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Nanomaterials and potential risks

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Abstract: The word "Nano" is developed from the Greek word meaning "dwarf". In more technical terms, the word "nano" means 10 $^{-9}$, or one billionth of something. For example, a virus is roughly 100 nm in size. Nanotechnology exhibits the top down phenomena, which means reducing the size of the smallest structures to the nanoscale. [1] Nanotechnology as a concept first raised by nobel winner physicist Richard P. Feynmann in 1959 with his call to new era for science by the lecture of "There's Plenty of Room at the Bottom"[3] The term "nanotechnology" was first defined by Tokyo Science University, Norio Taniguchi in a 1974 paper as follows: "'Nano-technology' mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or one molecule. [4] When we come up to 21st century a race began among nations to take the leadership of nanotechnology field, because it's seen a second industrial revolution or a new era. Billion dollar cost R&D studies made by developed countries. The United States, as a traditional technological power, attaches high priority to the development of nanotechnology. Since 1990s the United States has set related development policies of science and technology and guides the trend of nanotechnology development by absolute scientific research advantage and financial support.America is closely followed by Japan and China respectively. South Korea came in the fourth place with the application number gap between the top three being relatively large. [8] Making billions of dollars cost investment by both nations and private sector, we are using it more common in our daily life but still we do not have enough information about how this goods cycle continues in nature and also human body. Almost no direct data relevant to the fate and behavior of manufactured NMs in aquatic or terrestrial systems currently exist. Nevertheless, this is a rapidly developing area, and in the next few years a significant knowledge base will emerge in the scientific literature. [16] For example,CNTs are smiliar to asbestos as shape and a variety of kinase pathways important in proliferation are activated by asbestos leading to pre-malignant states and investigations are under way to determine whether fibrous CNT also affects these molecular pathways. Current research suggests that fibrous CNT can elicit effects similar to asbestos but more research is needed to determine whether they, or other nanofibres, can cause fibrosis and cancer in the long term. [20] And Titanium dioxide classified as group 2B carcinogen by IARC that means p*ossibly carcinogenic to humans.[22]* Compared with bulk TiO_2, smaller grain size of nano-anatase TiO_2 (5 nm) would allow easier entry to mouse cells and its higher surface makes its intake to the organs of mice easier. Combination of both resulted in the enhancement of the titanium in the organs.[24]Overall, these results show that TiO_2 nanoparticles may damage the development and proliferation of B- and T-lymphocytes, reduce the activity of macrophages, and decrease natural killer (NK) cell population levels, outcomes that appear to lead to an increase in tumor growth in situ. Some studies allow us to suggest that TiO_2 nanoparticles might have the potential to enhance tumor growth through immunomodulation of B- and T-lymphocytes, macrophages, and NK cells.[25] There are also some controversial studies that in short term nano-TiO_2 doesnt effect health of test animals. Debate goes on but we must be suspicious about these materials and we need new and detailed risk assessment methods than bulk counterparts. The newly launched Biocidal Products Regulation includes European Union's new assessment methods of nanomaterials. The Biocidal Product Regulation (BPR, Regulation (EU) 528/2012) concerns the placing on the market and use of biocidal products, which are used to protect humans, animals, materials or articles against harmful organisms, like pests or bacteria, by the action of the active substances contained in the biocidal product. [19]

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Keywords; Nanomaterial, Nanotechnology, Toxicity, Carbon Nano Tubes, Nano $Ti0_2$, Biocidal Products Regulation

*CNT: Carbon NanoTube

I. NANOTECHNOLOGY DEFINITION

The word “Nano” is developed from the Greek word meaning “dwarf”. In more technical terms, the word “nano” means 10^{-9} or one billionth of something. For example, a virus is roughly 100 nm in size. Naturally, the word nanotechnology evolved due to use of nanometer size particles (size of 1 to 100 nm). Nanotechnology exhibits the top down phenomena, which means reducing the size of the smallest structures to the nanoscale. [1]

According to OECD nanotechnology is the set of technologies that enables the manipulation, study or exploitation of very small (typically less than 100 nanometres) structures and systems. Nanotechnology contributes to novel materials, devices and products that have qualitatively different properties. Its advances have the potential to affect virtually every area of economic activity and aspect of daily life. [2]

II. NANOTECHNOLOGY BRIEF HISTORY

Nanotechnology as a concept first raised by nobel winner physicist Richard P. Feynmann in 1959 with his call to new era for science by the lecture of "There's Plenty of Room at the Bottom”. [3]

The term "nanotechnology" was first defined by Tokyo Science University, Norio Taniguchi in a 1974 paper as: "'Nano-technology' mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or one molecule. Nanotechnology and nanoscience got a boost in the early 1980s with two major developments: the birth of cluster science and the invention of the scanning tunneling microscope (STM). [4]

When we come up to 21st century a race began among nations to take the leadership of nanotechnology field, because it's seen a second industrial revolution or a new era. Billion dollar cost R&D studies made by developed countries.

III. NANOTECHNOLOGY APPLICATIONS

Nanotechnology is based on the investigation and manipulation of matter at the scale of billionth of a meter; borrowing approaches from academic

disciplines, which until recently were perceived more or less as isolated from each other. [5] Because of it is part of many disciplines such as medicine, physics, chemistry, engineering ultimately new areas was born like nanophysics, nanomedicine, nanoengineering. Improvements are closely related to nearly all industries such as health, energy, information technology, cosmetics.. etc.

Nanotechnologies are one of those rapidly growing fields that are attracting international gold rush. Unlike biotechnology, in which the United States took a lead from the start in the early 80’s, countries are now competing on a more equal basis for a slice of the nanotech pie. Marked advances in nanotechnologies are the result of years of work by scientists and millions of dollars of research funding. In addition, nanotechnologies tend to be highly interdisciplinary, involving scientists from different backgrounds and with various skills. Nanotechnologies are receiving increased publicity globally. In Japan, the total budget for nanotechnology research was about 82.5 billion yen in 2002 and increased to about 90.4 billion in 2003. This makes Japan’s budget fairly close to the national budget for nanotechnology in the US. [6]

The 2016 Federal Budget provides more than $1.5 billion for the National Nanotechnology Initiative (NNI), a continued investment in support of the President’s priorities and innovation strategy. The cumulative NNI investment since fiscal year 2001, including the 2016 request, now totals more than $22 billion. [7]

The United States, as a traditional technological power, attaches high priority to the development of nanotechnology. Since 1990s the United States has set related development policies of science and technology and guides the trend of nanotechnology development by absolute scientific research advantage and financial support. America is closely followed by Japan and China respectively. South Korea came in the fourth place with the application number gap between the top three being relatively large. [8]

Nanotechnology applies to almost every aspect of life and examples of products that are produced currently using nanotechnologies include:

Sunscreens and cosmetics;
Longer-lasting tennis balls and light-weight, stronger tennis racquets;
Stain-free clothing and mattresses;
Polymer films used in displays for laptops, cell phones, digital cameras;
Coatings for easier cleaning glass;
Bumpers and catalytic converters on cars; and
Protective and glare-reducing coatings for eyeglasses and cars. [9]

Near-term nanotechnology R&D trends can clearly be expected to emerge in the following areas:

Human health: drug delivery, imaging, cancer therapeutics;

Defence: energetic materials, lightweight armour composites;

Energy: hydrogen storage, improved efficiency, catalysis;

Agriculture: increased crop yields, secure packaging, chem/bio-detection and

Environment: water filtration, reduced air emissions, remediation, chemical and biological sensing.

These primary areas represent the intersection of several important variables including high market value, high social priority and availability of relevant materials. [10]

IV. NANOMATERIAL EU DEFINITION

Nanomaterial definition for European Commision is *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.*
In specific cases and where warranted by concerns for the environment, health, safety or competitiveness the number size distribution threshold of 50 % may be replaced by a threshold between 1 and 50 %. [11]

V. PROPERTIES OF NANOMATERIALS

The properties of nanomaterials do not only differ from their bulk counterpart but also between different nanoforms of the same chemical substance and hence do their effects and behaviour. The property changes can lead to e.g. differences in cell penetration, in the mode of action and in the toxicity level, and may also vary in dose-response relation-ships describing toxicity. Subsequently, the question arises how these specific properties influence behaviour and effects in the environment and whether existing risk assessment and mitigation methods can be applied to nanomaterials without further a do. [12]

I. VI. NANOMATERIALS IN NATURE

Making billions of dollars cost investment by both nations and private sector, using it more common in our daily life still wo do not have enough information how this goods cycle continues in nature and also human body.

In 2010, silica, titania, alumina, and iron and zinc oxides dominate the ENM** market in terms of mass flow through the global economy, used mostly in coatings/paints/pigments, electronics and optics, cosmetics, energy and environmental applications, and as catalysts. It is estimated that 63–91% of over 260,000–309,000 metric tons of global ENM production in 2010 ended up in landfills, with the balance released into soils (8–28%), water bodies (0.4–7%), and atmosphere (0.1–1.5%). While there are considerable uncertainties in the estimates, the framework for

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estimating emissions can be easily improved as better data become available. [13]

The reason we are using them instead bulk counterparts is its nouveal properties being more light, sustainable, optical and other chemical properties. Because of their small size and large specific surface area (SA), insoluble nanoparticles are almost not affected by the gravitational force and are generally formulated in stable suspensions or sols. [14]

Given the increasing production of NMs of all types, the potential for their release in the environment and subsequent effects on ecosystem health is becoming an increasing concern that needs to be addressed, especially by regulatory agencies. In doing so, it is necessary first to determine the fate and behavior of manufactured NMs in the environment. Do they retain their nominal nanoscale size and original structure and reactivity in aquatic and soil/sedimentary systems? Does an association exist with other colloidal and particulate constituents? What are the effects of solution and physical (e.g., flow) conditions? Is their effect on aquatic and sedimentary biota different from that of larger particles of the same material? Do biota, such as biofilms and invertebrates, modify the behavior of NMs? Answers to these and other questions will guide the setting of regulatory guidelines that will provide adequate protection to ecosystems while permitting the advantages that nanotechnology offers to be fully developed. [15]

Almost no direct data relevant to the fate and behavior of manufactured NMs in aquatic or terrestrial systems currently exist. Nevertheless, this is a rapidly developing area, and in the next few years a significant knowledge base will emerge in the scientific literature. It is instructive, however, to discuss the related and more mature field of natural colloids in aquatic and terrestrial systems. [15]

If we look at distrubition at mice body a study made by Sheng-Tao Yang et al the biodistribution of pristine single-walled carbon nanotubes (SWNTs) was determined by using the skeleton 13C-enriched SWNTs and isotope ratio mass spectroscopy. The results suggested that the SWNTs were distributed in the entire body, with major accumulations in the liver, lungs, and spleen over an extended period of time. The specimen from the effected organ tissues were examined by using transmission electron microscopy, aimed toward an understanding of the possible uptake mechanism. [16]

VII. NANOMATERİAL RİSKS?

CNTs are smiliar to asbestos as shape and a variety of kinase pathways important in proliferation are activated by asbestos leading to pre-malignant states and investigations are under way to determine whether fibrous CNT also affects these molecular pathways. Current research suggests that fibrous CNT can elicit effects similar to asbestos but more research is needed to determine whether they, or other nanofibres, can cause fibrosis and cancer in the long term. [17]

There is also a study about long, needle-like CNT, which share similar characteristics as asbestos, had the most profound effects of all of these types of graphene-based materials. These data suggest that the NLRP3 inflammasome activation is an important step in the harmful health effects caused by nanomaterials. [18]

In another study with Tio2, Braydich-Stolle et al. were able to identify that both size and crystal structure contribute to cytotoxicity and that the type of cell death initiated varies as a result of crystal structure. Furthermore, they show that the anatase TiO_2 which was previously thought to be non-toxic causes high levels of membrane leakage and necrosis. Based on these findings, the rutile TiO_2 ROS initiated apoptosis can be controlled for by treatment with antioxidants, thus making the anatase structure more toxic than the rutile. [19]

And Titanium dioxide classified as group 2B carcinogen by IARC that means p*ossibly carcinogenic to humans.* [20] Compared with bulk TiO_2, smaller grain size of nano-anatase TiO_2 (5 nm) would allow easier entry to mouse cells and its higher surface makes its intake to the organs of mice easier. Combination of both resulted in the enhancement of the titanium in the organs.[21]Overall, these results show that TiO_2 nanoparticles may damage the development and proliferation of B- and T-lymphocytes, reduce the activity of macrophages, and decrease natural killer (NK) cell population levels, outcomes that appear to lead to an increase in tumor growth in situ. Some studies allow us to suggest that TiO_2 nanoparticles might have the potential to enhance tumor growth through immunomodulation of B- and T-lymphocytes, macrophages, and NK cells. [22]

There are also some controversial studies that in short term nano-TiO_2 doesnt effect health of test animals.These studies showed that the systemic availability after oral, dermal, and inhalation exposures of the investigated Granular biodurable (GBP) nanomaterials and micromaterials was rather low. A relevant different translocation rate of GBP nanomaterials in contrast to GBP micromaterials was not observed. So far, studies providing clear evidence that GBP nanomaterials cause adverse systemic effects are not available. There was no evidence that GPB nanomaterials possess novel toxicological properties in comparison to their micromaterial counterparts. It is an open question whether long-term low-dose accumulation may lead to material levels high enough to provoke any systemic eff ects. [23]

The risks of damage to human beings can occur through inhalation of nanomaterials, through interaction with skin, by injection and by swallowing. Those who work in the factories producing or using nanomaterials and for making the industrial products stand at risk. It is therefore important to proactively address the ethical, social and regulatory aspects of nanomedicine to minimize its adverse impacts on the environment and public health and to avoid a public backlash. [24] At present, the most significant concerns involve risk assessment, risk management of engineered nanomaterials (ENMs), and risk communication in clinical trials. It is quite justified to call a revolution in Medicine and Dentistry due to the applications of Nanotechnology in these fields now commonly referred to as Nanomedicine and Nanodentistry. Although socioeconomic benefits to the society are much greater than the known risks there is a genuine need for emphasis on doing extensive R&D in this area so as to give protection to the public. [25]

For now there are no specific regulations with respect to the nanotechnology and nanomaterials but guidelines of regulations of toxic materials are used where necessary. In certain countries the consumer associations are conscious of possibility of risks involved in the use of nanotechnology and are active in safeguarding the rights of human beings. [24]

VIII. CONCLUSION

Increasing use of nanotechnology and its applications since 21st century it made our everday life easier and made new key technologies in almost every kind of science; medicine, computing,industrial fields, foods and textiles.. etc. This features spreading accross quickly we do not have much clue about how does it affects our nature, its accumulation, degradation and its access to food chain then our bodies.

Because of physical properties its entrance to our body may also be through also through our skin alongside inhalation and digestion. After all its effects may be at cellular level. Recently its suspected that carbon nanotubes which has similiar shape as asbestosis triggers DNA damage in cells. In a study made by Donaldson et al. their retention in parietal pleura, a consequence of length-restricted clearance through the normal stomatal clearance system, initiates inflammation and pleural pathology including mesothelioma. [26]

There are also some controversial studies that in short term nano-TiO_2 doesnt effect health of test animals. Debate goes on but we must be suspicious about these materials and we need new and detailed risk assessment methods than bulk counterparts.

European Union accepted new assessment methods with Biocidal Products Regulation. The Biocidal Product Regulation (BPR, Regulation (EU) 528/2012) concerns the placing on the market and use of biocidal products, which are used to protect humans, animals, materials or articles against harmful organisms, like pests or

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bacteria, by the action of the active substances contained in the biocidal product. [27]

Xia et al. propose the implementation of predictive toxicology for toxicity screening of nanomaterials. Their exercise is based on the establishment of compositional and combinatorial libraries, the development of mechanism-based in vitro toxicity screening assays, the development of multi-parametric high throughput screening assays, the building of computerized QSAR models, and the prioritization of in vivo assays to validate the predictability of in vitro assays. They think this is an appropriate approach to building a knowledge base that can meet the challenges of an expanding nanotechnology enterprise. [28]

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