Nanotechnology – Not as Small as You Hope

Introduction

Our group was well aware that the University of Alberta in Edmonton is Canada's National Institute for Nanotechnology; being interested in the subject, we pursued the idea of sharing technologies, specifically nanotechnology, as an issue of local and global relevance.

Technology has always been a deciding factor in how powerful a nation is, as having access to technologies that other nations do not gives a decisive advantage to one nation. For example, the Industrial Revolution occurred in Britain in about 1760, which is sixty years before it occurred in the rest of Europe, giving Britain a decisive advantage over other European nations and allowing the British Empire to be a dominant global power. Sharing technology also results in faster development, as shown by international collaboration today.

Simply put, nanotechnology refers to "a technology executed on the scale of less than 100 nanometers" (Dictionary.com, 2013). Matter at the nano scale can behave differently than bulk matter, allowing for the innovation of new products. As nanotechnology is an up and coming field, there was no trouble gathering research information through the abundance of available articles. We found information on the issue of sharing nanotechnology from a variety of different perspectives so as to have a general understanding of the effects of nanotechnology. This was required for an effective examination of the possible ramifications of sharing these nanotechnologies.

Environmental

The University of Alberta is developing many nanotechnologies; the production and research of these new technologies unavoidably creates waste and nano particles that pose various other risks to the environment. The key concern about this 'nanopollution' is the bioaccumulation of nanoparticles in organisms with potentially deadly effects.

Nanoparticles enter the environment through the products they exist in. For example, nanoparticles that assist in blocking UV rays are in sunscreen and enter the environment whenever someone wearing sunscreen washes it off their bodies. Nanoparticles can be absorbed by organisms of the microbial food chain, and as the thousands of protozoa that consume these particles are consumed themselves, predators accumulate exponentially greater amounts of these nanoparticles in their bodies. As most of these particles are manmade, it is highly unlikely that those organisms would have a prepared defense for the presence of these particles. A research project conducted by John T. James, in which nanoparticles were sprayed into the lungs of mice, showed that carbon nanotubes in the mice's circulatory systems were engulfed by white blood cells which promptly died and formed scab-like patches in the blood stream. In addition, a study from Tottori University in Japan showed "that within a minute of entering a mouse's lungs, carbon nanoparticles had penetrated through tiny gaps between the surface cells and burrowed into capillaries"(Partain, 2009). Southern Methodist University toxicologist Eva Oberdrster conducted a study on captive large-mouth bass, where the fish were exposed to a dome-shaped nanoparticle called Carbon-60. Evidence was found that the particles were small enough to breach the blood-brain barrier, taking a path normally reserved for smell signals (Tompkins, 2004). Although it is important to note that none of these studies have been done of human subjects, the same health concerns apply as nanoparticles move very easily through an environment.

Nanopollution aside, nanotechnologies are being developed to address other environmental concerns. For example, technologies are being developed to increase the cleanliness of water and the availability of fuel.

“Carbon nanotubes – special molecules made of carbon atoms in a unique arrangement – allow liquids and gases to rapidly flow through, while the tiny pore size can block larger molecules, offering a cheaper way to remove salt from water” (Lawrence Livermore National Laboratory, 2010). This technology can be applied to desalinate water or other liquid based separations, leading to cheaper and more efficient filters that require less pressure to separate contaminants from the water. In addition to being in filters, adding boron to carbon nanotubes causes them to form in a sponge-like formation. “The material’s mechanical flexibility, magnetic properties, and strength” (Oak Ridge National Laboratory, 2012), along with the fact that it attracts carbon molecules, makes it an ideal technology to clean oil spills from water.

“Whatever the source, burning ethanol instead of gasoline reduces carbon emissions by more than 80%” (Lashinsky, Schwartz, 2006), yet in the past ethanol was labeled as an expensive solution to the energy crisis because it drives the prices of corn up for consumers. Genencor is a biotech company that has devised a way to use nanotechnology to create enzymes that break up the cellulose of the corn stalks and turn the biomass into ethanol. This cellulose ethanol poses less of a threat to the food supply and allows for more ethanol to be produced at lower prices. “Genencor says its enzymes have cut the cost of making gallon of ethanol from $5 five years ago to 20 cents today” (Lashinsky, Schwartz, 2006). As Alberta is a large provider of oil for North America, and a source of revenue for Canada, any technology that affects the energy industry, especially a technology that provides an alternative to oil, will have a tremendous economic impact on the local area.

Economic

There are so many possibilities for the future of nanotechnology; virtually every industry has the possibility of being affected by new discoveries. At the University of Alberta, Jillian Buriak and her team of researchers are using nanomaterials to develop solar cells that will be easy to use and accessible to everyone, because they will be “thin, plastic-based solar cells that can be sprayed or rolled, like paint or wallpaper” **(**Buriak, 2013). This technology will hugely affect the energy industry, as making solar energy more accessible to the general public will provide an alternative to our dependence on fossil fuels. In Alberta, the oil industry is a cornerstone of our society, and a big change in the energy industry will affect us greatly. As well, this technology could have equally huge global impacts. In developing countries a cheap, easily accessible source of electricity would change the lives of many people in outlying regions where this isn’t available. This is but one of a long list of technologies that will have economic impacts radiating across the globe: the Canadian government is involved in the development and regulation of nanotechnology in food, there are many advancements in building eco-friendly homes using nanomaterials, and there are many applications in construction, recreation, textiles, medicine, cosmetics, etc. Since many industries have the possibility to be affected by developments in nanotechnology, the future benefits of nanotechnology on our economy will be broad. New technologies will open new markets, and Lux Research estimates that the global market for goods incorporating nanotechnology will be $3.1T by 2015 (Sheremeta, 2010). These new markets will not only create many new jobs, but will also drive economic prosperity. Other benefits arising from the sharing of nanotechnology would be the improvements to sustainability. In Alberta, there are many issues surrounding our oil industry, such as its nonrenewable nature. Developments in nanotechnology such as affordable solar cells will create a sustainable economy.

Aside from all the possible benefits of the sharing of nanotechnology on the economy, there are also risks to consider. Nanomanufacturing, which is essentially the process of production of nanotechnologies, comes with it’s fair share of risks. For one, there is the possibility that there will be economic disruption that will be overall negative, specifically if technologies lead to the development of cheaper products. Having too many cheap products may upset the economy in ways that we cannot predict. As well, there is the possibility of early monopolies being formed due to the lack of regulation, the high cost of development, and the possibility of one company developing a technology faster than other companies. Finally, there is the possibility of a black market forming. The possible development of dangerous weapons and surveillance equipment (such as nano-sensors, nanobots and nanopoison) could lead to the growth of a black market of illegal nanotechnology products. The economic problem with a black market is the lack of involvement of the government, leading to loss of tax dollars from profitable technologies.

Social

There is the risk that with the development of many new technologies, instead of eliminating the disparity between the poor and the rich there will be a nano-divide. This term refers to the possibility of a gap forming between the rich and the poor because of the development of nanotechnology. In this scenario, the high cost of development of nanotechnology along with the skilled workforce of first world countries will limit the development of nanotechnology to rich countries. This will propel these countries ahead of poorer countries, widening the existing gap between rich and poor and essentially dividing the world. The extremely unequal distribution of and access to nanotechnological knowledge and products between developed countries and developing countries may be unfair and unjust depending on one’s view of social justice. The ideals of distributive justice state that equality is not necessary, and individual successes should be recognized. In the case of nanotechnology, equality would allow for the increased quality of life of millions of people by addressing millennium development goals by improving maternal health, combating HIV, AIDS and malaria, and providing clean water (Maclurcan, 2012). For this reason, justice as equality is the applicable perspective when discussing the nano divide. An open access policy is one way to diminish this nanotechnological discrepancy between developed and developing nations. By allowing free access to research materials, open access allows developing countries to learn about nanotechnology, and use existing research to quicken the pace of their own.

National Security

Advances in nanotechnology could potentially apply to every aspect of the armed forces: tiny computers may be built into weapons, uniforms and military vehicles; targeted chemical and biological warfare agents could be created; sensory microchips could be placed on the battlefield to detect these agents; micro-robots could be deployed for communications and combat (Altmann, 2008). These technologies have a nearly unlimited ability to protect a nation, however they have an equally unlimited ability to destroy one. When weapons technology such as this is created in one nation, the equilibrium of mutual security in the global community is disrupted, causing the type of tension that can lead to a technological arms race. Development of nuclear weapons in the Cold War created stress between nations. This historical example can be used to predict social implications of an arms race in modern society.

In his 2008 paper discussing the military applications of nanotechnology and the measures that must be taken to ensure national security (Altmann, 2008) , Jürgen Altmann suggests the prevention of the proliferation of military-relevant technologies and knowledge through preventive arms control (PAC) agreements, such as non-proliferation arms control agreements (NACAs). The paper presents the criteria of PAC in three points based on the necessity for further development of effective arms control and international law, the maintenance and improvement of military stability to avoid an arms race, and the protection of human lives. Altmann's analysis shows that *all* weaponized applications of nanotechnology will affect military stability and contribute to a technological arms race. This supports the conclusion that arms control regulations must be created *before* the commercialization of these technologies. In contrast, four professors from Arizona State University conclude that although preventive arms control regulations are necessary, "several aspects of [NACAs] limit their applicability as models for nanotechnology" (Abbott, Marchant, Sylvester, Gopalan, 2006). This conclusion is based on the observation that international agreements control only states and not non-state actors (such as transnational terrorist organizations); the authors point out that this is particularly distressing because these non-state actors are the most likely to use nanoweaponry maliciously. Although there are differing opinions on how exactly militarized nanotechnology should be regulated, experts generally agree that *preventive* arms control is the only route to complete national security and the safety of the citizens.

Conclusion

After assessing what these technologies actually do from different perspectives, the risks and benefits are easier to see. Methods of creating renewable energy sources and cleaning waste from the environment are promising technologies for any modern nation, however they come at the cost of releasing nanoparticles from these devices into the environment with unknown effects. Nanotechnology also has the potential to revolutionize our global and local economies through the development of new markets with new technologies and the increase in sustainability, but there is also the possibility of the formation of black markets, monopolies or unstable economies. In addition, the possibility of a nano-divide, combined with militarized nanotechnology's potential to cause an technological arms, means much consideration is necessary before deciding if international relations regarding nanotechnology will be beneficial.

Solution A

One solution we considered is to continue researching nanotechnology in Canada and other countries where it is already being developed, while not sharing it among nations that have yet to have access to these technologies until accurate data can be found to either support or condemn the sharing of nanotechnology internationally.

From an environmental perspective, a nation's environment could greatly benefit by abstaining from the use of nanotechnology, therefore effectively eliminating the risks caused by nanoparticles. However, while nanopollution is eliminated from that country's environmental hazard list, technologies that could potentially benefit their environment, such as water purification technologies, would not be available to them. A final environmental drawback is the possibility that the nations that retain access to these technologies may cause permanent environmental damage within their borders, and may spread pollution to neighboring nations.

From an economics perspective, a nation that already has access to nanotechnology but does not sell it could cause nanotechnology to be an expensive burden on the national economy, since the costs of research could overshadow the profits from export. These regulations could also cause nanotechnologies to become black market merchandise and therefore destabilize the economy of the nations that have nanotechnology as well as the nations that are prohibited from accessing it.

From a social perspective, nations that have access to nanotechnology will have a decisive military advantage compared to nations that do not have access, causing the aforementioned nano-divide. In addition, secretive behavior regarding highly dangerous weapons limits the ability of the international community to protect nations from aggressive military behavior. In this way, limited collaboration between nations about nanotechnology could increase tension in the global community.

Although limiting international sharing of nanotechnology may be beneficial to the global environment, this solution would be pretty difficult to regulate and there are some major possible problems that could arise, such as the social and economic separations between nations that have nanotechnology and the nations that do not have nanotechnology. As a result of this, we do not believe this is the best solution.

Solution B

Another solution is the sharing of all knowledge of nanotechnology, and nanotechnologies themselves, to minimize possible risks (Morrison, 2011). By sharing nanotechnologies with all nations, solutions to potential and real risks can be determined and implemented most efficiently. At the same time, this solution puts all shareholders at risk.

From an environmental perspective, this solution is good because it recognizes the fact that all technologies are potentially dangerous, yet research on the risks can happen at the same time as benefits are researched. In addition, international collaborative research increases the total intelligence of the field, therefore accelerating the development of risk management, as well as nanotechnological abilities. A problem with this solution is that technologies will be developed rapidly with collaboration, meaning that nanopollution will be magnified, putting additional stress on the environment.

This would be the best solution from an economic perspective because it would encourage the development of a variety of nanotechnologies through funding from international governments and local companies. This would allow government involvement in the regulation of research and development, so as to prevent a black market or monopolies from forming. International collaboration is practical, and evidence of this can be found in the NINT's past international endeavours, for example through a Researcher Exchange Program with Taiwan. Additionally, international collaboration with the WTO and other multinational corporations would be a good way to standardize regulations, preventing a nano-divide from developing. However, there is a chance that this excess regulation would be limiting on the revolutionary sharing of nanotechnology and as it could prevent great technologies from emerging. In "Big Money, Thinking Small", Michael Mauboussin and Kristen Bartholdson compare the future of nanotechnology to the major economic revolutions caused by electricity, the steam engine, and railroads (. Limiting those technologies too much would not have been beneficial, and similarly it is in our best economic interest to let nanotechnology research and development continue. to be supported internationally.

From a social perspective, collaborating with other nations to develop nanotechnologies will bring nations closer together and relieve international tensions, much like the International Space Station has already been able to do; relieving the tensions between nations caused by the Cold War. This way it will be difficult for one nation to obtain technology that is superior to other nations' technologies. However, if all nations have access to these nanotechnologies for military purposes, it increases the devastation that can be caused by global scale war.

As the benefits of this solution outweigh the detriments, it is recommended that nations pursue this solution and continue to share knowledge and technologies, much like they are already doing. In the process of coming to this solution, we read many articles on the benefits and dangers of nanotechnology and constructed an understanding of the potential for nanotechnology to change (or destroy) the world as we know it. This is a topic that today's youth, the leaders of tomorrow, need to be more educated about. If Michiharu Nakamura, executive vice president at Hitachi, was right when he said "nanotechnology is the base technology of an industrial revolution in the 21st century" (Nanotech Quote Collection, 2013), it is imperative that the 21st century youth gain an understanding of this technology in order to prepare for the future.

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