NANOTECHNOLOGY AND PUBLIC HEALTH

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Nanotechnology is developing very quickly, and Japan is in many respects leading the world in this convergence of nanoscale engineering techniques. The public health community in Japan must start to think about the public health impacts of nanotechnology over the next 20 years. The responsibility for the benefits and the harms of nanotechnology lies with government, with corporations and the business community, with scientists and specialists in all related fields, and with NPOs and the public. There are very many questions of public health which are not yet being asked about nanotechnology. If nanoparticles are to be used in cosmetics, food production and packaging, how will they react or interact with the human skin and organs? What chemical-toxic effects on life might there be from the nanoparticles in car tires and vehicle plastic mouldings when they are disposed of by incineration? Will they pass into the soil and groundwater and enter into the food-chain? It is now an urgent ethical demand, based on the precautionary principle, that Japan join the governments of the world to take an intergovernmental initiative to intervene in the further development, production and marketing of nanotechnological products with precautionary research and regulation.

Key words: Nanotechnology, nanoparticles, public health, precautionary principle, risk, global governance

I. Introduction

It is very important to consider the development of nanotechnology in the context of public health. Nanotechnology is developing very quickly, and Japan is in many respects leading the world in this convergence of several technologies involving engineering at the scale of 1 nm–100 nm (approximately the scale of small bacteria and viruses). It was Taniguchi Norio who in 1974 invented the word 'nanotechnology' for machining with a tolerance less than micrometer (less than one-millionth of a metre). It was Iijima Sumio of NEC, Tsukuba, who discovered in 1991 the carbon nanotubes that now have so many applications in nanotechnology. The development is so fast in Japan and the East Asian region, and in North America and Europe, that the issue of safety has not been researched. Very few studies of the impact of nanoparticles and nano-devices on the environment, animal and plant life, and the human body have been undertaken so far. In Japan at the moment there is no such research, although there are some hopes that it will be initiated soon. In Japan we have learned the lesson of environmental, ecological and human damage caused by rapid industrial and technological development, and we must now lead the world not only in the technical aspects but in the social, environmental and health aspects.

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II. Why such small size is important

The properties and behaviour of nanoparticles are not just a smaller scale version of the properties and behaviour of microparticles and microdevices. The properties and behaviour are sometimes completely different, quite unexpected and currently unpredictable. Quantum effects appear. As responsible scientists and technologists we have to change our way of thinking: smaller is more useful, but now smaller has new and poorly understood risks. Below 100 nm there are changes in the properties of a substance, such as:

- Greater strength
- Different colour
- More reactive
- More toxic (only because of size)
- Lighter
- More or less water-mobile
- More heat-resistant

• Higher translucence
• Better electrical conduction or insulation
• Easier trans-barrier movement in living tissue. (70 nm particles cross through alveolar surfaces of the lung, 50 nm cross through cells, 30 nm through the central nervous system, and there are no comprehensive data on <20 nm particle movement.)

It is because of some new properties that nanoscale products are very useful, but the same new properties present new risks. We should not ignore the risks, while only focussing on the benefits[1].

III. Different kinds of nanotechnologies

At least seven general areas of nanotechnological development can be identified:
• Bio-medical
• Neural-cognitive
• Informatics (Information, Communications, Entertainment Technology)
• Food and Cosmetics
• Materials (transport, aeronautics, space engineering)
• Security and military
• Environmental management, monitoring and remediation

Biomedical nanotechnology includes particles in burn dressings as well as nanodevices for drug delivery systems, for metabolic system monitoring, *in vivo* cell tracking, capsules carrying haemoglobin (under development), cancer-cell destroying quantum dots, and nano-engineered bone prostheses.

Food packaging (and even food) may soon contain nanoparticles. Nanotech cosmetics now include lipsticks and other beauty products, nano-encapsulated perfumes, and sun-screen creams (*BASF*, *L'Oreal*).

Nano-engineered materials include particles in paints, building materials, tennis rackets and balls, tires, car bodies (*Toyota*) and car plastic interiors (*Renault*) to give strength and lightness, stain-resistant and deodorant fabrics, and long-lasting paper.

Environmental nanotechnology includes sensors to test water, and various self-cleaning or toxin-repellent surfaces.

Convergent-nanotech (nanobiotech hybrids) currently under development include the use of DNA as a nanotech material and 'molecular motors' as models for biomedical 'nano-robots'.

IV. Social, environmental and health aspects

The public health community in Japan must start to think about the public health impact of nanotechnology over the next 20 years. The responsibility for the benefits and the harms of nanotechnology lies with government, with corporations and the business community, and with scientists and specialists in all related fields, as well as with NPOs.

In the case of nanotechnology we have to be careful not to repeat the public health mistakes of the past. To survive we have to think in a new way and put an emphasis on:
• International cooperation and global governance, not competition and secrecy.
• The precautionary approach (principles), not a fragmented 'risk assessment' approach.
• Public accountability across borders and generations.

Unfortunately, nanotech developments are running ahead of global ethical understanding and precautions, and many nanotech products are already on the market without having undergone adequate safety evaluation.

In Japan, the public are becoming increasingly concerned about the health aspects of industrial policy because of the problems created by the chemical, food, and drug industries. One legislative response of the Japanese Government has been the passing of the law on Product Liability in 1995. Before the law, and even after, there have been many cases of public health problems created by new industrial substances in Japan. Perhaps the most well known case in Japan, which was the subject of legal action, concerned the Kanemi PCB-contaminated (polychlorinated-biphenyl) oil syndrome in 1960s. In Japan, the use of PCBs began around 1950 and the production of PCBs began in 1954. 59000 tons of PCBs were produced in Japan from 1954 to 1972. An incident called the Kanemi Yusho Case occurred in 1968. Many people became victims in this case because of the rice oil contaminated with PCBs. From 1970 to 1972, the Japanese Ministry of International Trade and Industry banned the use of PCBs in open system facilities.

We must learn from such incidents. In many cases there were early warnings, but late action that allowed matters to become worse. Certainly, new chemical substances and new industrial processes, including those involving nano-engineering, require rigorous testing if nanoparticle health disasters are to be avoided.

Nanotechnology shows us that we must think in a new way, not only about the technical and scientific aspects but about the public health and environmental health aspects of industrial technology. We now need an interdisciplinary approach to the risk management of nano-technological developments on the basis of the 'precautionary principle'.

V. Current lack of safety evaluation

Vicki Colvin, Director of the Center for Biological and Environmental Nanotechnology at Rice University (Houston, USA), said about nanotechnology in 2003: "In a field with more than 12,000 citations a year, we were stunned to discover no prior research in developing nanomaterials risk assessment models and no toxicology studies devoted to synthetic nanomaterials"[2]. Nanotech products are being developed largely in a state of ignorance about their safety, and even in ignorance of how to evaluate their safety. As we have already mentioned, nanoparticle safety evaluation will have to operate on different scientific principles from existing particulate evaluation because the properties of a chemical substance change at the nanoscale.

Furthermore, it is not clearly understood which nanoparticles at which sizes can pass through which tissue and cell barriers. Titanium oxide nanoparticles already being used in American cosmetics showed that they varied between about 20 and 50 nanometres, and therefore many of these may be able to pass into the central nervous system, and cells and accumulate in organs[3]. Tests that have been done are of limited use because most involve experiments such as the three-month effects of direct injection into rodents' lungs of single-walled carbon tubes only. Various programmes of safety evaluation are now under way, and a few nanoparticle manufacturers are coating their particles or finding other means to minimize their potentially damaging effects.

In the USA the Environmental Protection Agency now has a $4-million research project to investigate what happens to manufactured nanomaterials in the environment and their impact on human health. Also, The USA's National Institute of Environmental Health Sciences' (NIEHS) National Toxicology Program has just started a $3-million project to study inhalation exposure effects of quantum dots, titanium dioxide and carbon nanotubes. There are similar research projects under way in the European Union. But nanoparticles are not the only potential risk. Other areas of danger are being entirely ignored, especially nano-biotechnology, which involve questions of compatibility between nano-engineered particles and the natural nanoscale functions and activities of living organisms.

There are very many questions of public health which are not yet being asked about nanotechnology. If nanoparticles are used in cosmetics, food production and packaging, how will they react or interact with the human skin and body? Will they move through the blood and eventually into the brain and other organs? What chemical-toxic effects on life might there be from the nanoparticles in car tires and vehicle plastic mouldings when they are disposed of by incineration? Will they pass into the soil and groundwater and enter into the food-chain?

VI. Some specific risks (recent toxic warnings)

The Canadian environmental NPO called ETC has listed some recent discoveries that should serve as early warnings[4]. Here is the list, which now includes some other references:

In 1997 it was found that titanium dioxide/zinc oxide nanoparticles in sunscreens cause free radicals in skin cells, damaging DNA[5]. In 2002 researchers from the Center for Biological and Environmental Nanotechnology (CBEN, Rice University, Houston) reported to the US EPA that engineered nanoparticles accumulate in the organs of laboratory animals and are taken up by cells[6]. In March 2003 researchers from NASA/Johnson Space Center reported that nanotubes in the lungs of rats produced more toxic responses than quartz dust[7]. In March 2003 the UK toxicopathologist Vyvyan Howard published the first scientific literature survey on nanoparticle toxicity, which concluded that the smaller the particle, the higher its likely toxicity and that nanoparticles have various routes into the body and across membranes such as the blood brain barrier[8]. In July 2003 *Nature* documented work by CBEN that showed fullerene 'buckyballs' can travel unhindered through the soil, entering the food chain through earthworms[9].

Studies by Gunter Oberdörster have shown that nanoparticles are able to move easily from the nasal passageway to the brain[10~12] and nanosafety researchers from the University of Leuven, Belgium, write in *Nature* that nanoparticles will require new toxicity tests[13]. Also in January 2004, at the first scientific conference on nanotoxicity (Nanotox 2004), Vyvyan Howard presented initial findings that gold nanoparticles can move across the placenta from mother to fetus[14]. Researchers have discovered that cadmium selenide nanoparticles (quantum dots) can break down in the human body, potentially causing cadmium poisoning[15~16].

In March 2004 Eva Oberdörster reported to an American Chemical Society meeting that fullerene 'buckyballs' cause brain damage after only 48 hrs in juvenile fish along with changes in gene function[17]. They also are toxic to small crustaceans (water fleas). Although buckyballs have not yet been incorporated into commercial products, they are currently being considered for applications in drug delivery, cosmetics, agricultural fertilisers, fuel cells and solar cells. A company in Japan called *Frontier Carbon* (a joint venture of *Mitsubishi Corporation* and *Mitsubishi Chemical*) is operating a facility with a production capacity of 40 metric tons per year and claims it has 300 buyers for its fullerenes[18].

At the annual meeting of the American Chemical Society in late March 2004, CBEN presented preliminary findings indicating that different kinds of nanoparticles do not flow in uniform ways in water; therefore there might be unpredictable groundwater consequences of nanoparticles in the environment[19].

Specialists in the field of public, occupational and environmental health must research the possible impacts of nanotechnology in Japan so that we are in line with international thinking and legal risks and requirements. The international law of corporate responsibility has developed greatly in the last decade or so, in the wake of environmental and pharmaceutical disasters. Insurance companies are fully aware of these legal developments. The second largest re-insurance company in the world *Swiss Re* has warned that the unknown and unpredictable risks associated with nanotoxicity or nanopollution could make nanotechnology un-insurable[20].

VII. Precautionary principle: early warnings, late action

The precautionary principle is now being accepted by national, regional and international regulatory agencies all over the world. The precautionary principle is this: if a course of action entails the possibility of seriously harmful, even irreversible, consequences, then it should not be undertaken, even if there is no current proof (scientific evidence) that the course of action will have such consequences. Further publicly open research should be first performed.

The precautionary principle should be applied when a decision (to do something or not to do something) . . .

1) could have serious harmful consequences for many people.

2) could have irreversible (non-reversible) harmful consequences.

3) takes place in a situation of uncertainty or ignorance.

4) could have long-term or long-delayed consequences.

5) has long term financial costs (of the consequences of decision) that could be very much greater than the cost of the preventive measure.

This is quite a different approach from the existing principle that 'If there is no evidence that X is harmful, we may do X'. The precautionary principle is the ethical outcome of a century of environmental and public health disasters in UK, USA, Japan and elsewhere[21]. It should now be applied to nanotechnology, before it is too late. It took 70 years for warnings about chlorofluorocarbons (CFCs) in the atmosphere to be listened to, 73 years for PCBs, and 33 years for asbestos—and then many more years before real action was taken. In the case of nanotechnological pollution and ill-effects, it is possible that without regulation the damage could be widespread, irreversible and continue its effects far into the future. However, the main obstacle to early listening and early action is unregulated economic competition.

Conclusion: global governance

It is now an urgent ethical demand, based on the precautionary principle, that Japan join the governments of the world to take an intergovernmental initiative to intervene in the further development, production and marketing of nanotechnological products with precautionary research and regulation[22]. There should now be in place an intergovernmental panel, involving consultation with NPOs and consumers, to regulate nanotechnology in all its forms on the basis of the scientific knowledge necessary to balance the potential benefits and harms to humanity. If nanotechnology is to truly benefit humanity then we must all proceed with caution and cooperation.

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