEARCH STANDARDS AND PRACTICES TO PREVENT THE DESTRUCTIVE APPLICATION OF BIOTECHNOLOGY, NAT'L RESEARCH COUNCIL, BIOTECHNOLOGY RESEARCH IN AN AGE OF TERRORISM 52 (2004), *available at* http://www.nap.edu/catalog/10827.html.

[17] *See* INT'L CTR. FOR TECH. ASSESSMENT, PRINCIPLES FOR NANOTECHNOLOGIES AND NANOMATERIALS OVERSIGHT 3 (2007), *available at* http://www.icta.org/doc/Principles%20for%20the%20Oversight%20of%20Nanotechnologies%20and%20Nanomaterials_final.pdf. For example, the United Kingdom's Department for Environmental Food and Rural Affairs and the United Kingdom Strategy Board have a program called the Voluntary Reporting Scheme to gain information on activities of companies and researchers in the nanotechnology field. U.K. DEP'T FOR ENV'T, FOOD, AND RURAL AFFAIRS, THE UK VOLUNTARY REPORTING SCHEME FOR ENGINEERED NANOSCALE MATERIALS: SEVENTH QUARTERLY Report 1 (2008), *available at* http://www.defra.gov.uk/environment/nanotech/pdf/vrs-seventh-progress-report.pdf. From September 2006 to August 2008, there were only 11 submissions, with nine from the industry and two from academia. *Id.*

[18] *See* PANEL ON BIOLOGICAL ISSUES, *supra* note 11, at 29.

[19] *Id.* at 38.

[20] *See, e.g.*, NAT'L SCI. ADVISORY BOARD FOR BIOSECURITY, *supra* note 10, at 19.

[21] *See* PANEL ON BIOLOGICAL ISSUES, *supra* note 11, at 27.

[22] *See id.* at 40 (noting that local planning should involve human response needs, engagement of experts in the field, and existing surge capacity locations).

[23] *See* COMM. ON SCI. & TECH. FOR COUNTERING TERRORISM, NAT'L RESEARCH COUNCIL, MAKING THE NATION SAFER 130 (2002).

[24] *See* PANEL ON BIOLOGICAL ISSUES, *supra* note 11, at 42.