Current Status of Nanotechnology Consumer Products and Nano-Safety Issues

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ABSTRACT

This manuscript is divided into 2 parts to present a review on nanotechnology consumer products ('Nanotech' products) and a current status on 'Nano-Safety' issue. The first part focuses on up-to-date information of 'Nanotech' products that were already on the market as reported by Project on Emerging Nanotechnologies of the Woodrow Wilson International Center for Scholars. There are more than 500 products for a variety of applications, among which health and fitness products are the largest category. The products in this group consist of clothing, cosmetics and sunscreens. Silver is the most commonly used material, followed by carbon in the forms of either nanotubes or fullerenes, and silica, respectively. It is reported that the number of the 'Nanotech' products significantly increased about 124% within the past 14 months. Companies based in the United States share more than 50% of the products while, approximately, a quarter is shared by companies in East Asia. The rest are for Europe and other countries as well as Thailand.

In the second part, studies concerning Nano-Safety have been evaluated. A preliminary study has been made exclusively to nanoparticles and nanotubes. There are currently over 100,000 scientific journal articles related to nanoparticles or nanotubes. However, it was found that less than 1% of these articles are focusing on the safety of these nanomaterials. In addition, some articles discuss toxicity of various types of materials such as single- or multi-walled carbon nanotubes, copper nanoparticles or silica nanoparticles.

Key words: Nanotechnology, Consumer Products, Nano-Safety, Review

INTRODUCTION

Nanotechnology covers wide range of areas, including tools, techniques and potential applications. One of the definitions, according to the Royal Society and the Royal Academy of Engineering, is that "*nanotechnologies are design, characterisation, production and application of structures, devices and systems by controlling shape and size at nanometer scale*" (Royal Society and Royal Academy of Engineering, 2004). This manuscript is divided into 2 parts to present a review on nanotechnology consumer products ('Nanotech' products) and a current status

on 'Nano-Safety' issues.

Current status of nanotechnology consumer products

At present, information of nanotechnology consumer products that were already on the market are listed in the inventory compiled by Project on Emerging Nanotechnologies (2005). There are more than 500 'nanotech' consumer products for a while range of applications, among which health and fitness products are the largest category. Food and beverage come secondly, followed by home and garden category. Other main categories are cross cutting, electronics and computers, automotive, appliances and goods for children. The numbers of products that are available in each category are illustrated in Figure 1.

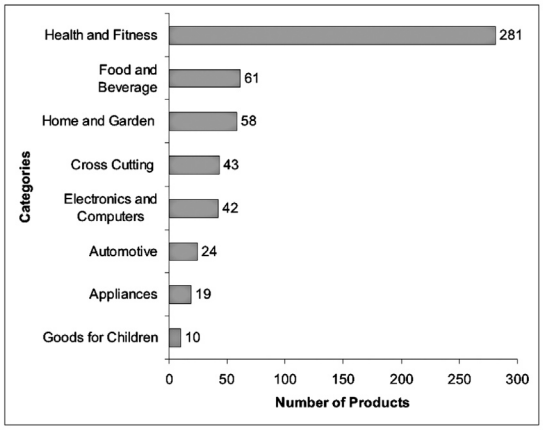

Figure 1. The number of 'nanotech' Consumer products classified by main categories.

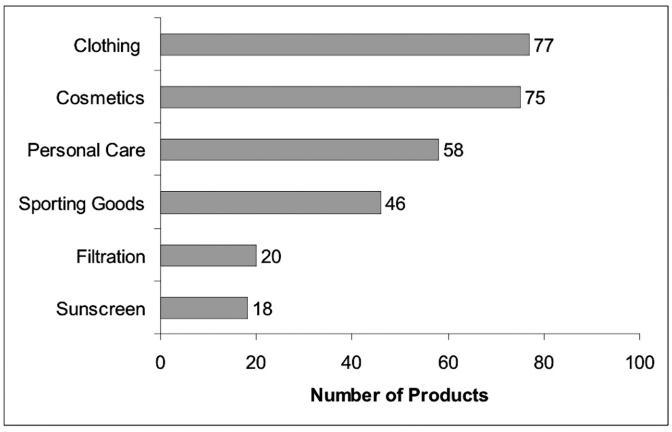

Figure 2. The number of 'nanotech' consumer products in health and fitness category.

In the health and fitness category which is more than 50% of the total products reported at present, clothing and cosmetics are the most popular sub-categories. Figure 2 shows various sub-categories of the health and fitness group, including personal care, sporting goods, filtration and sunscreen.

Figure 3 presents number of products classified by types of materials. Silver is the most commonly used material, followed by carbon in the forms of either nanotubes or fullerenes. Another regularly used materials group is metal oxide which comprises silicon dioxide (SiO_2), titanium dioxide (TiO_2) and zinc oxide (ZnO). Metallic gold nanoparticles are also employed in 'nanotech' consumer products.

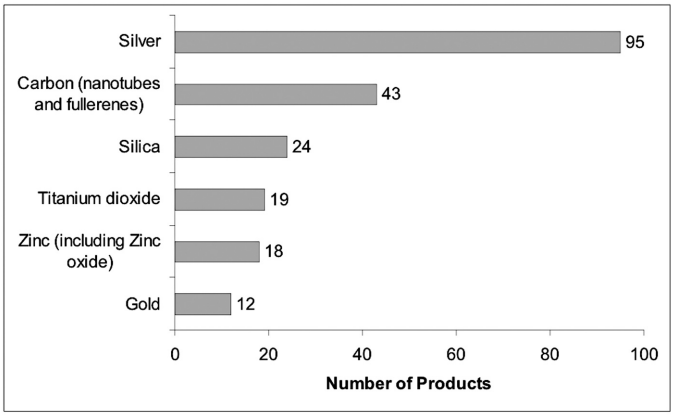

Figure 3. Number of 'nanotech' consumer products sorted by types of materials.

It is reported that the number of 'nanotech' consumer products significantly increased about 124% within 14 months (from March 2006 to May 2007). Detail of the number of products is presented in Figure 4.

In addition, it is reported that companies based in the United States share more than 50% of the total products, while, approximately, a quarter is shared by companies in East Asia, including Japan, China, Taiwan and Korea. The rest are Europe and other countries as well as Thailand. The diagram of the share market in the world is shown in Figure 5.

In Thailand, the National Innovation Agency organised a seminar "Innovation business in nanotechnology" in July 2007 which brought researcher, academia and industries together. This can be implied that more products will come out to the market in Thailand, excluding the products that were already imported from other countries. Therefore, a question has been raised whether these nanotechnology products are safe or not.

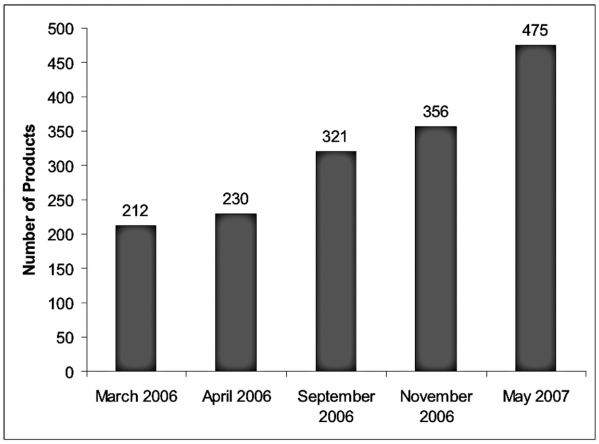

Figure 4. An enhancement of the number of 'nanotech' consumer products from March 2006 to May 2007.

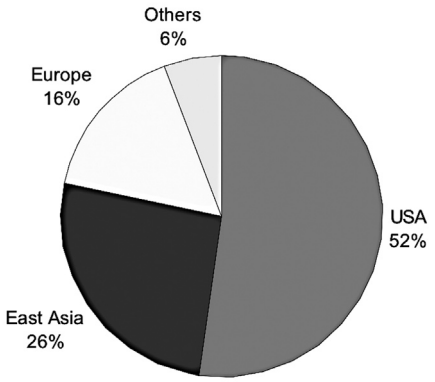

Figure 5. Market share of 'nanotech' consumer products classified by region.

Nano-safety issues

In this manuscript, "Nano-Safety" issues concern safety for 3 groups of people. Firstly, safety is concerned for researchers who conduct laboratory work in small scale in research institutes or in the universities. Secondly, safety is concerned for workers in industrial sectors fabricating nanotechnology products in a large scale. Lastly, concern of safety is focused to consumers who pay for the products and use them. Besides, safety to animals, plants and the environment should not be neglected.

Table 1. Relationship particle size with number of particles and surface area, adapted from Oberdoster et al., 2005.

Particle Diameter (nm)	Number of Particles (per cm^3)	Particle Surface Area ($\mu m^2/cm^3$)
5	153,000,000	12,000
20	2,400,000	3,016
250	1,200,000	240
5,000	0.15	12

Table 1 shows that the substantially high number of nanoparticles per given mass will probably be important for a toxicological point of view, especially when these particles interact with cells. Similarly, the high value of surface area will also be significant.

It is generally known that nanomaterials are materials that have at least one dimension at the nanoscale i.e. less than 100 nanometer. The properties of these materials differ considerably from their bulk properties. The preliminary study, as presented in this manuscript, concentrated mainly in nanoparticles and nanotubes. At present, there are more than 100,000 scientific journal articles related to nanoparticles and nanotubes. However, it was found that less than 1% of these articles are focusing on the safety of the nanomaterials. The number of articles, searched from the ISI Web of Science database, using nanoparticles and nanotubes as keywords in December 2006 and in May 2007 increased 12% and 11%, respectively. When keywords nano* and safety were used, the number of articles increased 17% within this 6 months. The results is shown in Figure 6. Moreover, about 1300 articles were found when nano* and toxicity were used to search for related information, as illustrated in Figure 7.

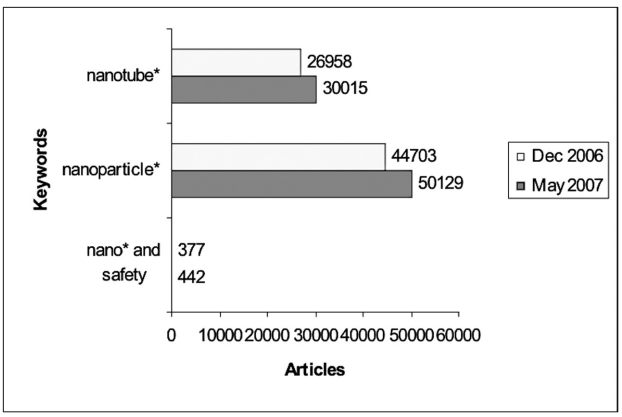

Figure 6. Comparison of various search terms for scientific articles in the database between December 2006 and May 2007.

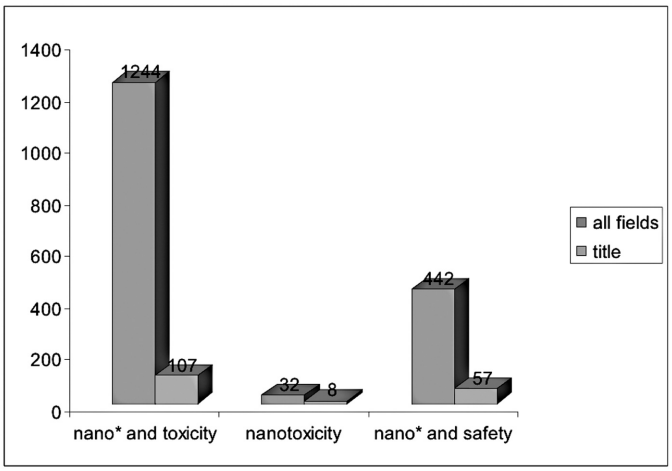

Figure 7. Results of various search terms from ISI web of science database, evaluated in May 2007.

While searching for information through internet, it was found that there are 3,966 US Patent since 1985 that related to nanotechnology and 1,408 US Trademarks with "nano" in them (Lux Research Report, 2006) In response to the emerging technology, the nanotechnology, the Royal Society and the Royal Academy of Engineering published a report entitled "Nanoscience and nanotechnologies: opportunities and uncertainties". The report recommended that nanoparticles and nanotubes should be treated as new chemicals from a view point of their risks (Royal Society and Royal Academy of Engineering, 2004). In addition, manufactured nanoparticles used in consumer products should be recorded in their ingredients lists and the regulatory of consumer products containing nanoparticles should be reviewed. Following the Royal Society and the Royal Academy of Engineering's report, the Institute of Occupational Medicine published 2 more reports that concern about safety issues. The two reports are "Nanoparticles: An occupational hygiene review" (2004) and "A scoping study to identify hazard data needs for addressing the risks presented by nanoparticles and nanotubes" (2005).

In April 2005, the Project on Emerging Nanotechnologies (PEN) was established as a partnership between the Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts (Project on Emerging Nanotechnologies, Online). The main objective of the project is to ensure that as nanotechnologies continue, possible risks are minimised, public and consumer engagement remains strong, and the potential benefits of these technologies are recognised. One of the PEN reports, entitled "Nanotechnology: A Research Strategy for Addressing Risks", was released in July 2006. It prioritises research area needs in order to evaluate risk associating with nanotechnologies. Immediate research needs are, such as, sources of exposure, exposure routes and exposure measurement methods. This PEN report also states early investment in medium-term and long term-research needs, including risk assessment, life cycle analysis, computational toxicology, nanomaterials release into the environment and ecotoxicology. Moreover,

some recommendations from the report are, for example, 1) alteration should be made in risk research responsibility within the federal government, 2) sufficient grant should be given for highly relevant risk research, and 3) a short-term strategic research plan should be developed and implement.

We have heard the word "nanotechnology" for several years. It has potential applications in many areas, however, very little is known about their toxicity, risk and impact to an environment or a society. Recently, some research works have been done to study the toxicity of nanoparticles or nanotubes which could possibly enter human body by breathing, eating or through skin. The toxicological study showed that these nanomaterials could create toxicity to liver, kidney or spleen (Chen et al., 2006; Muller et al., 2005; Lam et al., 2004).

It is interesting to point out that the effect of manufactured nanomaterials cannot be predicted or derived from the known toxicity of the bulk materials. Carbon nanomaterials, in the forms of fullerences (C60), nanofibers, nanotubes, and others, are one of the most commonly used in nanotechnology consumer products. Recently, a special issue of the journal "Carbon"compiles the research works in the field of nanotoxicology with a special focus in carbon nanomaterials (Hurt, 2006). These carbon nanomaterials can enter human body through skin, by eating, inhalation or injection i.e. in a similar way as the exposure of chemical substances to human body. Not only that these nanomaterials may affect the body, they may also possibly affect microorganisms, plants or animals if released into the environment.

International Organisation for Standards (ISO), the network of standardization organization from 157 countries, launched ISO Technical Committee 229 (ISO TC 229) in November 2005. The ISO TC 229 is chaired by representative of British Standard Institute. The committee has 3 working groups:

1) Working Group on Terminology and Nomenclature, chaired by Canada

2) Working Group on Metrology and Characterisation, chaired by Japan

3) Working group on Health, Safety, and the Environment, chaired by the U.S.

In September 2006, Organisation for Economic Co-operation and Development (OECD) also established "Working Party on Manufactured Nanomaterials" (WPMN) under chemical committee. This working party organised occasionally meeting in order to exchange information and create internationally network. The working party composed of 6 steering groups which are:

SG1: Development of research database

SG2: Environment, health and safety (EHS) research strategy on manufactured nanomaterials

SG3: Safety testing of a set of representative manufactured nanomaterials

SG4: Manufactured nanomaterials test guidelines

SG5: Co-operation on voluntary schemes and prevention

SG6: Co-operation on risk assessment and exposure measurement

This two examples show that it is now a globally concern on the safety of manufactured nanomaterials to human and to the environment. Figure 8. presents a diagram of Nano-Safety Initiatives, adapted from a presentation given by Dr.

Lerson Tanasukarn in August, 2007 at Thailand Research Fund.

For Nano-Safety issues in Thailand, it is recommended (Tanasukarn, 2007) to, firstly, monitor open sources for new development. Secondly, to organise and circulate nanosafety information, especially for the manufacturers and consumers. Thirdly, to conduct nanosafety studies, including toxicity, risks, and fate. Fourthly, to establish a national comprehensive nanoafety programme. Finally, to continually participate in international forum, particularly in OECD and ISO.

In conclusion, it is necessary to note that in order to achieve a successful research, effort has to be made by collaboration and in a constructive way.

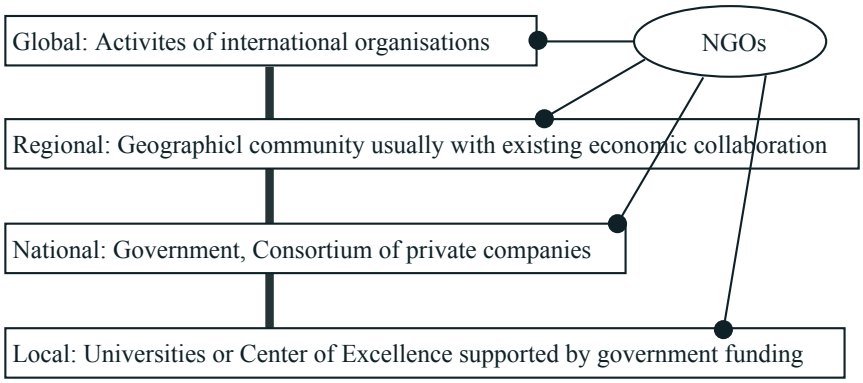

Figure 8. Diagram of nanosafety initiatives, adapted from Dr. Lerson's presentation.

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