VIETNAM ENVIRONMENT ADMINISTRATION
POLLUTION CONTROL DEPARTMENT

REPORT ON

Assessment of current state and trend of research and application of nanotechnology and nanosafety in Vietnam

Hanoi, 2015

CONTENT

ABBREVIATIONS

CNTs	Materials carbon nanotubes
HCMC	Ho Chi Minh City
IWAMSN	International Workshop on Advanced Materials Science and Nanotechnology
LED	Light Emitting Diodes
MWCNTs	Multi-wall Carbon Nanotubes
NAFOSTED	National Foundation for Science and Technology Development issued by Ministry of Science and Technology
NANOMATA	Nano-Materials, Technology and Applications
NIHE	National Institute of Hygiene and Epidemiology
PPMS	Physical Property Measuring System
SAICM	Strategic Approach to International Chemicals Management
SEM	Scanning Electron Microscope
SWCNTs	Single Wall Carbon Nanotubes
TEM	Transferred Electron Microscope
VNU	Vietnam National University

INTRODUCTION

Nanotechnology plays an innovating role in different areas from research to life science. This modern science conveys revolutions on sustainable developments of high technological industries by revealing an excellent chance to resolve the problem of a lack of raw materials. Researching of synthesis and applications of nano-materials in Vietnam has been undertaken for nearly 20 years. Later, in the last few years, there are more and more applications interesting Vietnamese researchers; such as new energy resources, catalytic applications, and sustainable treatment.

In 2012, in a speech, Dr. Prof. Nguyen Hoang Luong (VNU-Hanoi University of Science) said: "If fundamental researches of nanomaterials only convey opportunities for their applications then researching their applicability plays most important role for the development of nanotechnology in life science and commercial industries". In the last few years, applicability researches on nanomaterials are of the most remarkable topic in domestic research institutes. It is noticed that some research results could provide commercialized product for everyday life, for example viral DNA separation KIT (project No. 2/2010/HD-NCCBUD) or new type of water filter system from Prof. Tran Hong Con (Department of Chemistry, VNU-Hanoi University of Science). However, despite the innovation in research, there is very little domestic research results found in commercialized industries. To solve this problem, a prepared policy is needed in order to bring these new high technology products to market systematically and sustainably.

Before issuing a safe, sustainable systematic legal framework, it is necessary to evaluate the developing ability, applicability and influence of nanomaterials in general public. The evaluation would provide an overview of the present conditions and integration of nanotechnology in Vietnam. This assessment also initiates a helpful system for bringing nanotechnology products to public.

I. Definition and demand of nanotechnology development

Nanomaterial means a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm-100 nm.

As the definition of Prof. Norio Taniguchi – former professor of Tokyo University, nanotechnology is a science that works on the design, synthesis, analysis and application of the materials, devices and/or structures at nanometer scale (10^{-9} m scale).

There are two methods commonly used to make nanomaterials. The first approach is "bottom up": namely the use of synthetic molecular method, colloidal chemistry, polymer science, and related fields to assemble atomic units or molecules with together to form nanoscale structures. This approach is still relatively new, is increasingly attracting the attention of many research groups in the world and requires modern equipment. Compared to physical methods (top down) was commercialized in industrial applications to produce nanostructures, chemical methods are dominant for conducting simple methods and possibilities forms obtained nanostructures have better morphology and high uniformity. The second method is the "top down", ie derived from the large sizes, especially small micrometer, then reduce the size characteristics of nanoscale materials down. The products manufactured in this way can adjust pretty good size with physical characteristics very well and often use physical methods photolithography overseas, accompanied by ion beam, the beam, the electron beam and can be made of materials with the size of 50 nm.

The types of nanostructures can be divided into groups based on size, function, their structure. Here we consider the issue of size by measuring some kind nanostructures, divided into groups based on the methods by which they are created.

The molecules (1-6 nm): The most complex nanostructures molecules. An important task of chemistry is how to put atoms inside molecules or structures are open with atomic precision. Art chemical synthesis, particularly synthesis of organic molecules and organometallic, is one of the most complex issues of science.

Contacts glue, small crystals, aggregation (1-100nm): Chemical glue and small aggregates (nanocrystals, micelles, small polymer particles) have a long history, but only recently developed into nanoscience. The nanoscale objects are always created difficulties when working with them: they can not be identified by molecular methods; they are too small to see with the naked eye; and they are often not uniform in size and nature.

In addition to the nano-structured materials are divided by function: Electrical, Optical, from; or divided according to their structure.

More information on nanomaterials and nanotechnology is presented in the Annex I.

II. Current research and application state of nanotechnology

1. Current state of research

a. State of research in domestic research institutes

- Research directions

In a conference about worldwide development issues in the Netherlands in 2012, five problems were considered to be the most pressing. They are: Energy, Water, Environment, Health and Food, respectively. Considering the attention, nanotechnology is now focusing research on these problems, and so do the Vietnamese scientists.

We take account on the statistic of researching probes from two international conferences: International Workshop on Advanced Materials Science and Nanotechnology (IWAMSN- Halong, Vietnam 2014) and International Symposium on Nano-Materials, Technology and Applications (NANOMATA – Hanoi, Vietnam 2014). There were nearly 420 scientists from 13 countries taking part in the IWAMSN and discussing energy, environment, food and medicinal applications. Scientists from Vietnam National University and from Vietnamese Academy of Science and Technology were interested in the problems of new sustainable energy and bio-medicine applications of nanomaterials. It was discovered that about 8% of scientists from the NANOMATA and 10% from the IWAMSN are scientists from abroad. They were mostly from Japan and Korea. Nearly 1% from the IWAMSN participants were from Europe and America.

Figure 2.1 gives the statistic about the research directions that is collected from the above conferences. Besides the internationalization of research, the high impact of energy and environment-focused investigation shows that our scientists are conveniently following the worldwide research direction. There are 61% of publications from the NANOMATA and 44% of publications from IWAMSN focus on new fundamental studies of nanomaterials. There are 18% of results from NANOMATA and 12% from IWAMSN based on the investigations of sustainable energy. The proportions of environmental treatment from these two conferences are 11% for the NANOMATA and 7% for the IWAMSN; of the bio-medicine applications are 5% for the NANOMATA and 20% for the IWAMSN, respectively.

National scientific developing plan for the period from 2015 to 2020 toward 2030 has assigned to be focused on green energy, food, environment and the development of East Economic Corridor. It is reflected on the percentage of green energy researches taking part on the conference's' energy section. There are 22 of 32 publications from the NANOMATA and 37 of 43 publications from the IWAMSN relating to green sustainable energy. Besides, there are not as much results studying about the water resource, which is consequence of the country's geopolitical position. It is also experienced that there are very small amount of solution for waste treatment from the environmental section; in comparison to the number of the research focusing on hazardous material detections.

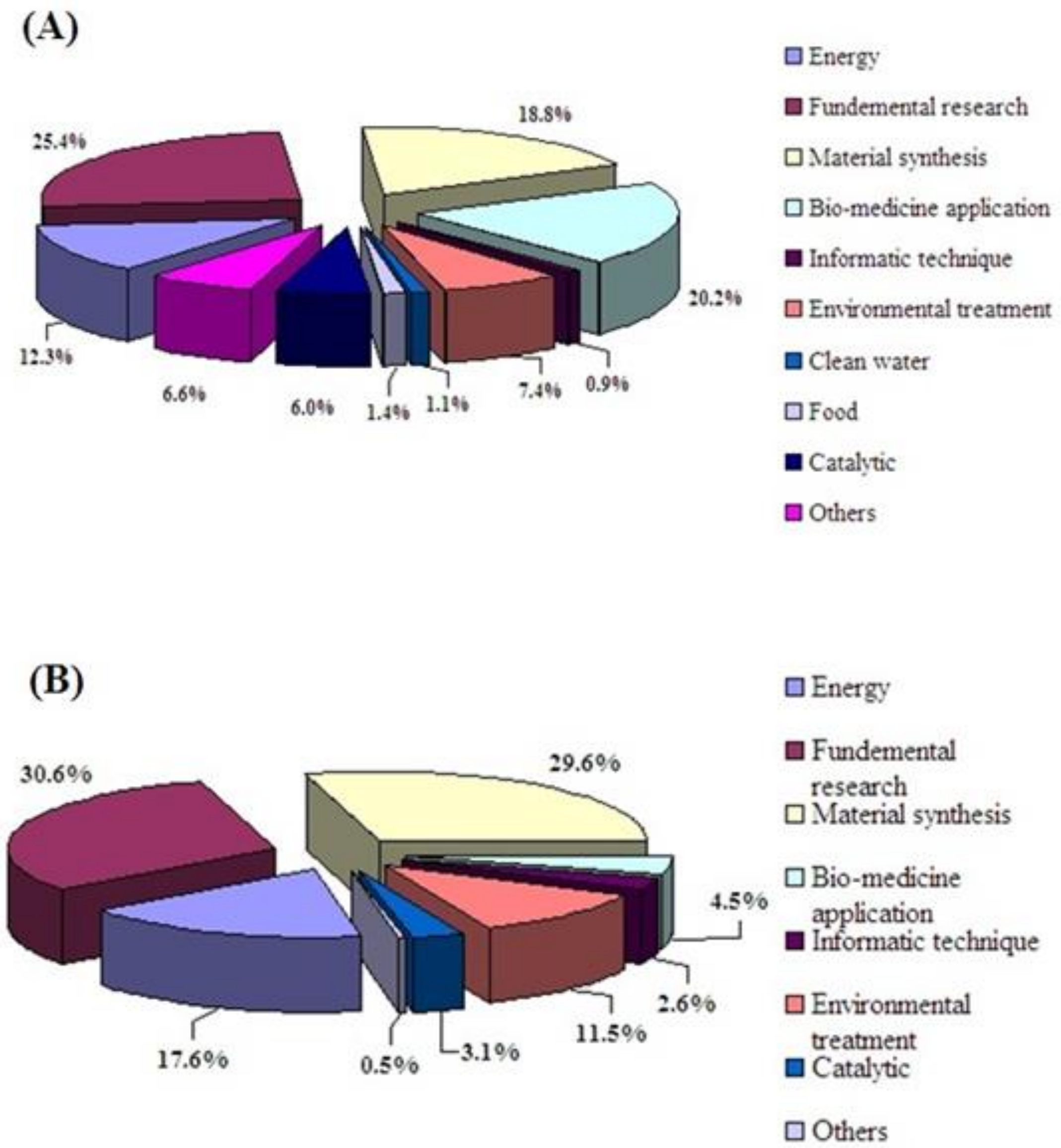


Figure 2.1. *Statistic of research results published at two international conferences in 2015 at (A) NANOMATA – Hanoi and at (B) IWAMSN – Ha Long 2014.*

In parallel with the research direction evaluation in nanotechnology, it is necessary to estimate the role of nanoscience in domestic current research topics. We use the data base of the National Foundation for Science and Technology Development issued by Ministry of Science and Technology (NAFOSTED) from 2009 to recent. Considering only the projects that contain studies about materials and their applications, there are 21 projects which were funded by the NAFOSTED. Belonging to these projects, the applications focused on biological and environmental applications. In 2012, 33 of 40 Physics projects and 13 of 44 Chemistry projects were funded for investigation of nanotechnology. This project focused on the synthesis, fundamental properties and applicability of new type nanomaterials, of which the number of applicability investigating projects increased. There were 5 projects working on inventing new sustainable energy, 12 projects on biomedical application, 6 projects on environmental treatment and 1 project on catalytic applications, respectively. Up to 2014, the increase of nanotechnological projects's portion was found. There 36 of 44 Physics projects and 14 of 26 Chemical projects concentrated on nanotechnology. Belong to those, there were 29 projects based on research of applicability.

Figure 2.2. illustrates proportions of the project numbers that nanotechnology takes part in from 2009-2011 period, in 2012 and 2014, respectively (blue one) and the proportions of applicability research (red one). The increase of the projects' number and proportion shows that nanotechnology is/has been creating a potential position in domestic scientific society. Besides, there are more application directions found and followed, such as biomedicine, environment, catalytic, and mechanics, which illustrates the potential of nanotechnology in research institutes.

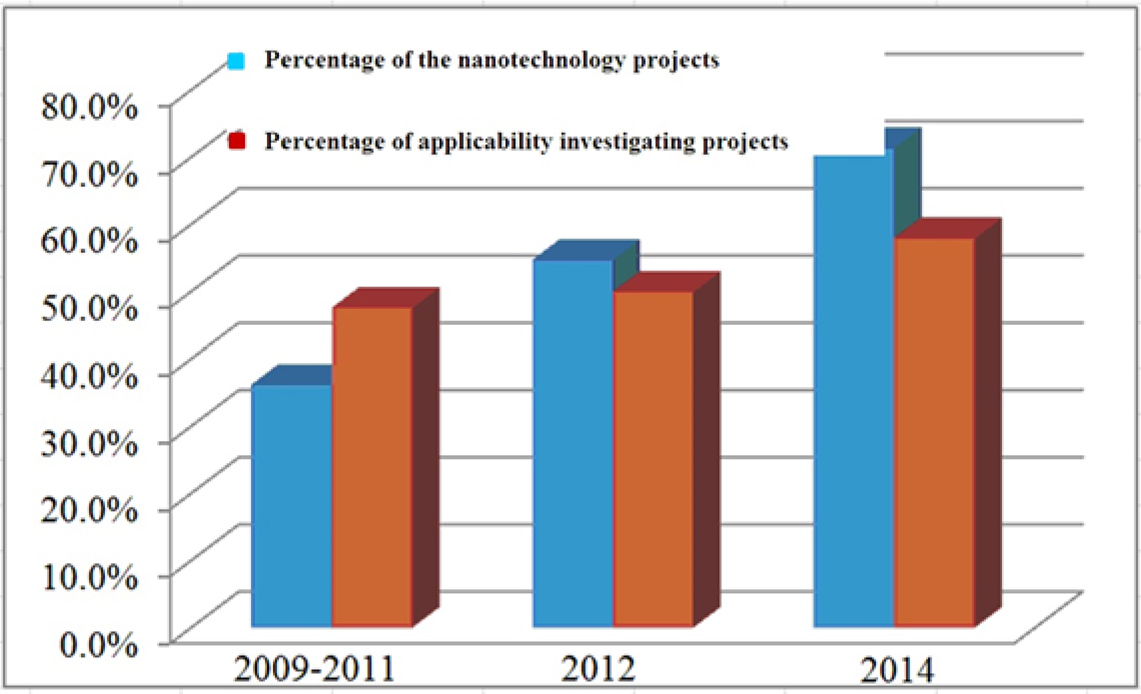


Figure 2.2. *Proportions of the project numbers that nanotechnology takes part in from 2009-2011 period, in 2012 and 2014, respectively (blue one) and the proportions of applicability researching (red one).*

- Current state of applications in public

In recent years, number of the commercialized products started by research projects is increasing. However, some project products reach the standard but still need to take a final step to be commercialized. However, adequate conditions are needed in order to take this step to bring them to market. They are public acceptability, systematic supporting legal framework for nanotechnological products and, most importantly, the commitment of entrepreneurs. Despite that, we can evaluate the potential of nanotechnology applicability from current research directions. The following table lists some research directions of some famous research institute in Vietnam:

No	Institute	Address	List of research directions
1	Institute of Physics Institute of Materials Science, Vietnamese Academy of Science and Technology	18 Hoang Quoc Viet, Cau Giay, Hanoi	- Application of nanomaterials in telecommunication, radar communication. - Application of nanotechnology in developing sustainable energy. - Application of nanotechnology in environment treatment; - Application of nanotechnology in biomedicine and biotechnology; - Application of nanotechnology in new construction materials. - Application of catalytic properties of nanomaterials in new type of energy and in chemistry. - Fundamental investigations of new nanomaterials.
2	International Training Institute for Materials Science, Hanoi University of Science and Technology	No 1, Dai Co Viet, Hai Ba Trung, Hanoi	- Application of nanotechnology in environment treatment, biomedicine and biotechnology; - Fabrication of nano-thin-film and application in bio-sensors, light emitting diode and LED TV screen. - Application of nanomaterials in telecommunication.
3	Advanced Institute for Science and Technology, Hanoi University of Science and Technology	No 1, Dai Co Viet, Hai Ba Trung, Hanoi	- Synthesis and fabrication of nanomaterials and their investigations. - Long term research projects about nanomaterials containing their synthesis, fundamental investigation. Investigation of new method for nanomaterials fabrication. - Fabrication of nanoscale devices and investigating their advanced properties. - Investigating the applicability of nanomaterials and starting up the technology transfer based on

No	Institute	Address	List of research directions
			nanotechnology to energy industry, environment, medicine, electronics and communications.
4	VNU – Hanoi University of Technology.	144 Xuan Thuy, Cau Giay, Hanoi.	- Employing magnetic, piezomagnetic and magnetorestric nanomaterials in Earth magnet sensing and further applications. - Investigation of microelectromechanical system (MEMS) for biosensing. - Fabrication of thin-films for solar cell applications and for creating smart absorption materials.
5	VNU – Hanoi National university of Education.	136 Xuan Thuy, Cau Giay, Hanoi.	- Light sensing thin-films and their advanced properties. - Nutrient elements in nanoscale. - Applications of nanomaterials for environmental treatment, bio-sensing, chemical catalytic.
6	National Center for Technological Progress	25 Le Thanh Tong, Hoan Kiem, Hanoi	- Investigation of microelectromechanical system (MEMS) for sensing. - Application of nanotechnology in photoelectronic and electronic devices. - Application of nanotechnology in telecommunication and sustainable energy. - Application of nanotechnology in environment safety. - Application of nanotechnology for visualization technology.
7	VNU – Hanoi University of Science.	334 Nguyen Trai, Thanh Xuan, Hanoi.	- Synthesis and application of metal, fluorescent semiconductor and magnetic nanoparticles in biomedicince, environment and in sustainable energy. - Fabrication of thin-films for solar cell applications and gas-sensors. - Synthesis and investigation of

No	Institute	Address	List of research directions
			advanced properties of nanomaterials in order to apply in healthcare. - Synthesis and fabrication nanoscale nanomaterials and their investigations. - Investigation of photocatalytics of nanomaterials.
8	Laboratory for Nanotechnology, Vietnam National University – Ho Chi Minh City.	Linh Trung, Thu Duc, Ho Chi Minh City.	- High power LED lamps for public illumination. - Fabrication of nano-biosensor for diabetes and cancer diagnosis and therapeutic. - Silic thin film technological solar cell for green energy supplication. - Radio Frequency Identification (RFID) cards for storage management, bus and automatic administration. - Synthesis and application of nanomaterials for antimicrobial purposes, environment safety and for energy saving. - Inkjet process and ink on metal for fabrication of nanodevices.

b. State of research in enterprises

Due to the Decision No. 592/QD-TTg of the Prime Minister about supporting technology enterprises issued in May 22nd, 2012 and the Resolution No. 20-NQ/TW issued on 6th Central Government Meeting in December 31st, 2012, producing enterprises are requested to establish artificial intelligence into production.

In order to improve the intelligence into production, an individual laboratory is usually required. While the basic equipment are relatively reasonable i.e. ventilation system, magnetic stirring, centrifugation, digital balances; the equipment for analysis are exclusive. The suitable equipment needed for the analysis are usually transferred electron microscope (TEM), scanning electron microscope (SEM), X-ray diffractometer (XRD), and physical property measuring system (PPMS). As the knowledge of the authors, some enterprises are paying for their investigation by purchasing such as equipment. For example SAMSUNG Vietnam newly established a

Nano-SEM (Nano-Scanning Electron Microscope) model NOVA NPE 119 for device production; CANON Vietnam or VICEM Haiphong purchased high resolution XRD (unknown model) for analyzing the crystal phases within the products. However, these analysis equipment are only available through national fund or huge business groups. At higher level of developing the knowledge into the production, modern laboratories are used to be required - such as clean room for device production (already established by SAMSUNG Vietnam and CANON Vietnam).

Besides, instead of establishing a new campus for investigation of nanomaterial application, enterprises could cooperate with scientists and research institutes in order to utilize their equipment. To do this, there is legal policy needed for this cooperation type, which is currently not comment in our country.

2. Current commercialization of nanotechnological products

Base on the review of Strategic Approach to International Chemicals Management (SAICM), with their very interesting properties, nanomaterials and nanotechnology are attractive to be applied in various commercial fields. They are used in mechanically hardening of concrete, building walls, ceramics, animé, rubber products. They would provide the higher conductivity for high speed printing ink, high speed chips. Sometime, they are employed in healthcare or cosmetic industry for skin care and lightening, such as zinc oxide, nanostructure carbon, silicon dioxide, gold nanoparticles. Thin-film semiconductors are the most effectively applied in public life. They are used for designing a lot of type solar cell for sustainable energy support or would take part in public lightening in order to saving energy in light emitting diodes (LEDs). In higher rank of applications, nanomaterials play very important role in bio-molecular science: in bio-imaging diagnostic applications, in commercialized DNA separation KIT, and in amount of biological therapies. Furthermore, nanotechnology is also present in agriculture in some fertilizer products, such as: nutrient supporting products, in monitoring the life of plants during culture, and in gene technology to create higher productivity. Thus, nanotechnology is playing its very important role in most industries worldwide, which evidently shows the high potency of nanotechnology in life.

This report includes a small survey about the commercialized products that employ nanomaterials. This report not only provides the information about the current state of using nanotechnology in domestic market, but also gives a forecast about the development of nanotechnology in public commercial life Vietnamese enterprises. Table 2.2 illustrates the results from nearly 50 companies which use nanotechnological products and some information about these products.

Table 2.2. *Static survey of nearly 50 enterprise using nanotechnological products and their product information.*

Applying field	Company/ Enterprise	Product	Material	Origin
Agriculture	Tratipha	Nano Bac	Silver nanomaterial	Vietnam
	Bacson Technology	Multinano	Silver, Mg, Cu, Calcium and Fe nanomaterial	Vietnam
	Thuong Hai fertilizer Co. Ltd.	Nano Mg	Magnesium and Fe nanomaterial	China
	Showa Denko	Nano Carbon	Carbon nanomaterial	Japan
	Nanosilver Technology Ltd.	Silver nano	Silver nanomaterial	Vietnam
	Sao Viet fertilizer Ltd.	Cu Fertilizer	Copper nanomaterial	Vietnam
	Thuan Phong Production and Commercial JSC.	Nano Mg Fertilizer	Magnesium nanomaterial	Vietnam
		Cu Fertilizer	Copper nanomaterial	Vietnam
	Visa Pharma Co. Ltd.	Nano Ca	Nanoscale Calcium, vitamine, mineral	Vietnam
	Bao Huong Duong MTV Co. Ltd.	Nano Silver	Silver nanomaterial	Vietnam
	Dien Khanh Ltd.	G8 Nano Copper	Copper nanomaterial	Thái Lan
	Huetronics JSC.	Shrimp Nano Silver	Silver nanomaterial	Vietnam
	AnPhu Saigon Ltd.	Nano Copper	Copper nanomaterial	Vietnam
		Nano Niken	Nikel nanomaterial	Vietnam
Pharmacy	Sanofi-Synthelabo pharmacy Company	Calcium Corbiere	Calcium and Fe nanomaterial	Vietnam
	Mediplantex Pharm JSC.	Nano Curcumin	Fe nanomaterial, nano Curcumin	Vietnam
	NanoViricides Group	Antivirus medicine	Unknown	American
	NanoBio Group	Nanomedicine	Unknown	American

Applying field	Company/ Enterprise	Product	Material	Origin
	NanoBioTech Company	Diagnostic KIT	Unknown	American
	NanoBioTix Company	Cancer therapeutic medicine	Unknown	France
	NanoLight Technology Ltd.	Photonic nanotechnology diagnostic	Unknown	American
	Nano Carrier Ltd.	NanoCarrier medicine	Unknown	Japan
	Nanospectra Biosciences Co.	Tumor diagnostic equipment	Unknown	American
	A My International Commercial Co.	Amymama Nutrient food	Nano Fe, nano Zn, nano Ca, vitamin	Vietnam
	BioPro JSC.	Siro Canxi Nano Kaguru	Calcium and Mangan nanomaterial	Vietnam
Food and Nutrient	Biofocus Biotech-Pharm JSC.	Com Smart nano Nutrient food	Calcium nanomaterial	Vietnam
	Asia International Pharmacy JSC.	Com Nano Calcium Biokids Nutrient food	Calcium nanomaterial	Vietnam
	Nutifood Ltd.	NuCalci Gold Nutrient food	Calcium nanomaterial	Vietnam
	Au Co Production JSC.	Canxi Kids Grow Nutrient food	Calcium nanomaterial	Vietnam
	VN Pharm	Canxi nano Plus Nutrient food	Calcium nanomaterial	Vietnam
	An Phu Company.	Fe-nana Nutrient food	Calcium, Fe and copper nanomaterial,	Vietnam

Applying field	Company/ Enterprise	Product	Material	Origin
			vitamin	
	Melinh Pharm. Ltd.	Cansua 3 Nutrient food	Calcium nanomaterial	Vietnam
	Good Health Ltd.	Siro Bio	Zinc nanomaterial, vitamin	Vietnam
		Bio Fervit	Fe nanomaterial, vitamin	Vietnam
	A Chau Pharm Ltd.	Zimin AC Nutrient food	Zinc nanomaterial, vitamin	Vietnam
	Puritan's Pride Pharm Ltd.	Puritan's Pride Nutrient food	Calcium, Fe and Magnisium nanomaterial	American
		Zinic Puritan's Pride	Zinc nanomaterial, vitamin	American
Water product	Van Phuc Ltd.	Geyser Water filter	Unknown	Russia
	Kangaro Group	Kangaroo Water filter	Activated carbon, silver nanoparticles.	Vietnam
	Anh Duong Tech. JSC.	Sunny Eco Water filter	Unknown	Vietnam
	Bacson Technology Ltd.	Nano N200 Pro	Silver nanomaterial	Vietnam
Energy	California University	NanoBatery	Nanoscale Lithium	American
	Microsoft	Microdevices	Unknown	American
	MIT, NASA	Nanopolymer	Nanoscale Carbon, polymer	American
	HANEL Ltd.	Thin-film solar cell		
	Son Ha JSC.	Titan warm water supplier	Titanum nanocolloids	Vietnam

Nearly 100 products from 50 companies using nanotechnology are concentrated in agriculture, pharmacy, food, water production and energy; this report finds products in the agriculture, pharmacy and food sectors are the most prevalent. There 30.4% of the products belong to agriculture, 23.9% and 26.1% belong to pharmacy and food industries, respectively (Fig. 23a). Belong to the domestic productions, there are 35.6% of products are metallic and 37.8% are oxides (Fig. 2.3b).

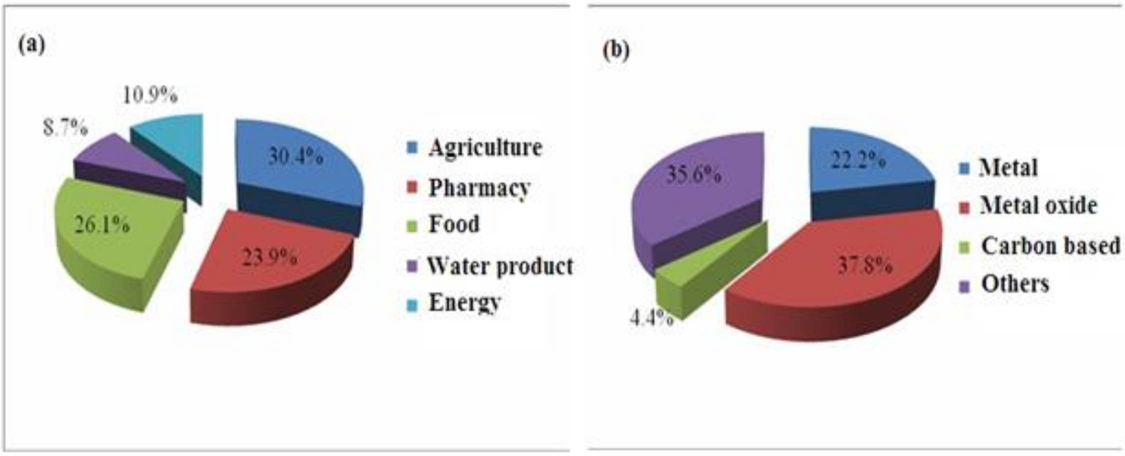


Figure 2.3. *Distribution of nanotechnology products on Vietnamese market due to (a) field-like classification and (b) material classification*

Notably, it is not easy to have the market accept a new product. As a very interesting example, the Head of VINAPHARM said it took almost 7 years to introduce a nanotechnological cancer treatment product to be accepted in the Hanoi market.

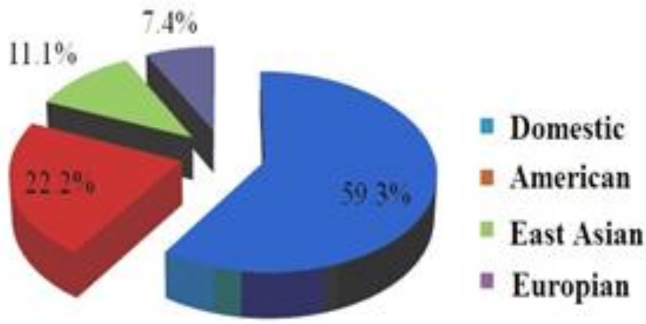


Figure 2.4. *Classification of nanotechnology products based on origin.*

It is also noticed that the pharmacy products generally have foreign origins, mostly from America, France and Japan. There are 40.7% of products with foreign origins, of which 22% have American origins, 11% East Asian and 7% European (Fig. 2.4). The result reflects that the domestic production only provides simple nanomaterials as raw-materials for agriculture or nutrient. In case of higher technological products, such as DNA KITs or solar cells, the basic infrastructural industries and technology are not sufficient enough to produce.

3. Application potency and developing capability

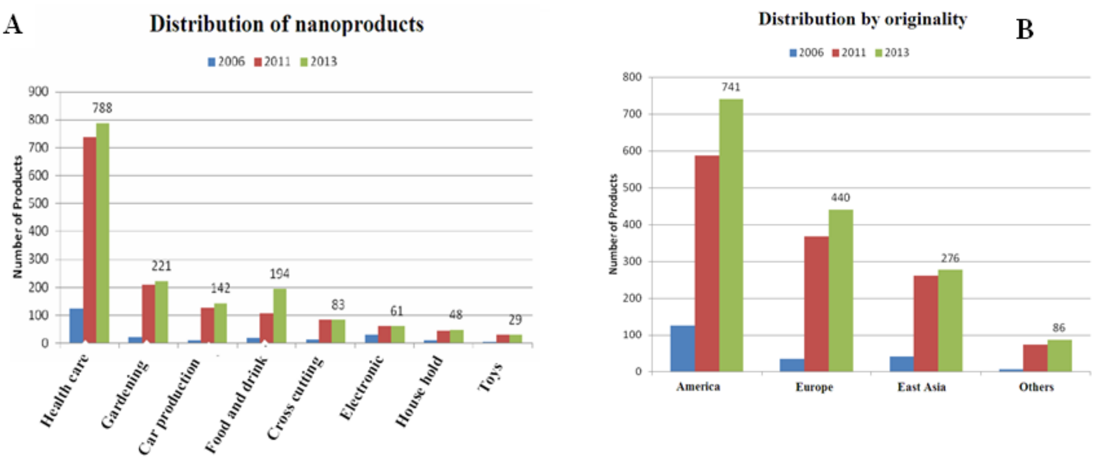


Figure 2.5. *Distribution of nanotechnology product based on (a) trading profession and on (b) origin*

In comparison with the domestic market, worldwide commercial life is much more active with new technology products. Nanotechnology products are also accepted more easily. The reason might not be the worldwide commercial market more accommodating, but it is always ready for new products. Besides, with a long period development of auxiliary industry, new technologies are always prepared to be adaptable. Nanotechnology brings a large spectrum of applicability in other technologies and industries; hence, it makes a huge benefit for enterprises, institutes when working on (see Annex II).

Figure 2.5 shows the development of nanotechnology in other industrial market. The survey results are collected by Nanotechnology Application in Life project. From 2005 to 2013, it is experienced that there is enormous increasing of nanotechnology products' number in many trades (Fig. 2.5 a) and all over the world (Fig 2.5 b). Belonging to these products, more than 50% goes to health care industry, which reflects the demand of public society: health is often considered the most important.

Carbon nanomaterials

Materials carbon nanotubes (CNTs) with mechanical properties, physics, chemistry and potential special innovative applications are increasingly attracting high attention of businesses. In Vietnam, there was a unit of study, transfer and application of this material in industrial production.

Ministry of Industry and Trade is one of the few units at the forefront of research, transfer and application of CNTs in industrial production, the scientists from the Institute of Materials Science (Institute of Science - Technology of Vietnam) has designed, construction equipment chemical vapor deposition temperature, continuous operation, using solid catalysts, materials allowing synthetic multi-wall carbon nanotubes (MWCNTs) commercial standards. At the same time, successfully fabricated single wall carbon nanotubes (SWCNTs) super long (several mm), 1-3 nm in diameter. These new materials can be modified with suitable functional groups, to strengthen the ability dispersed in different substrates.

Experiments, applications in manufacturing CNTs reinforced radiator cream commercial for computer processors and high-power LED components offer significant effect. Specifically: use multiple materials single wall carbon nanotubes and fibers sprouting orientation to reinforce in cream radiators for computer processors and high power LEDs. Examination results, the real proof positive, this material may reduce the temperature of the processor unit computer down 5°C. In addition, the material also increases the durability of the processor 3 times longer than when using conventional radiators creams. Similarly, maintaining the relationship between light output power with currents up to 500mA inlet without reaching saturation should improve optical performance of LEDs. And researchers used materials carbon nanotubes to reinforce the hardness, durability, adhesion and corrosion resistance of the electroplated layer Ni, Cr. Test results show that Ni electroplating layer, Cr mixed carbon nanotubes, two times harder than Ni electroplating layer, Cr usual; Abrasion resistance is also enhanced. Further, actual results also showed that the mechanical properties of natural rubber reinforced with 5-10 wt% MWCNTs will have durability, abrasion resistance three times higher with advanced materials rubber, reinforced with carbon powder.

Obviously, materials CNTs have opened up new applications in manufacturing, such as flat-panel manufacturing - low power; electron emission components stature; radiator materials in electronic devices of high performance materials electromagnetic wave absorption, hydrogen storage materials; and battery production. Especially with good mechanical properties: lightweight, ultra high strength, abrasion resistance and good chemistry, large surface area, CNTs are ideal reinforcement materials for a variety of material combinations new metallic wallpaper, wallpaper polymer, rubber, epoxy with a very broad range of applications.

Recognizing the benefits and importance, Materials Science Institute signed a contract associated with Hai Duong Pump Factory, used materials multi wall carbon nanotubes to reinforce vulcanized natural rubber (manufacture wire crab-roa). The results showed that the mechanical properties of vulcanized natural rubber are increased from 8 to 10%. In addition, the rubber composite materials (MWCNTs / NR) were applied to the silver self-lubricating water pump system in some localities in the country. Our products are used in a number of training institutions, scientific research such as: University of Technical Education Hung Yen and Materials Technology Faculty (Polytechnic University of Ho. Ho Chi Minh City); Research and development applications in life with several units in and out of Vietnam Science and Technology Institute.

Notably, the results of research and testing achieved over here is the basis for the Institute of Materials Science in collaboration with established partners IQCT International Nanotech Co., Ltd. Vietnam - Vinanotech activities in the field commercialization of equipment, production technology and application products of carbon nanomaterials. The leaders of these organizations hope the products from this partnership program will meet the needs of growing businesses.

Nano polymer

Nano polymers have very broad applications; most likely apply to all industries such as plastics, construction, printing, petroleum, and medicine. For example when adding nano metal complex polymer bearing as Mn (Manganese), Fe (iron) in petrol A83, the polymer nano would increase the gasoline octane; or when adding the polymer nano to oil, the polymer nano-particles will suck oil and release it slowly so that the engine can operate more without regular oil change; or the semiconductor, LED application today conductive polymer nano.

One of the strong developments of nano-polymer applications in the world and Vietnam is in medicine. For example, polymeric nano change application form included in the blood vessels against obstruction. Or nano polymer applications to take heavy metals out of the body from poisoning due to the ability of metal complexes with these polymers. Most applications of nano polymers in medicine are used as a drug carrier. In addition, the polymer nano can also attach functional groups to increase the interoperability of the body.

In Vietnam, there has been some research on nano-polymer applications, such as:

- Institute of Chemical Technology introduces nano applications branch as carrier polymer anticancer drug 5-fluorouracil, anticancer drug cis-platinum.

- Danapha pharmaceutical company (Danang) launched a series of pharmaceutical products are wrapped in the nanoparticles-liposome as estoposide liposomal cancer treatments, glipizome (treatment of diabetes), amlodisome (high blood pressure), lovastasome (cardiovascular treatment, condition of high blood cholesterol).

- Materials Science Institute are some studies have high applicability of such polymer nano nano polymer mix in PVC helps increase the mechanical properties of PVC; Applications star polymer nano-mechanical increase of dentures; conductive polymer nano applications in paint to avoid corrosion on the surface. Also oriented research institute also uses nano polymers for slow release drug carriers, using nano polymers bind to the active anti-cancer drug to a highly motile and reduced toxicity, using nano polymers for as carrier to target drug.

Nano in bio

Nano biotechnology is the interface betweeb nanotechnology and biology, and is a combination of many research fields of high technology. In other words, nano biotechnology is biotechnology at nano level related to methods of using materials and equipment nanotechnology to study biological systems. Applications of nano biotechnology are increasing rapidly, especially in the field of medicine. Some nano biotechnology devices have been manufactured in Vietnam.

Currently the research and application of nanotechnology deployment in general and nano biotechnology in particular is being done in a number of research units and deployed, mainly concentrated in HCMC and Hanoi. Typically Nanotechnology Laboratory National University HCMC, research and development centers of high-tech in HCM City, the Institute of Materials, Academy of Science and Technology of Vietnam, Hanoi University of Science and HCM City Polytechnic University of Hanoi and HCMC. Initial research has been published: "Glucose sensor based on platinum nanowires: A clinical study" – International Journal of Nanotechnology 10(3-4) 166-177. The team has developed equipment directly determine blood glucose in diabetic patients is based on the activity of the enzyme glucose oxidase fixed on Pt nanowires allows determining the concentration of blood glucose variability in approximately 125 to 15.5 mM with a tolerance of ± 3%.

Research centers and training EDA HCMC National University in cooperation with the Research Centre implementing the HCM City Hi-tech Park is the investment of HCM City Department of Science and Technology successfully manufactured biochip called crystal micro balance QCM quartz (Quatzt Crystal microbalance) capable of measuring very small mass distribution (ng) based on the changing frequency of the quartz resonator oscillators. Biochip enables rapid detection of cholera. Biopharmaceutical Nano, one of the leading companies in research and development of pharmaceutical products from birth-recombinant DNA technology to proteins in the Asia-Pacific also based in high-tech park in Ho Chi Minh City area of 15,000 m^2 area reached WHO GMP standards (5/2011).

The team of Nguyen Cong Hao et al (Institute of Chemical Technology in Ho Chi Minh City Institute of Science and Technology of Vietnam) has created b-cyclodextrin-alginate carrier material medicines .Nguyen Anh Dung et al (Center Biotechnology, University Highlands) Ongoing research-chitosan nanoparticle fabrication as carrier stimulate an immune response to the H5N1 flu vaccine. The authors used three methods to create nanoparticle-chitosan, being: ionic gel in TPP (tripolyphsphate), emulsified in NaOH-methanol and crosslinking linking of glutaraldehyde. Then use the method fixed by adsorption and confining surface antigen-chitosan nanoparticles.

Bui Huy Du and Nguyen Quoc Hien and research by making colloidal silver nano-Co-60 gamma radiation fungicidal effect of blast (Piricularia Cavara oryzae) and nuts Tickle lem disease (Pseudomonas Kurita et Tabei glumae.

Tam Phuong Dinh team (Polytechnic University of Hanoi) was fixed on the sensor DNA sequence identified herpes virus.

Nguyen Thi Phuong Phong (Lac Hong University) Research Cu solution nano fabrication method for reducing oxalate Cu, $CuCl_2$, $CuSO_4$ by reducing agents glycole ethylene, diethylene glycole, glycerin combined support of the microwave and use Cuba solution makes use of nano materials fabrication plant protection drugs kill fungal disease resistance and hip Corticium salmonicolor, Powdery mildew on the rubber.

TiO_2 nano

Because many anomalous properties and potential application in the field of nanoscale TiO_2 which are research scientists, synthetic. Featured applications of nanoscale TiO_2 talked in recent times is antiseptic kills bacteria and mold; Self-cleaning and anti-blur steam; and wastewater treatment, and emissions. In 2012, at the Technology Center of Hue University of Sciences has made a line of paint products nano TiO_2 / Ag. After spray-coated on a ceramic tile floor and burning at 600^0C, coating TiO_2 / Ag exterior features antibacterial, self-cleaning even higher hardness enamel background, does not alter the color of the brick.

Ag nano solution

- Use of shrimp: In Vietnam, the disease acute necrotizing pancreatitis in shrimp liver (EMS) began to appear from 2010, and an expansion from January 3/2011, causing great losses for farmers. However, so far scientists have not found a comprehensive cure. Under these circumstances, Huetronics Corporation developed a variety of nano products, including nano-Ag and deploy applications in prevention and treatment of shrimp in some key provinces of East shrimp Mekong Delta as Tra Vinh, Ben Tre, Tien Giang, Bac Lieu, and Ca Mau. Preliminary results have shown that the nano-Ag helps to increase efficiency of the shrimp farms by reducing costs (about nearly 20% cheaper than normal aquaculture) and diseases (30% reduction).

- Use in tissue culture: $HgCl_2$ used is common disinfectant in tissue culture. The study results showed that concentrations of 5 ppm silver nano influence best bud regeneration ability of the body segments.

- Use of livestock: research results have shown that efficiency of nano-Ag application for treatment of wounds and ulcerates in bulls is 98%; treatment of wounds caused by castration on pigs is 100% when applied directly to the wound; incision recovered after 4 days; hoof diseases treatment efficiency is 93%. Ag nano solution use is highly effective in the prevention and treatment of diarrhea for rabbits.

Information on applications of nano materials is shown in the Annex II.

III. Nano-safety and nano-safety management solutions in Vietnam

There are numbers of researches reporting the harmful effect of nanomaterials on living cell and/or organisms, which raises attendances on safety working and using nanomaterials – *see annex III*. Since 2005, the International Organization for Standardization (ISO) has been working on the classifications of nanomaterials based on their properties, effectiveness, application fields in order to manage the present their effects on our environment. Due to this, annual conferences are held discussing not only the hazard of nanomaterials but also about their controlling management. Despite all of that, there is little in terms of research results and/or regulations working on nano-safety problems. The reason might be the limited number of nanotechnology applications brought to social market. Hence, the researchers are still focusing on positive effects of nanomaterials and "forget" about their negative effects.

Information on effects of nanomaterials on the environment and living subjects is shown in the Annex III.

1. Current state of nano-safety in Vietnam

There are very few evidences of nano-safety works detected in our study. In Vietnam, only safety *regulation decisions* are found announcing about safety manufacturing with new materials, such as Regulation No. 02/2001/TT-BKHCNMT, Environment Protection Law 2014, Chemical Law 2007, High-Technology Law 2008. They are only the basic regulations, from which we could contribute a systematic legal framework that works on nano-materials and safety of usage of nanomaterials.

In academic research, we found two projects working on hazard effects of nanomaterials funded by the NAFOSTED. They both successfully ended in June 2015, which discussed the harmfulness of silver and TiO_2 nanoparticles on living cells. One of two project managers from the National Institute of Hygiene and Epidemiology (NIHE) – Dr. Tran Quang Huy – said: "There are too many projects working on the effectiveness of nanomaterials. But they really forget that the more the materials are effective the more they are harmful. We need to work with a *safety-first* culture to become healthier".

In a short interview with environmental staffs of Canon (Japan) in Vietnam, we discussed the safety culture of such enterprises. With the question that what happens if a new vendor shows them new technical products which is related to nanotechnology, the answer was: "We firstly do not like to work with these products, because many steps are needed in order to bring them to our company. But we also have our own regulations for them. We have to check all their harmful effects due to Vietnamese legislation. If their harmfulness is not issued then we treat them as they are harmful materials during use. Masks, gloves, boots or other protective wares are afforded to be used".

Due to this, solutions for nano-safety management are needed.

2. Solution for nano-safety management in Vietnam

Implementation methods

1. Surveys, research, evaluation, forecasting / warning nano pollution in

2. To raise capital for nano safety management

3. Develop standard system, set standards for nano safety legislation and safety management in nano.

4. Training of human resources and safety management nano

5. The basic product

- Survey data, the national database on nano-pollution and safety.

- The system of standards, regulations and safety of nano pollution.

- The products of technology in control and pollution treatment nano.

Some specific solutions

1. The solution for the organization, management, mechanisms:

a) Review and propose and finalize the organization, mechanisms, policies and legal documents on nano safety;

b) Develop and submit to the Prime Minister for approval and implementation planning of control and nano pollution treatment and environmental for human health;

c) To integrate the control and nano pollution treatment into strategies, planning and development of environmental industries; strategy, planning and economic development - local and regional society;

d) Develop, promulgate and apply the standards, technical regulations in the field of industrial nanosafety of environment;

e) Promote social mobilization to attract, strengthen and diversify investment resources for sustainable development of nanomaterials industry have to consider the safety factor for the environment and human health;

f) Encourage the establishment of advisory services organization nano

2. Solutions of investment, financial and market:

a) State support through state credit for developing research and application control technologies and nano-pollution treatment;

b) To encourage organizations and individuals and foreign investment in development of technology control and pollution treatment in different sectors nano;

c) Preferential policies will be applied to business activities in the nano fields which have positive contributions to the of sustainable development of Vietnam;

d) To encourage organizations and individuals to fund nano safety, development of economic instruments to invest in developing control technologies and nano-pollution treatment;

e) To establish and facilitate market development activities in the fields of nano-safety.

3. Solutions on science and technology:

a) To promote scientific research, application and effective transfer of new technologies, new products created in the country in activities in the fields of nano safety management;

b) Closely combine the activities of scientific research, technology development of research institutes, universities and businesses related to nanomaterials technology.

4. Solutions to international cooperation and human development

a) Strengthening the formulation and implementation of programs, schemes and projects of cooperation with other countries to develop advanced control technologies and nano-pollution treatment in Vietnam;

b) Encourage the participation of foreign experts, especially overseas Vietnamese people engaged in the fields of nanotechnology and nano safety management.

c) Promote training, retraining and capacity building in the country and abroad for staff operating in the field of nano-safety management.

5. Solutions for communication, awareness-raising:

a) Strengthening and diversifying the forms of communication and education to raise awareness and responsibility to develop technologies to control and treat pollution of nano organizations, individuals and communities, especially businesses;

b) Early built and put into use the national database on nano applications and nano safety.

The effectiveness of the scheme

- Identify and provide warning on risks, potential risks of nanotechnology on the environment and human health.

- Establish a system of standards, to set standards on environmental factors related to nanotechnology.

- Research and survey technologies to minimize the harmful effects of nanomaterials on the environment and human health.

- Identify economic and social problems related to nano safety management.

- Establish systems for management of production, transportation, storage and discharge related to nanomaterials.

IV. Conclusions

The main characteristic advantages such as increasing total surface area creates a turning point in breaking through the barriers of performance, saving raw-materials and providing more new applications. There are many products branded *nano-application* of technological advances that delivers very high benefit and new gadgets.

Together with technology, in recent years, the research departments and institute of science and technology in the country have transformed themselves to generate new research groups in order to come in line with nanotechnology. There are many groups focusing on the applications of nanotechnology in biomedicine, environmental treatment, catalytic and new green energy or energy saving.

Although the auxiliary industries are not developed enough, the development of the nanotechnology in public life is quite basic and still does not bring real breakthroughs in core value; but the latest research results in the country clearly show the promising potential of this new technology.

To connect the research results and turn them into valuable products still needs support of all sides as well as the interdisciplinary cooperation/collaboration of researchers and businesses. Besides, to provide a fast access for applying the above-mentioned results into society, the country should have a management system which combines an open nature with high commitment to the safety of human health and the environment.

ANNEX

ANNEX I. Nanomaterials and nanotechnology

Defining nanomaterials and/or nanotechnology is very important for their safe and systematic management and application. It is necessary to understand not only the description but also the existing conditions of nanomaterials and/or the application of nanotechnology. Besides, the detailed definition is attracted to be investigated in order to classify the nanomaterials for easy management and for creating a safety database of nanomaterials.

In this chapter, we only study the general definition and some existing conditions of nanomaterials and nanotechnology.

a. Nanomaterials and nanotechnology

Norio Taniguchi – former professor of Tokyo University - father of the *nanotechnology* word.

Beginning of 1950s, the demand of biotechnology development and revolutions of molecular biology raised a challenge of deepening the knowledge about tiny structures: from the cell with micrometer sizes to smaller organics with nanometer sizes, such as protein and nucleic acids. Nanomaterials were attracted to solve the above problem because of that their sizes coincided with the target structures' sizes. Beside, it was noticed that at critical small size some physical properties of materials changed and expressed a lot of applications for other sciences and for public industries. Since then, nanomaterials became a focus for scientists' attention and research into nanomaterials became a new science: nanotechnology or nanoscience. As a result, there were newly invented products found to have influence on society which were belong to the development of nanotechnology: such as LED, grapheme, thin-film solar cell …

Nowadays, when talking about nanotechnology, we are talking about revolutions for science and life. In 1974 the word nanotechnology was born.

b. About the existence of nanomaterials

Base on the definition, there are many physiochemical existing states of nanomaterials. Nanomaterials might be inorganic and/or organic compounds with one or higher dimension presenting at nanoscale. Nanomaterials might be artificial; for example, thin-file solar cell or LEDs. Or they cancan be found in nature, such as proteins and DNA. There are many ways to administer and classify nanomaterials: from their sizes, from their chemical existence, from their physiochemical properties and from their applications. For examples, measuring size and size distributions in nanomaterials is challenging in many cases and different measurement methods may not provide comparable results. Harmonized measurement methods must be developed with a view to ensuring that the application of the definition leads to consistent results across materials and over time. Until harmonized measurement methods are available, best available alternative methods should be applied.

Nanomaterials could carry huge benefits for society but also have negative effect on sustainable development if we do not pay enough attention to their hazardous effects. It would be considered that there are two types of nanomaterials: artificial and naturally found. Artificial nanomaterials are the products from researching results and/or other industrial applications. They are directly made from social demand. On the other hand, naturally found nanomaterials are quite multifarious. They might occur in organic and inorganic form; i.e. they can be found everywhere and they are not easily managed. Even if there are a lot of existing states of nanomaterials, it is always essential to create a data base containing the profiles of materials, which considers their status: possible existing states, sizes, properties, hazardous properties and their application abilities.

General properties and demand of nanomaterials

- Total surface area:

Making a simple example, we could evaluate that there would be 10^9 times increasing of total surface area of a soccer ball if it was cut to 10^9 times, which would fill up an area of a football field. The increasing of total surface results in nanomaterials having new properties and functions for applications.

o Having the size which coincides with bio-molecules

When the size of materials decreases to nanometer it coincides with the size of biological items from some micrometer cells to hundreds of nanometer macroorganic and nanometers DNA or protein. It is possible to use nanomaterials as indicator in order to investigate and/or develop those biological organic. Furthermore, nanomaterials are employed for biomedicine application, diagnosis and other targeted therapeutic.

Although this new science has been developed and studied for a long time, nanotechnology has only been developed by scientists from the end of the 20th century. Since then, there are increasing applications of nanotechnology found. From 1974 to end of the 20th century, nanoscience only focused on synthesis of new type nanomaterials with new fundamental investigations.

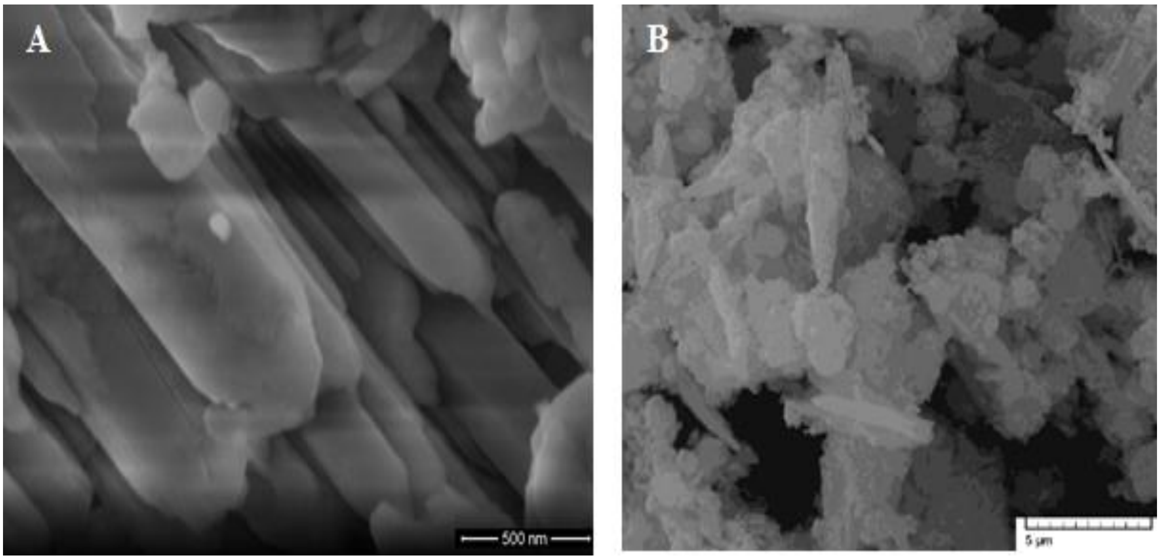


Figure A.1.1. *Scanning electron microscopic (SEM) image of (A) activated carbon made from bamboo and (B) silica coated Fe_3O_4 colloids*

- More powerful interaction

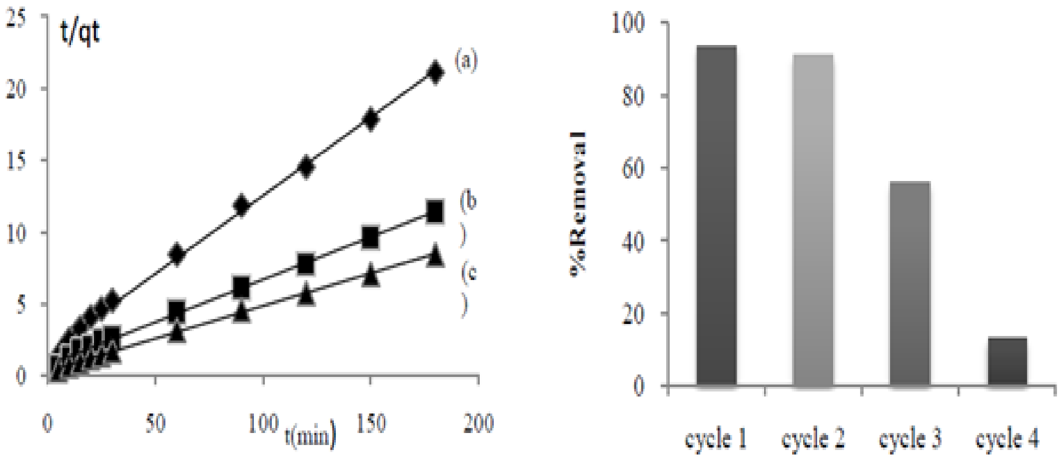


Figure A.1.2. *A sample of increasing the materials activity by decreasing the size to nanoscale, it is methylene blue (MB) absorbability of SiO_2 coated Fe_3O_4 nanocolloids.*

One of the most important consequence of increasing total surface area is more powerful interaction and/or catalytic. It was found that porous structure such as activated carbon or porous silica could absorb more organic chemical, organism and are employable in hazardous water and waste treatments. Besides, the catalytic materials show higher efficiency when the total interaction surface increases and would be applied in a lot of chemistry and biology technological industries. On the other hand, signal transducing materials hit higher transduction records when their total interface area enlarges, which would increase the sensitivity of sensors, information transferring velocity for sensing or electronic industries …

Figure A.1.2. shows methylene blue absorption ability of SiO_2 coated Fe_3O_4 nanocolloids. By increasing the porous surface, the total surface area of the colloids increases; hence increase their organic chemical absorption ability. This property is often repeated with porous activated carbon or activated carbon based materials in order to show their potential on waste water treatment and/or catalytic, antimicrobial ability …

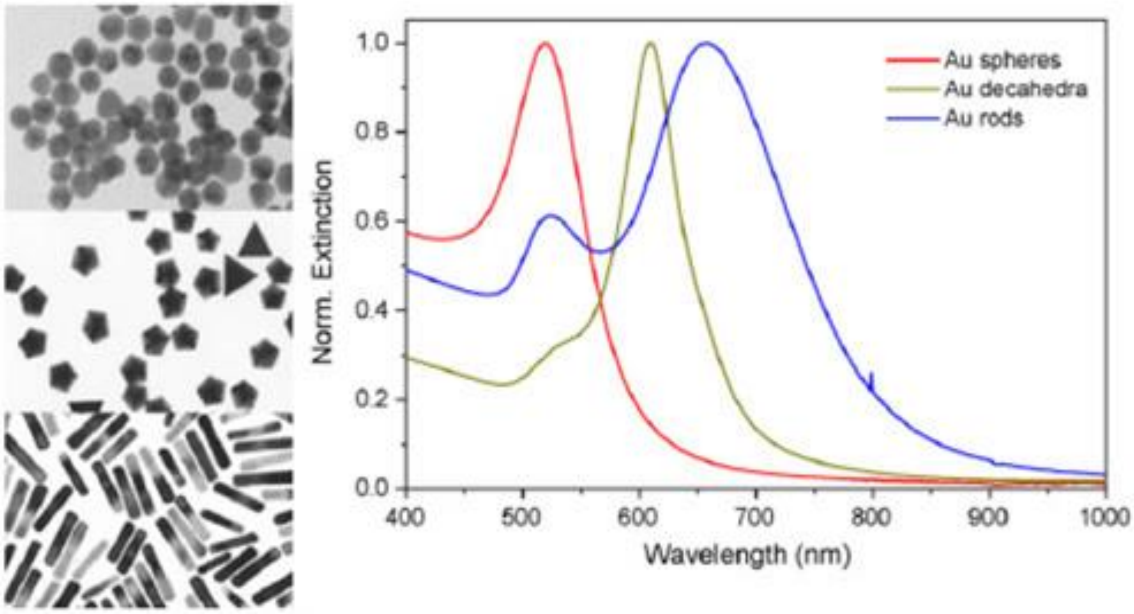


Figure A.1.3. *A sample of light absorption of gold nanoparticles with different shapes at nanoscale.*

- Decrease the amount of material consumption

In some earlier research, nanomaterials were discussed as a solution for saving raw-materials. With a small amount of material the same amount of energy is generated by thin-film solar cells (a-silic thinfilm solar cell), or of light by light emitting diodes (LEDs), for example. These are the examples for saving materials but still keeping up the demand. When the population increases the demand of raw-materials for a lot of industrial economies also increases. Hence, society is facing the problem of a lack of raw-materials. The public is challenged by a new problem of saving fossil fuel energy sources, raw-minerals and mined ores, among others. Some have suggested that the 21st century will be the century of nanotechnology.

At present it is possible to measure the specific surface area by volume for dry solid materials or powders with the nitrogen adsorption method ('BET-method'). In those cases the specific surface area can be used as a proxy to identify a potential nanomaterial. New scientific knowledge may expand the possibility to use this and other methods to other types of materials in the future. There can be a discrepancy between the measurement of the specific surface area and the number size distribution from one material to another. Therefore it should be specified that results for number size distribution should prevail and it should not be possible to use the specific surface area to demonstrate that a material is not a nanomaterial.

- New properties

It was discussed that nanomaterials have new physical properties when their sizes decrease to nanoscale. In case of metal nanoparticles, when the particles' size is smaller than 60 nm the scattering cross section is negligible when compared to the absorption cross section. Hence, the particles can absorb visible light at this scale-size i.e. gold nanoparticles used to absorb light with wavelength close to 530 nm, silver nanoparticles absorb light with wavelength near by 420 nm … Other phenomenon occurs when semiconductive materials' sizes reach nanoscale.

ANNEX II. Applications of nanotechnology world wide

To understand the potency and to forecast the development of nanotechnology in Vietnam; we review the applicability of nanotechnology through the worldwide applications. Later, we provide a short survey of the important domestic commercial fields, in which would be able to bring nanotechnology in.

According to Soldatenko currently some 1300 products are in use. In April 2011 the Woodrow Wilson Center Consumer Products Inventory included 1317 products with nanomaterials. These products were produced by 587 companies in 30 countries. This number could be higher due to the difficulties of identifying the products which contain nanomaterials.

Governments and the private sector invest significant amounts in research and development of nanomaterials. The public sector in the US for instance invested $ 12 billion since 2001. Germany, which is in this respect the frontrunner in the EU and ranks fourth on the international level (behind the US, China and Japan) allocated € 400 million to nanotechnology in 2010. A small part of the funding is allocated to research related to risk assessment and management. For example, Switzerland allocated SF 12 Million to safety research for the period 2010 to 2015 for the National Research Programme on Opportunities and Risks of Nanomaterials.

The market situation of four classes of nanomaterials (fullerenes, carbon nano tubes (CNT, metals and metal oxides) was described in the 2009 ENRHES report:

- The fullerenes market was worth around $ 58 Million in 2007. The energy sector is the most prominent for fullerenes (fuel cells, solar cells, batteries).

- There is a great demand for CNT, especially in the electronics and polymers sectors. In 2006 the global CNT production capacity was estimated 271 tons per year (WTEC 2006). The price for 1 kg CNT used to be up to $ 1000, but has been lowered due to research efforts. The market for CNT was approximately $ 168 Million in 2008.

- Metals: Nanometals include cobalt, copper, gold and silver. Silver nanoparticles are applied most, because of the anti-microbial properties. It has been reported that in 2008 the silver nanoparticles production was 500 tons per year.

- Metal oxides: Metal oxide nanoparticles are manufactured and applied worldwide for cosmetics, coatings, solar cells and plastics, such as cerium oxide for car catalysts and for diesel fuel additives; zinc oxide for metal work; ceramic nanoparticles for scratch resistant automobile coatings; titanium dioxide for paints, plastic stabilizers and sun screens. The global nano-titanium dioxide production was estimated between 5000 and 64 000 metric tons for the year 2008.

While market demand has not matched the considerable hype that nanotechnology has generated in the last decade and a half, nanomaterials have managed to attain an appreciable commercial presence. Market information about manufactured nanomaterials has commercial value; it is collected and sold by many private companies and is not freely available. This is one reason why there is no overview about the situation. Other reasons are the wide application of manufactured nanomaterials in all sorts of product categories and the absence of information in governments about which products contain nanomaterials. Many of the projections for the size of the future global market might therefore not be very accurate and will depend highly on the assumptions and definitions which were used in these studies. While there is an apparent general agreement on an important growth potential for the nanomaterial market, factors which make it difficult to estimate its future more accurately include: high processing cost; intellectual property issues; health and environmental regulations and safety concerns. A wide variety of numbers about the expected market size can be found, and these numbers are not always in accordance. Nevertheless, some of the information is provided below as an illustration.

One estimate indicates that the global market for pure nanomaterials to grow from $ 413 million in 2005 to $ 3.6 billion by 2010. In 2007 the global market was worth around $ 1.6 billion. Azonano projects that this will reach $ 10 billion by 2012, and there are projections which mention that the market will be worth $ 20.5 billion in 2015. It has been reported that global nanomaterial demands will continue to rise by 20 % per year. Another estimate mentions that by 2025 nanomaterials are expected to reach over 34 billion in sales, having still only scratched the surface of the market potential. According to a Greenpeace report, the market of nanomaterials is estimated to be over $ 340 billion within a decade. The US National Science Foundation projected in 2001 that by 2015 the size of the nanotechnology market will be $ 1 Trillion.

It has been estimated that the area of nanoelectronics (semiconductors, ultra capacitors, nanostorage and nanosensors) will be worth around $ 450 billion in 2015. The information and communication technology market is projected to see an increase due to the use of nanomaterials in displays, with a forecast of $ 1.1 billion by 2015. Health care (nanobiotechnology including medical applications, drug delivery and microbiocides) was the second largest market for nanomaterials in 2008, but is expected to overtake electronics as the leading outlet in 2013 and beyond. It has been reported that the total market for nanobiotechnology products was $ 19.3 billion by 2010 and is growing to $ 29.7 billion by 2015. The global market for nanotechnology products used in water treatment was worth an estimated $ 1.4 billion in 2010 and is expected to grow at a compound annual growth rate of 9.7% during the next 5 years to reach a value of $ 2.2 billion in 2015.

Currently the market is mainly focused on the fields of electronics and health care, but it is expected that the market will become much broader in terms of the variety of products and producers.

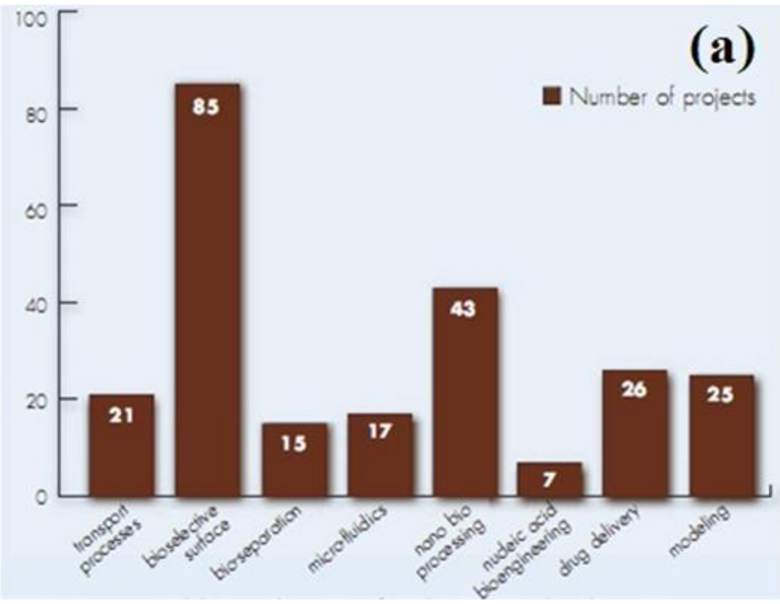
Manufactured nanomaterials not only have industrial and consumer product applications. These materials can be also of use in the health area (nanomedicine) and in the environmental field. Some of them are already in use, while others are in a more or less advanced stage of research or experimental use. In many research programmes, especially in developing countries and economies in transition, these aspects get priority attention. In the NANOTEC research programme of Thailand, for example, six of the eight so called flagship projects are directly related to health and environmental applications. Some examples of beneficial uses of nanomaterials for health and for the environment are discussed below.

Application of nanotechnology in economical fields

Application in agriculture

Base on the nanotechnology application projects for agriculture from America from 2000 to 2006, there are about 160 different techniques employed. The research and application fields of nanotechnology for agriculture might distribute in to transport, sureface bioselective, bioseparation, microfluidics, nano bio-processing … Belong to those, surface bioselective technology and nano bio processing technology are attracted more attention (about 53% of the project number). The employed technologies are also very abundant with biosensing, environment processing, bioprocessing for food, nano bioindustrial processing and pathogen detecting …

Here we only introduce a very short view of the technology that nanotechnology could contribute in agriculture. To understand them more precisely, we need to focus on smaller groups and take more time for investigation.



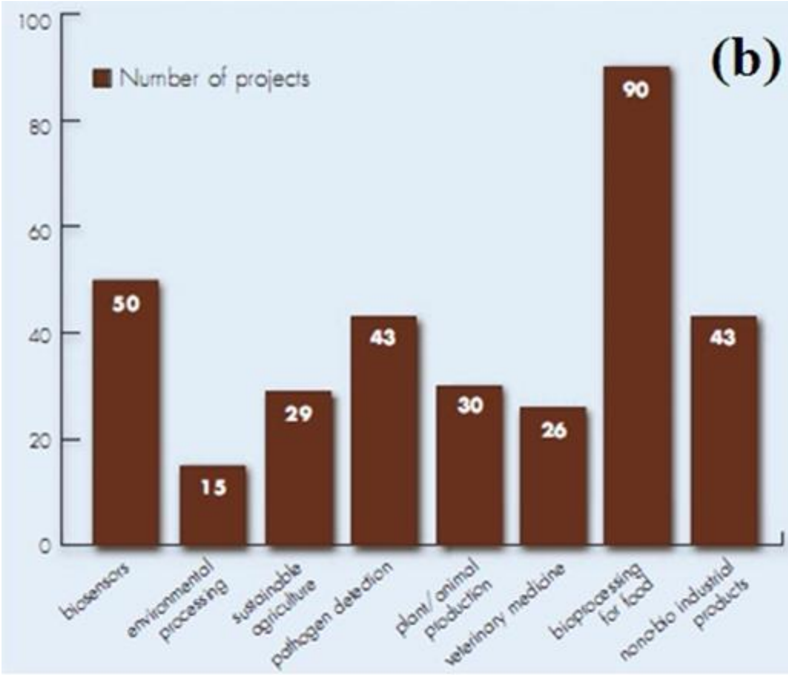


Figure A.2.1. *Distribution of nanotechnology products in agriculture by (a) used technique and by (b) addressed topic.*

Nanotechnology could take part in the *environment treatment* in agriculture. With this process, the culturing environment not only becomes protected, but also has good conditions for the target plants, which later could bring higher productivity. Nanotechnology can join with *biosensing* process. With this, early detection of *disease*s is well-known and discussed with higher execute and selectivity in a localized area. Biosensing takes part the monitoring the growing process of plants and helps to control the growing conditions within every sections of growing. Besides, nanotechnology plays role in *gen technology*.

Application in sustainable energy

Nanotechnology is found as one of the most important impact for green energy industry development. There are three main fields that nanotechnology would take part in: energy production, catalytic for new energy resource and energy storage.

- Energy production

Solar energy is considered as unlimited energy resource. Mining this resource has been still a hot topic for finding a green energy for a long time. Since 2000, it has believed that solar energy would become the main energy when raw-minerals are facing depletion danger (see figure A.2.2). The chart showed in figure A.2.2 also shows that nuclear energy is planed to shut down in 2050, and the fact is that this energy type was decided to stop working since 2011, after the nuclear accident at Tsunami. The lack of future oil, natural gas and coal has been forcing energy industry to find new resources: photovoltaic, biomass, solar thermal … which are considered to be sustainable and green.

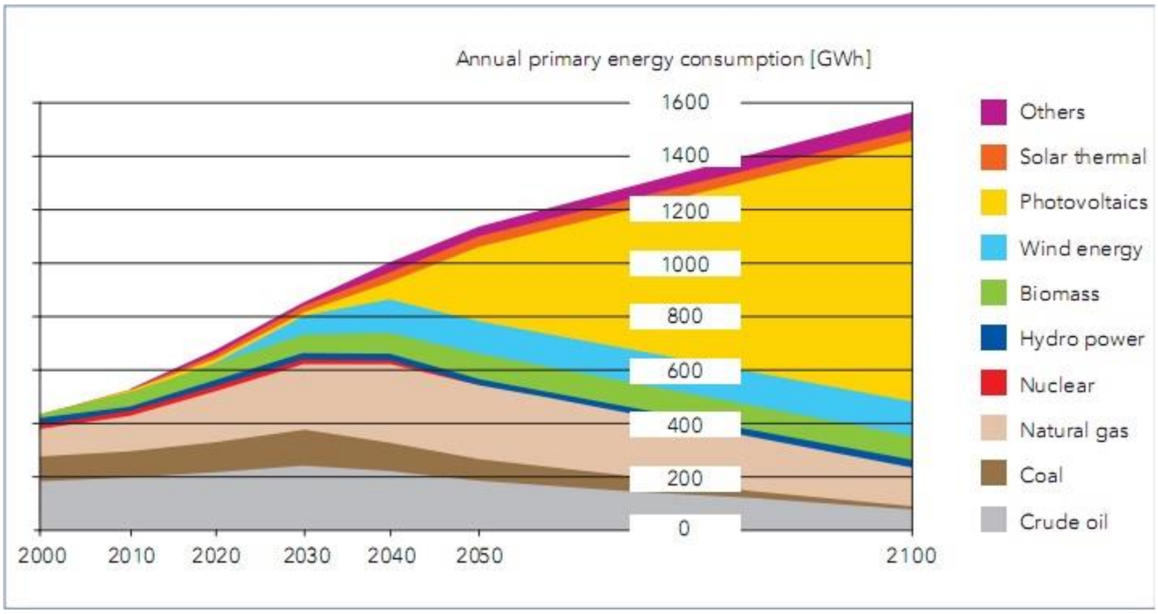


Figure A.2.2. *Scenario of development of global energy demand – source: www.solar-swirtchaft.de).*

Nanotechnology plays a very important role in this project. It not only take part in finding new type of energy resource and/or mining the solar energy such as thin-film solar cell, but it could also provide the answer for raw-material saving.

- Application in catalytic for fuel cell

Figure A.2.3. *Nanotechnology application in fuel cell*

Fuel cell is an interesting artificial invention. By increasing the interface between fuel and energy transferring surface and let the reaction energy change straightly to electric energy, fuel cell is a very good way to save energy, hence to save raw-materials. Figure A.2.3 shows a simple example about application of nanotechnology to increase the reaction surface for fuel cell that uses hydrogen. Nowadays, besides hydrogen classical fuel, such as ethanol, methanol and oil are attracted to be fuel in fuel cells. If it is successful, then fuel cell would replace most of classical energy producing process because it could give higher efficient energy transduction. And nanotechnology is discussed to increase this efficiency.

- Energy storage

With high total surface area, nanomaterials can achieve a new role for fuel storage, such as hydrogen storage for fuel cell, which is used in astronomy, and for creating new type of battery, the super capacitor, which could store more energy and is easier to charge.

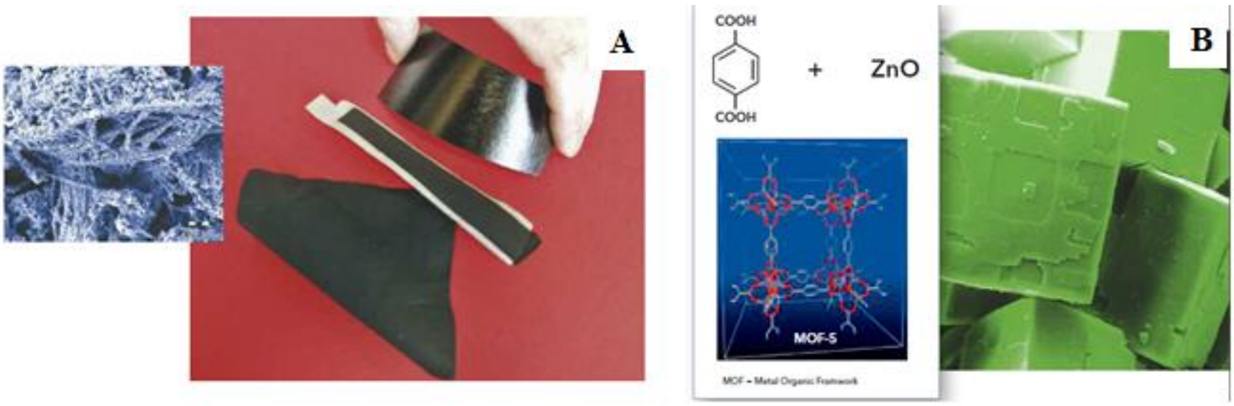


Figure A.2.4. *Application of porous activated carbon in energy storage : (a) the super capacitor and (b) hydrogen storage*

Applications in health care and cosmetic

Healthcare and cosmetic industries are claimed to start using nanomaterials very early. The materials used in cosmetic and healthcare are normally nutrients and small amount of catalyst for cell care and especially for skin lightening. It is found that most famous commercial trademarks are using nanomaterials. Table A.2.1. shows the materials that are used in cosmetic products. It is noted that the nanomaterials are simple compounds, which reflect a fact that we need to be very careful in order to bring nanomaterials in these human touching products.

Table A.2.1: Usage of nanomaterials in healthcare products

TRADE MARK	USING NANOMATERIAL	INFLUENCE OF THE MATERIAL
AVON	Small amount of TiO_2 and ZnO (unpublished amount)	Transparent to visible light and anti-ultraviolet. Helps skin lightening.

TRADE MARK	USING NANOMATERIAL	INFLUENCE OF THE MATERIAL
NIVEA/BEIERSDORF	Small amount of TiO_2 and ZnO (unpublished amount)	Transparent to visible light and anti-ultraviolet. Helps skin lightening.
THE BODY SHOOP	TiO_2, ZnO	Anti-ultraviolet
BOOTS	TiO_2 and ZnO.	Anti-ultraviolet
THE GREEN PEOPLE	TiO_2 in Green People Sun Lotions SPF8, SPF22 or Organic Children Sun Lotions SPF25 Lavender.	Prevent ultraviolet light in UVA and UVB sections.
KORRES	Nanoscale ZnO, TiO_2 and some nanoemulsion for hair care.	Anti-UV and hair care.
L'ORÉAL	TiO_2 and some nanoemulsion for hair care without technical information.	Anti-UV and provides nutrient mineral oil for hair.
UNILEVER	TiO_2 and ZnO nanomaterials in PONDS products.	Transparent to visible light and anti-ultraviolet. Helps skin lightening.

Application in biomedicine, pharmacy and biotechnology

It takes long time to apply a new technology in medicine and pharmacy. First, the effect of the medicine must be demonstrated, by publishing the research results, taking enough evidence. Then the medicine is tested on animals before being commercialized. However, nanotechnology is raising a revolution in bio-medical and pharmacy science and industry. New type of medicines are found by so called drug delivery system, where tiny amount of drugs are packed in nanoemulsion bag and are delivered to targets by physio-biological selective interaction. Nano-CHIPs are developed in order to detect pathogens, diseases more precisely and faster… Nanodevices could be employed to inserted to the target for monitoring the react of single cells on pharmacy treatments,…

Application in environment treatment

There are 3 main purposes of applying nanotechnology in environment treatment: environment remediation by nanocolloids, application for filter film production and employing nanomaterials in monitoring the hazardous subjects.

Nanotechnology filters or nanobeads based filter layers are quite usual in commercial market. Some products are naturally found such as ceramics, clays … Some are artificially made, such as activated carbon, polymer nanobeads … The surface of these nanomaterials is modified in order to be able to absorb ions for filtering heavy metal ions or for application of filtering radioactive ions in nuclear power plans… Some other catalytic nanomaterials are deposited on porous materials' surface in order to have more active roles: such as TiO_2 for cleaning organic subjects …

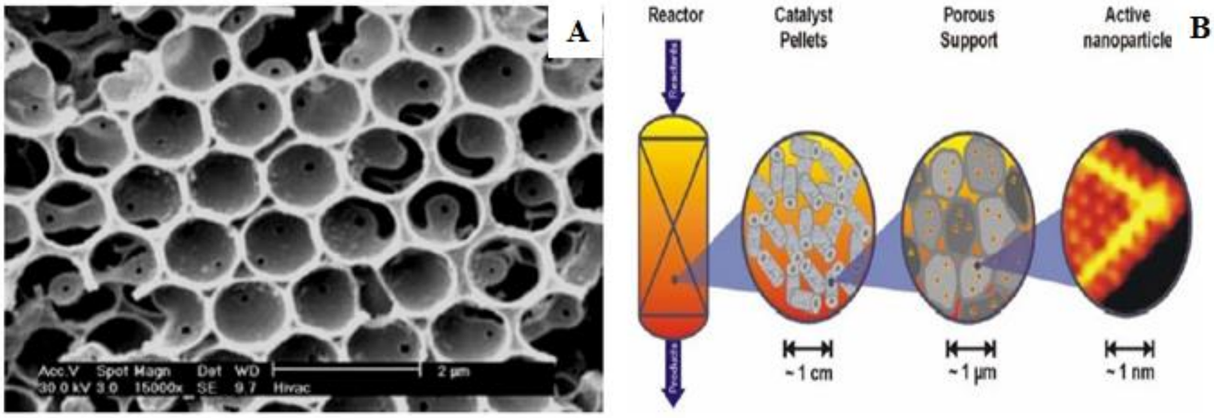


Figure A.2.4. *Application of porous films in producing filer layers: (a) nanostructural ceramics for water filter and (b) catalyst enhanced porous filtering layer*

In parallel with filtering or waste treatment, monitoring the hazard components, mainly heavy metal ions, is very important. Nanoscale thin-films are attracted to create very sensitive electrode for sensors for these purposes. Size and close contact helps these sensor having higher and higher sensitivity and selectivity. Later, the tiny size devices are made in order to be embedded to a localized target to monitor online and to control the environment condition on time.

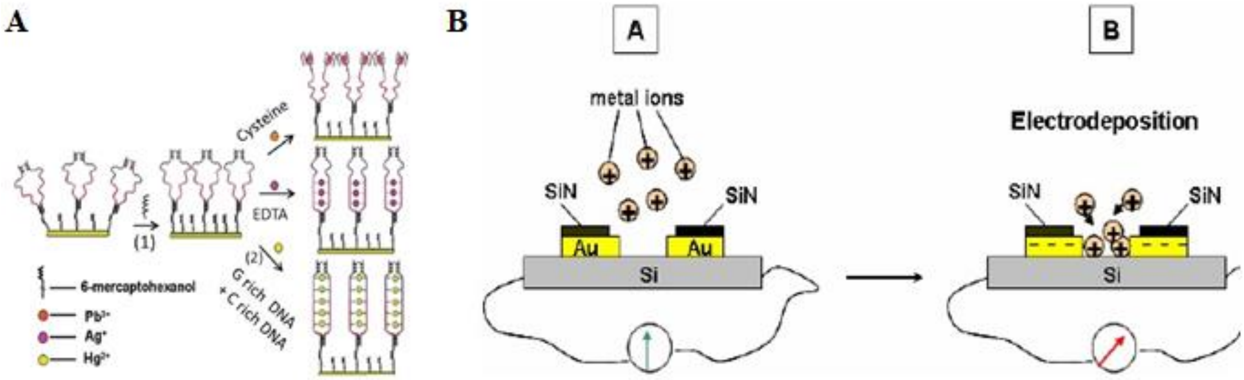


Figure A.2.5. *Application of nanoscale thin-film in small size biosensor for environment detection.*

Application in textile industry

Nanomaterials help materials becoming harder, more durable and more stable against mechanical attacks. Hence, textile products are found to have demand on those advanced properties. Table A.2.2. lists some nanomaterials applied in textile industry and their function. During this report, we find that there are some domestic products using nanomaterials: i.e. Ngoc Kim Fashion using silver and ZnO for antimicrobial and anti-UV purpose, Kissy – antimicrobial and dust absorption mask, KOVA – clothes against bullet and fire …

Table A.2.2. Usage of nanomaterials in textile products

Nanomaterial	Application in textile
Black carbon, Carbon nanotube, copper, Polyrrol, Polyalanine	Increasing the conductivity
Al_2O_3, SiO_2, Carbon nanotube, ZnO, PBA	Increasing the elasticity
Ag, Chitosan, SiO_2, TiO_2, ZnO	Antimicrobial
Fluoroacrylate, SiO_2, TiO_2	Self cleaning
TiO_2, MOF – metal organic framework	Humidity controlling
Nitride hydrocarbon, SiO_2	Increasing hardness, decreasing defects.
TiO_2, ZnO	Against ultraviolet
Nanoscale carbon, Sb_2O_3	Against fire

Application in construction industry

Nanotechnology is bringing interesting properties for construction materials and may provide new benefits for this industry. With thin-film technology, solar cell systems are built directly upon the surface of building in order to save energy. Thin-film products are installed on glass surface in order to absorb UV-light and for close infrared light reflection against heat. Nanomaterials are embedded in concrete to increase their elasticity, hardness … (see Figure A.2.6).

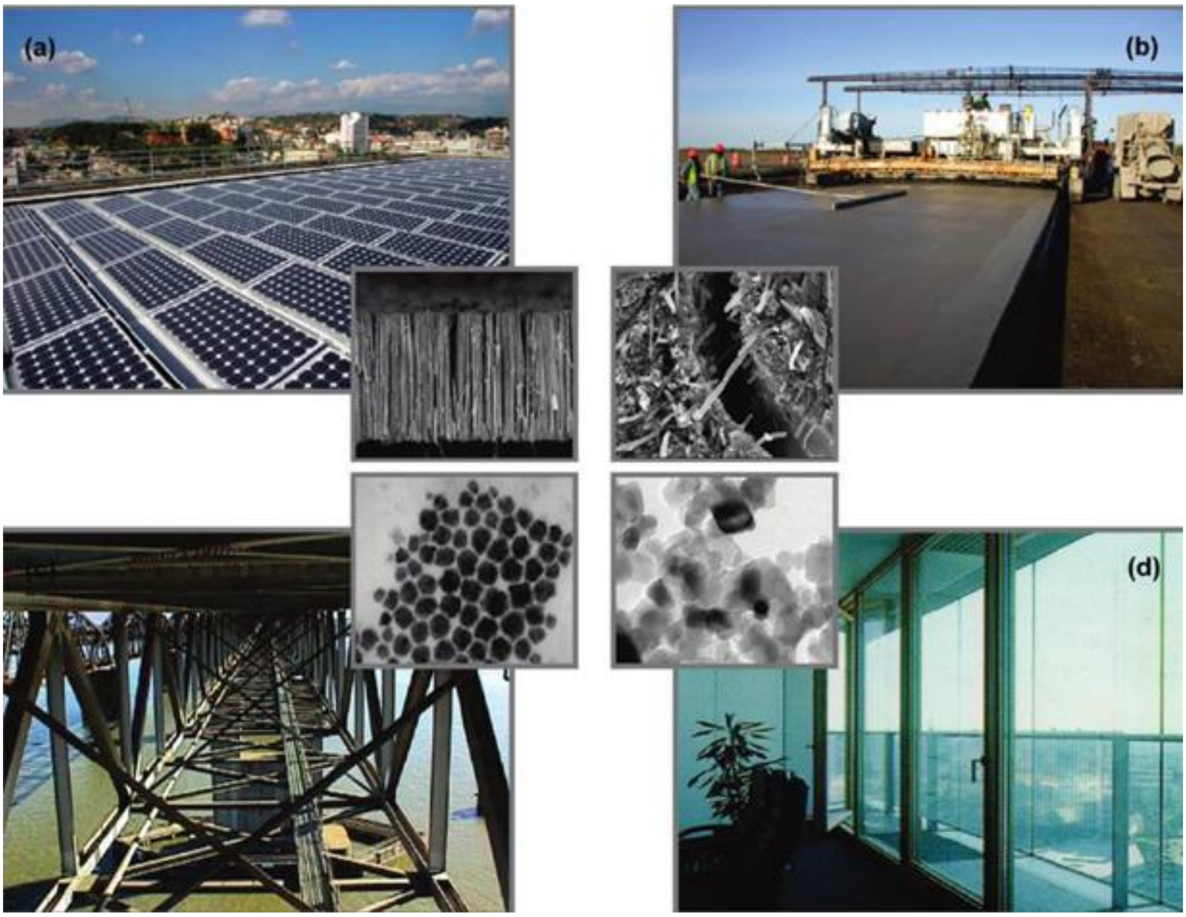


Figure A.2.6. *Application of nanotechnology in construction. (a) Application of thin-film SiO_2/TiO_2 bilayer for solar cell – inserted: TiO_2 layer. (b) Carbon embedded concrete – inserted: carbon nanotube fibers. (c) Copper nanoparticles inserted) in steel for enhancing elasticity. (d) TiO_2 particles in glass for window against UV-light.*

Table A.2.3 shows the nanomaterials applied in construction industry and their functions. We realize that bringing nanotechnology in construction is quite complicated and needs high technical auxiliary supports. But it is comfortable to use nanotechnology for constructing a sustainable and even more stable product. Hence, nanotechnology could be the future for construction industry.

Table A.2.3. Nanomaterial applying in construction and their functions

Material	Application field/material	Effect
Carbon nanotube	Concrete Ceramics Fluidic in material edges Solar cell	Increasing mechanical hardness Heat resistance Online monitoring the materials Green energy
SiO_2 particles	Concrete Ceramics Windows	Increasing mechanical hardness Cooling effect against fire. Anti-reflection
TiO_2 nanoparticles	Cement Windows Solar cell	Self clean, fast drying Superhydrophilic, against sponge Green and sustainable energy.
Fe_2O_3 nanoparticles	Concrete	Enhancing the mechanical resistance
Copper nanoparticles	Steel	Increasing the flexibility, hardness.
Silver nanoparticles	Paint/Covering	Antimicrobial

ANNEX III: Effects of nanomaterials on the environment and living subjects

Effects of nanomaterials on the environment and living subjects

The International Organization for Standardization (ISO) has been working on developing a vocabulary and core terms for nanomaterials and nanotechnologies since 2005; it was agreed to refer to the size range between approximately 1 nm and 100 nm. Questions have been raised about the scientific justification of single lower and upper boundaries for regulatory risk management purposes for all nanomaterials given that the boundaries of nano-specific phenomena vary with material composition and property under consideration. Nevertheless, it is widely recognized that size is universally applicable to define all nanomaterials and is the most suitable measurement parameter. Moreover, an understanding of the size distribution of a nanomaterial is essential and the number size distribution is the most relevant consideration".

Risk management of nanomaterials requires their extended physical-chemical characterization. A number of lists describing physical-chemical properties needed for different aspects of risk characterization have been developed by international organizations. A more comprehensive list includes seventeen physical-chemical parameters (agglomeration/ aggregation, catalytic properties, composition, concentration, crystalline phase, dustiness, fat solubility/ oleophilicity, grain size, hydrodynamic size/particle size measurement/ distribution, length, purity, shape, specific surface area, surface charge, surface chemistry, water solubility/ hydrophilicity, zeta potential), which have been identified as a necessary requisite for risk characterization of nanomaterials. Even though, only three of those seventeen properties (concentration, surface charge and catalytic properties) did not have standard measurement methods developed or under development by international organizations, more work is needed to further validate and refine physical-chemical characterization methods for nanomaterials for regulatory purposes. This need for standardization of methods for nanomaterial characterization is further highlighted by the strong dependence of measured values on the method used.

Nanomaterials contain a potential risk affecting human health. Nanomaterials are synthesized from many different sources heterogeneous structure: inorganic, organic; small size, survival and dispersal in diverse environments, the ability to interact with human body tall and capable of entering the human body through different pathways: respiration, digestion, absorption through the skin and also the nanoparticles tend to accumulate and form larger structures, so as exist in the human body will cause great impact on human health.

The survey, to evaluate the effects of nanomaterials on the health of workers, consumers and people in general is being implemented, but the new assessment analysis stop at workplace from direct contact with nanomaterials. However, the existence of nanomaterials are very diverse, from different sources should interfere with the ability to assess accurately quantify the impact of nano to human health. Besides, many kinds of nanomaterials is still very new, there have been no specific studies in order to assess the impact of all of them to a man.

With the ultrafine nanoparticles, have a high surface area, the lower solubility, so entry through the respiratory tract will cause pneumonia, tissue damage, causing lung tumors. Long and hard nanofibers once inhaled, will cause mesothelioma (fibrosis).

- Pose hazard due to dissolving ions (e.g. the toxicology of nanoscale silver due to silver ions) and due to their physical shape (e.g. toxicity of long, rigid fibers);

- Act as carriers of other material due to high adsorptive properties, and therefore can deliver hazardous chemicals present in the ambient air to biological compartments which would otherwise not be accessible to those chemicals;

- Exert biological activity through protein parts deposited on nanomaterial surface in biological environments; and

- Exhibit immunological functions, genotoxic action, or catalytic potential.

Therefore, the study of a particular way-point chemical reactions may occur in the presence of nanomaterials is the basis for building predictive models the impact of nanomaterials, help improve in summing materials, minimize the impact of materials on human health. Besides, the research and application of life cycle of nanomaterials will help the management of production and use of a deeper way.

Workers are routinely exposed to objects directly through their role in production in general, and in particular nanomaterials. For nanomaterials, different stages in its life cycle will potentially contain different influences. Therefore, determining the source life cycle and nanomaterials will minimize potential risks for workers exposed to nanomaterials. Currently there is no document to assess the risks of workers exposed while working directly with nanomaterials, which only have the documentation of emissions assessment of nanomaterials in some workplaces. The preventive measures are widely used today, such as the use of personal protective equipment, use of production methods that are more secure, organized and modern, and implementing health care epidemiology regularly for workers. However, in low and middle-income countries, these measures are limited.

Determining the exact latency is very difficult. The identification of factors such as the shape, size, surface properties and chemical composition plays an important role in determining the amount of the hazardous properties, have an impact on the environment. Similar to the chemicals, it is quite easy to measure the direct harmful effect of nanomaterials on living subjects. Education is urgently needed because of the impact on the ecology, genetics, as well as chemically modified products will create enormous potential risks directly impact on the environment and then the human health. European scientific institutes gave a very specific report entitled "Nanotechnology: Environmental Safety Assessment and Health (ENRHES)" mentioned medium containing nano properties, toxicity ecology of nanomaterials. The report also refers to the testing of nanomaterials in the aquatic environment.

Control measure for the harmful effects of nanomaterials

New technologies have been coming to the market all through human history. This has always had economic implications in the market. Sometimes there are situations where all players win, but often there will, in addition to the winners, also be some losers. While on the macro-scale a technology could be beneficial for society, at a more micro-scale there are social implications to consider. This could for example concern changing employment perspectives, necessary training of workers and education of consumers. In view of the globalized economy, such issues will not only play at the national level, but impacts should be considered in a global context. Nanotechnology should not be seen alone, but as one of the elements of the so-called Converging Technologies which are widely seen as the vehicles for future improvement of human performance: information technology, biotechnology, nanotechnology and cognitive science.

With the development and introduction of nanotechnology, obviously similar considerations as for other new technologies will play a role, including the question of social utility. To answer that question the potential contribution of specific applications from nanotechnologies to solve specific socially relevant problems such as climate change, water shortages and increasing food production should be analyzed. Health and environmental risks and implications for society and economy should be taken into account as well as existing alternative solutions. The merits of particular options may be specific to particular countries or regions.

Another social issue is related to the question is the extent to which a new technology will benefit all layers of a society. At the global level the same issue applies to the variety of countries with different levels of economic advancement. While overall arithmetic can show positive results, care should be taken that all can benefit from this and not selected groups. There is a concern that job losses which could be brought on by changes in the commodity market will hurt the poorest and most vulnerable, particularly those workers in the developing world who do not have the economic flexibility to respond to the demands for new skills. Public dialogue based on adequate communication will be an important element to help develop policies which will deal with the social aspects of nanotechnology introduction in a balanced way.

Nanotechnology is often presented as having the potential to produce considerable economic benefits. However, potential risks for human health and the environment, if not adequately managed, might lead to hidden costs for society, which should be taken into account when considering the claim of potential economic benefits. On the other hand there is an expectation that technological innovations, including those resulting from nanosciences and nanotechnologies, can play a key role in promoting a more efficient use of our resources. Natural resources are an important factor in the economy and an important element of our welfare. The way in which we use available natural resources also has effects on our health and on the environment.

Integrating socio-economic analysis (SEA) in chemical risk management decision making has a long tradition. Socio-economic analysis can help to determine whether risk reduction measures which are under consideration, are necessary or desirable. It addresses questions such as:

- What are the different regulatory or non-regulatory options for reducing the risks identified through risk assessment?
- What will be the benefits of risk reduction?
- Who will be impacted by the each of the options being considered?
- What will be the costs of implementing each of the options?
- How will such costs be distributed?
- What is the cost/benefit ratio of the options under consideration?

The principles of SEA developed for chemicals risk management can also be applied - mutatis mutandis – to manufactured nanomaterials. In the context of risk management of chemicals a number of methodologies for socio-economic analysis exist, and when adequate information is available, many of them can also be applied to manufactured nanomaterials. For example, SEA guidance documents have been produced for the implementation of the Stockholm convention and by OECD.

Information management

Improved data sharing is a crucial need to accelerate progress in risk characterization of nanomaterials for regulatory purposes. This would involve the removing of the barriers presented by the current “siloed” data environment and providing semantic search and sharing of data and models, and web-enabled tools for rapid initiation of collaboration across disciplines. This would enhance the ability to gather information regarding similar and different nanomaterials, structures, environments, mechanisms, and pathways. One of the main outcomes of establishing such a collaborative informatics infrastructure would be the development of computational models of nanomaterial structure, property, activity relationships to support the design and development of nanomaterials with maximum benefit and minimum risk to humans and the environment. Such models would also facilitate anticipatory risk management of nanomaterials.

Risk management on the life cycle

The term "manufactured nanomaterial" includes a wide category of nano-substances with very different structural characteristics, such as fullerenes, carbon nanotubes, metals or metal oxides. The structure plays, in addition to chemical properties, an important role in determining the hazard characteristics. This is not a new finding, because it is well known that for asbestos its structure is the key factor in determining its hazards. In the discussion about the possible risks of nanomaterials, the resemblance in the structure between asbestos and carbon nanotubes has been one of the early concerns.

Risk assessment involves the application of analytical tools, data, and expert knowledge for the evaluation of the potential exposure of humans and the environment to nanomaterials and the hazards that exposure might engender. Risk management methods for nanotechnology identify and implement strategies to address potential hazards. Nanomaterials are produced through the use of a new technology, which means that at the moment there is still a lack of good quantitative information for each specific substance. This means that the spectrum of possible responses to controlling nanomaterial exposures ranges from, at one end, the full application of the precautionary approach, which could be considered as inaction with respect to advancing a new technology, to inaction regarding the management of the health and environmental safety aspects while developing novel materials, at the other end. The former is typified by an assumption that new materials are highly hazardous until proven otherwise, while the latter assumes the inverse: negligible hazards until proven otherwise. Both extremes disregard risks of conventional technologies such as existing chemicals that nanomaterials are replacing. Of course there are intermediate approaches within this range.

An effective risk management framework involves the use of all relevant information to guide science-based, risk-based management decisions. The risk assessment process incorporates the best available data on the potential health effects of a nanomaterial and the exposure potential to humans and to the environment. The quality of the results of the studies and data obviously determines the reliability of risk estimates. Risk management aims to quantify risk to the extent possible. It's:

- employs basic scientific information;
- uses comparative risk assessments for different nanomaterials with different properties, applications, or intended uses that can affect effects and exposure, and result in different risk parameters and decision making;
- integrates life cycle considerations;

- considers ethical, legal, and societal implications (ELSI) such as stakeholders' values, communication needs, and other aspects of decision analysis; risk research will play an important role in understanding these factors and integrating them into an effective risk management scheme.

The current risk assessment approach used by FAO/WHO and Codex is suitable for engineered nanomaterials in food and agriculture, including the effects of engineered nanomaterials on animal health. FAO/WHO should continue to review its risk assessment approaches, in particular through the use of tiered approaches, in order to address the specific emerging issues associated with the application of nanotechnologies in food and feed.

The Scientific Committee of the European Food Safety Authority considered that:

"The risk assessment paradigm (hazard identification, hazard characterization, exposure assessment and risk characterization) is applicable for engineered nanomaterials", and it adds that" the specific properties of the engineered nanomaterials in addition to those common to equivalent non-nanoforms" should also be considered.

More information can be found in the OECD Report of the workshop on risk assessment of manufactured nanomaterials in a regulatory context. In summary, as regards the application of the risk management methods used for traditional chemicals to manufactured nanomaterials, it is considered by many scientists that the current frameworks are in principle adequate and appropriate for dealing with manufactured nanomaterials, but that more research is needed to get a better insight into those aspects in which the methodology has to be adapted for nanomaterials risk management, and in the possibilities to quantify the risks. At the moment therefore often a case-by- case evaluation has to be relied upon, and on qualitative outcomes when risk quantification is not possible. In those cases where an unacceptable level of uncertainty or concern is identified, precaution is applied.

ISO has prepared a Nanomaterial Risk Evaluation Framework which builds on the Nano-Risk Framework developed by a Nano-Partnership of the Environmental Defense Fund and Dupont.

It includes six steps:

1) Describe material and application

2) Material profiles

3) Evaluate risks

4) Assess risk management options

5) Decide, document and act

6) Review and adapt

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