An Overview on risk and Opportunities of Nanobiotechnology

Akshay Mathur, Om Prakash Janu
B.Tech III Year Student,Dept of Electrical Engg., JNU Jodhpur
akshaymathur23@gmail.com

Abstract**—Nanotechnology is regarded as one of the key technologies of the future and associated with high expectations by politics, science and economy. In this paper with a general overview of nanobiotechnology, their applications, the challenges, potential hazard and advantages has been surveyed.**

I. Introduction

NANOTECHNOLOGY and Biotechnology are two of the 21st century's most promising technologies. Nanotechnology (sometimes referred to as nanotech) is defined as the design, development and application of materials & devices whose least functional make up is on a nanometer scale. Generally, nanotechnology deals with developing materials, devices, or other structures possessing at least one dimension sized from 1 to 100 nanometers. Meanwhile, Biotechnology deals with metabolic and other physiological processes of biological subjects including microorganisms. Association of these two technologies, i.e. nanobiotechnology can play a vital role in developing and implementing many useful tools in the study of life.

Nanotechnology is very diverse, ranging from extensions of conventional device physics to completely new approaches based upon molecular self-assembly, from developing new materials with dimensions on the nanoscale to investigating whether we can directly control matters on/in the atomic scale/level. This idea entails the application of fields of science as diverse as surface science, organic chemistry, molecular biology, semiconductor physics, microfabrication, etc..

II. Development and Application Fields of Nanotechnology Products

A great number of innovative developments in different technological fields and for a number of applications and branches of industry is expected. Although the development and market penetration of many nanotechnological methods and products are still at a very early stage, a number of products and production methods are already commercially available or on their way to appear in the market.

The report "Nanotechnology" published by the Office of Technology Assessment at the German Bundestag (TAB) constitutes an important source of information on the various fields of their application, listing seven fields and presenting a number of examples in more detail, i.e.

- ***Surface functionalization and refinement*** (for example thermal and chemical protective coatings, nanometer-thin coatings for computer hard disks, biocidal coatings);
- ***Catalysis, chemistry and materials synthesis*** (for example catalytic nanoparticles, catalytic exhaust gas converters for motor vehicles, nanoporous filters, nanoreactors);
- ***Energy conversion and use*** (for example dye-sensitized solar cells, fuel cells, batteries/accumulators with a higher capacity, LEDs);
- ***Construction*** (for example plastic materials containing nanofillers, new metallic compounds with improved mechanical and thermal properties, improvement of properties of construction materials by means of concrete additives);
- ***Nanosensors*** (for example magnetic field sensors, optical sensors, biosensors (lab-on-a-chip systems)); • Data processing and transmission (for example organic light-emitting diodes (OLEDs), electronic components having nanometer dimensions); and
- ***Life sciences*** (for example use of nanobiotechnology in analysis and diagnostics, targeted transport of active substances (drug delivery systems), biocompatible artificial implants).

Due to the potential environmental and health effects of nanoparticles, special attention should be paid to those products and production processes which are suspected of releasing nanoparticles, these include cosmetic products, biocides, processes of environmental rehabilitation and the production of nanoparticles proper. The current state of development and the uses of nanotechnology products have been listed in the table below.

	Already available on the market	Awaiting marketability	Under development	Existing as concept
Chemistry	Inorganic nanoparticles Carbon black	Chemical sensors Nano-layered silicates Organic	CNT composite materials Highly	Self-healing materials

	Polymer dispersions Micronized active substances Surface refinement Easy-to-clean coatings	semiconductors Dendrimers Aerogels Polymer nanocomposites Glossy paints	efficient hydrogen storage systems	
Automotive engineering	Fillers for car tyres Components with hard coatings Antireflective coatings Scratch-resistant paints	Nanopigments Magnetoelectronic sensors Fuel cells Nanocomposites Fuel additives Anti-fogging coatings Polymer windscreens	Thermoelectric waste heat recovery	Smart paints Ferrofluid shock absorbers
Electronics	GMR HDD	CMOS electronics	PC RAM Molecular electronics RTD Milliped	DNA computing Spintronics
Optical industry	White LED	Ultraprecision optics OLED	CNT FED Quantum cryptography EUVL optics Quantum dot laser Photonic crystals	
Life sciences	Biochips Sun protection	Antimicrobials Magnetic hyperthermia Drug delivery Contrast media	Biosensors Lab-on-a-chip Tissue engineering	Neuronal coupling to artificial systems Biomolecular motors
Environmental engineering	Membranes for sewage treatment	Catalytic exhaust gas converters	Filter systems to collect ultrafine particulates Products for treatment of groundwater and soil	

III. ADVANTAGES OF NANOBIOTECHNOLOGY

The pathophysiological conditions and anatomical changes of diseased or inflamed tissues can potentially trigger a great deal of scopes for the development of various targeted nanotechnological products. This development is like to be advantageous in the following ways:

i. Drug targeting can be achieved by taking advantage of the distinct pathophysiological features of diseased tissues;

ii. Various nanoproducts can be accumulated at higher concentrations than normal drugs;

iii. increased vascular permeability coupled with an impaired lymphatic drainage in tumors improve the effect of the nanosystems in the tumors or inflamed tissues through better transmission and retention.

iv. Nanosystems have capacity of selective localization in inflammed tissues.

v. Nanoparticles can be effectively used to deliver/transport relevant drugs to the brain overcoming the presence of blood–brain barrier (meninges).

vi. Drug loading onto nanoparticles modifies cell and tissue distribution and leads to a more selective delivery of biologically active compounds to enhance drug efficacy and reduces drug toxicity.

IV. CHALLENGES FOR NANOBIOTECHNOLOGY

No single person can provide the answers to challenges that nanotechnology brings, nor can any single group or intellectual discipline. The five main challenges are to develop instruments to assess exposure to engineered nano-materials in the air and water. It is fairly understood that exposure of humans and animals to the environment potentially contaminated with nano-materials may need to be monitored for any adverse consequence. The challenge becomes increasingly difficult in more complex matrices like food. The second challenge would be to develop applicable methods to detect and determine the toxicity of engineered nano-materials within next 5 to 15 years. Then again, proposing models for predicting effects of these nano-materials on human health and the environment would be an inevitable issue. The next challenge would be to develop reverse systems to evaluate precise impact of engineered nano-materials on health and the environment over the entire life span that speaks to the life cycle issue. The fifth being more of a grand challenge would be to develop the tools to properly assess risk to human health and to the environment. Commercialization challenges of nanobiotechnology include uncertainty of effectiveness of innovation, scalability, funding, scarce resources, patience etc. A broad majority of company recognizes a great potential in nanotechnology for the development of new products and the improvement of existing products. A new potentially disruptive technology like nanotechnology raises fundamental questions about the need for new regulations. Authorities around the world should evaluate possible risks and an appropriate regulatory response to the extensive use of this advanced technology.

V. POTENTIAL HAZARDS OF NANOPARTICLES

Nanoparticles, as a result of their extreme microscopic dimension, which gives unique advantage, have potential hazards similar to particulate matters. These particles have the potential to cause varied pathologies of respiratory, cardiovascular and gastrointestinal system. Intra-tracheal instillation of carbon nanotube particles in mice has shown that carbon nanotubes have the potential to cause varied lung pathologies like epitheloid granuloma, interstitial inflammation, peribronchial inflammation and necrosis of lung. The toxicity produced by carbon nanotube was found to be greater than that produced by carbon black and quartz.

It has been shown that nanomaterials can enter the human body through several ports. Accidental or involuntary contact during production or use is most likely to occur via the lungs, from which a rapid translocation is possible to other vital organs through the bloodstream. On the cellular level, an ability to act as a gene vector has been demonstrated for nanoparticle. Nanoparticles can enter the central nervous system either directly through axons of olfactory pathway or through systemic circulation through the olfactory bulb. Studies done on monkeys and rats have shown accumulation of carbon and manganese nanoparticles in the olfactory bulb through the olfactory pathway. This shows that nanoparticle-mediated delivery can, in future, provide a means of alternate route, circumventing the blood brain barrier. However, this can also result in the inflammatory reactions/responses in the brain, which needs to be evaluated.

Radomski *et al* have observed the pro-aggregatory effects of nanotubes on platelets in *in vitro* studies and acceleration of vascular thrombosis in rat. It was also observed that fullerenes do not have the property of inducing platelet aggregation. Thus, for designing nanoparticle-based drug delivery systems, fullerenes may be a safer approach as compared to nanotubes.

The toxicity of nanoparticles can also be extrapolated to gastrointestinal system, resulting in inflammatory bowel diseases. The toxicity of nanoparticles may be related to its ability to induce release of pro-inflammatory mediators resulting in inflammatory response and organ damage. If ingested, the nanoparticles can reach the circulation and reach different organs and systems and possibly result in toxicity [58]. These have been studied *in vitro* and in animal models and the effect on human system is difficult to extrapolate from such studies. Their use in humans requires further research and much needed caution.

VI. Conclusion

Nanobiotechnology is still in its early stages. The multidisciplinary field of nanobiotechnology is bringing the science of the almost incomprehensibly small device closer and closer to reality. The effects of these developments will at some point be so vast that they will probably affect virtually all fields of science and technology. Nanobiotechnology offers a wide range of uses in medicine. Innovations such as drug delivery systems are only the beginnings of the start of something new. Many diseases that do not have cures today may be cured by nanotechnology in the future. Although the expectations from nanobiotechnology in medicine are high and the potential benefits are endlessly enlisted, the safety of nanomedicine is not yet fully defined. Use of nanotechnology in medical therapeutics needs adequate evaluation of its risk and safety factors. Scientists who are against the use of nanotechnology also agree that advancement in nanotechnology should continue because this field promises great benefits, but testing should be carried out to ensure the safety of the people. It is possible that nanomedicine in future would play a crucial/unparallel role in treatment of human diseases and also in enhancement of normal human physiology. If everything runs smoothly, nanobiotechnology will, one day, become an inevitable part of our everyday life and will help save many lives.

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