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Review Article

Nanotechnology in India: A Need for a Holistic Approach

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Abstract *- Nanotechnology has been emerging as one of the sustainable sources of meeting the mismatch between the demand and the supply of resources in the ecosystem. With the increasing population across the globe, the pressure on the ecosystem has increased manifold, thereby calling for new innovations which are sustainable amidst climate change. Though the concept of nanotechnology has been at the infancy stage in emerging economies like India, it has been optimally used by advanced economies like the United States, Japan, Germany, etc. The funding and the significance of nanotechnology have been on the rise. It has been meeting the diversified needs of different industries such as electronics, medicines, automobiles, food processing, etc. The paper has analyzed the descriptive study of Nanotechnology and has emphasized the need for a holistic approach to expanding its horizons beyond the clinical trials so that the effectiveness of nanotechnology is really proved to be beneficial to human civilizations. The paper has recommended the need for uniform and dynamic regulations in the applications of Nanotechnology in India.*

Keywords *- Nanotechnology, Emerging, Patents, Sustainable, Funding.*

I. INTRODUCTION

Nanotechnology refers to controlling, building, and restructuring materials and devices on the scale of atoms and molecules. A nanometer (nm) is onebillionth of a meter. It includes making products that use parts small, such as electronic devices, catalysts, sensors, etc.—having its applications in organic chemistry, molecular biology, semiconductor physics, energy storage, microfabrication, molecular engineering, etc. The ideas and concepts behind nanoscience and nanotechnology started with a talk entitled “There’s Plenty of Room at the Bottom” by physicist Richard Feynman at an American Physical Society meeting at the California Institute of Technology (CalTech) on December 29, 1959, long before the term nanotechnology was used. In his talk, Feynman described a process in which scientists would be able to manipulate and control individual atoms and molecules. Over a decade later, in his explorations of ultra-precision machining, Professor Norio Taniguchi coined the term nanotechnology. It wasn't until 1981, with the development of the scanning tunnelling microscope that could "see" individual atoms, that modern nanotechnology began. Although modern nanoscience and nanotechnology are quite new, nanoscale materials have been used for centuries. Alternate-sized gold and silver particles created colours in the stained glass windows of medieval churches hundreds of years ago. The artists back then just didn’t know that the process they used to create these beautiful works of art actually led to changes in the composition of the materials they were working with. It was for the first time that in 1959 Richard Feynman described the possibility of synthesis via direct manipulation of atoms. However, the term "nano-technology" was first used by Norio Taniguchi in 1974. Since then, lots of research has taken place in nanotechnology, thereby diversifying its applications in almost every aspect of human life.

Today's scientists and engineers are finding a wide variety of ways to deliberately make materials at the nanoscale to take advantage of their enhanced properties such as higher strength, lighter weight, increased control of light spectrum, and greater chemical reactivity than their larger-scale counterparts.

II. METHODOLOGY OF STUDY

The study has been purely descriptive in nature. The data has been collected from different national, international reports, websites, and articles. The views of experts from the files of Nanotechnology have also been analyzed.

III. APPROACHES TO NANOTECHNOLOGY

The following are the current approaches to Nanotechnology:-

A. Bottom-Up Approach

Bottom-up, or self-assembly, approaches to nano-fabrication use chemical or physical forces operating at the nano-scale to assemble basic units into larger structures. As component size decreases in nano-fabrication, bottom-up approaches provide an increasingly important complement to top-down techniques. Inspiration for bottom-up approaches comes from biological systems,

where nature has harnessed chemical forces to create essentially all the structures needed by life. Researchers hope to replicate nature's ability to produce small clusters of specific atoms, which can then self-assemble into more-elaborate structures. Nanotechnology

B. Top-Down Approach

The most common top-down approach to fabrication involves lithographic patterning techniques using short-wavelength optical sources. A key advantage of the top-down approach—as developed in the fabrication of integrated circuits—is that the parts are both patterned and built-in place so that no assembly step is needed. The top-down approach combines both conventional and unconventional methods to generate and replicate nano-scale structures in a fashion similar to "carving" smaller objects from large bulk material.

C. Biomimetic Approaches

This fruitful collaboration between materials science, biology, and biomedicine for the advancement of biomaterials collects the most promising solutions provided by nature for the field of biomedicine, showing how to achieve the desired functionality by using biomimetics. It consists of Bionics or biomimicry: having normal biological capability or performance enhanced by or as if by electronic or electromechanical devices. Bionanotechnology: are terms that refer to the intersection of nanotechnology and biology.

D. Functional approaches

These seek to develop components of the desired functionality without regard to how they might be assembled. Molecular scale electronics seek to develop molecules with useful electronic properties. These could then be used as single-molecule components in a nano-electronic device. For an example, see rotaxane. Synthetic chemical methods can also be used to create synthetic molecular motors, such as in a so-called nano-car.

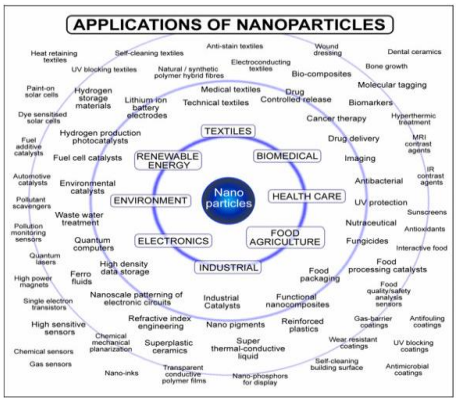
E. Speculative

These subfields seek to anticipate what inventions nanotechnology might yield or attempt to propose an agenda along which inquiry might progress. These often take a big-picture view of nanotechnology, with more emphasis on its societal implications than the details of how such inventions could actually be created.

IV. APPLICATIONS OF NANOTECHNOLOGY

Nanotechnology has been playing a significant role in meeting the increasing and diversified needs of human civilizations. On account of their nanoscale dimensions, they have high surface-to-volume ratios and thus very specific properties. Nanotechnology has been resulting in lower consumption of materials and energy and decreased harm to the environment, as well as offering environmental remediation. Recent innovations in nanotechnology have transformed a number of scientific and industrial areas, including the food industry. Applications of nanotechnology have emerged with an increasing need for nanoparticle uses in various fields of food science and food microbiology, including food processing, food packaging, functional food development, food safety, detection of food-borne pathogens, and shelf-life extension of food and/or food products. Further, the emerging field of nanotechnology has long been thought of as obscure, if not even a little scary. However, nanotech is proving its potential across different sectors, causing businesses to think about how their organization could benefit from minuscule machines and materials. Here are six areas in which nanotechnology has already shown giant promise.

1) Nanomedicine 2) Manufacturing 3) Energy 4) Electronics 5) Food 6) Smart cities etc. Other applications include the use of nonmaterial's in power plants, water treatment facilities, and road infrastructure, as well as the installation of nanosensors to monitor air pollution levels and other environmental metrics. Nanotechnology isn't just about tiny, autonomous robots. Sector-wise, healthcare stands out as the most enthusiastic adopter. Recent applications in energy, especially concerning solar, have helped to pique corporate interest in nanotechnology. And as smart cities move from theory to reality, nanotechnology could provide an answer to data dilemmas. Not only that, but nanotech is already contributing to more sustainable environments. Nanotechnology has moved beyond the pages of science fiction to represent an opportunity for essentially every industry.



V. TRENDS OF NANO TECHNOLOGY IN INDIA

The global nanotechnology market is valued at $1,055.1 ml (2018) and is projected to reach $2,231.4 million by 2025. It grew at a CAGR of 10.5% from 2019 to 2025. There has been Increasing Investment in Nano Technology across the globe. The Indian Nanotechnology Market is expected to be USD 100 million in the years to come. In terms of its composition, it is found that Nanomaterials constitute 85% (Largest), followed by Nanotools, Nanolithography and the least share is of Nanodevices. In India, the efforts to promote research in nanotechnology began early in the Millenium. The "NanoScience and Technology Initiative" started with a funding of Rs. 60 crores. In 2007, the government launched a 5-year program Called Nano Mission with

wider objectives and larger funding of USD 250 million. The funding spanned multiple areas like basic research in nanotechnology, human resources development, infrastructure development, and international collaboration. Multiple institutions like the Department of Information Technology, Defence Research and Development Organisation, Council of Scientific and Industrial Research, and Department of Biotechnology provided the funding to researchers, scholars, and projects. National Centers for Nanofabrication and Nanoelectronics were started in the Indian Institute of Science, Bangalore, and the Indian Institute of Technology, Mumbai(CENSE, 2018). Further, India has been marching ahead in nanotechnology, as can be seen from the following Table 1

Table 1. Published Nano papers (2019)

RANK	Countries	Published Nano papers
1	China	74387
2	USA	23999
3	India	15083
4	Iran	10494

Source: Global Nanotechnology Market Outlook

China has been leading from the front in the publications of research papers on different aspects of Nanotechnology. The advanced country, the United States, has been far behind China in terms of such publications. However, in terms of patent applications, India's share has been very marginal at 0.52% as compared to that of the USA, which has 45% of patent applications followed by South Korea, Japan, and China? India has to a lot of investment in nanotechnology and its applications. The need for its applications has been on the rise. The world population has been rising from 7.6 billion to 11.2 billion by 2100. This has been increasing pressure on the ecosystem.

Table 2. Nanotechnology Patent Applications at USPTO & EPC (Sept 2019)

Rank	Countries	Published Nano Patents	Share 9%)
1	USA	4666	45.16
2	South Korea	1105	10.69
3	Japan	918	8.88
4	China	825	7.98
5	Taiwan	481	4.65
6	Germany	428	4.14
7	France	262	2.54
8	UK	197	1.91
9	Canada	182	1.76
19	India	54	0.52

There has been a mismatch of demand & Supply of the resources that can fulfil the needs of mankind. The global climate has been undergoing a change. The question is, will world agricultural systems be able to cope with global climate change? Currently, there has been an inefficient use of Inputs resulting in lots of wastages. As per the European Commission, the wastages have been to the tone of 90 ml. Tonnes in 2019. Further, the European Commission has considered nanotechnology as one of the six Enabling Technology towards a sustainable Greener Economy. There has been increasing literature on the applications of nanotechnology, which has shown a positive relationship between Nanotechnology & agriculture. The applications such as "plant nano bionics has facilitated the faster growth of plants & further engineer greater absorption of solar energy---step towards greener economy (MIT). The concepts of nano fertilizer, nano pesticides, nanoherbicide, nanosensors have diversified the applications of nanotechnology. Modern agriculture, sustainable production, and efficiency are unimaginable without the use of agrochemicals such as pesticides, fertilizers, etc. However, every agrochemical has some potential issues, including contamination of water or residues on food products that threaten human beings and environmental health. Thus the precise management and control of inputs could allow reducing these risks (Kah, 2015). The development of the high-tech agricultural system with the use of engineered smart nanotools could be an excellent strategy to make a revolution in agricultural practices, and thus reduce and/or eliminate the influence of modern agriculture on the environment as well as to enhance both the quality and quantity of yields (Sekhon, 2014; Liu and Lal, 2015).

VI. CONCLUSION

Though nanotechnology has been serving the purpose in terms of reduced cost of production and efficiencies, India is still at its infancy stage. It has to step up its funding in R & D in Nanotechnology. Further, the absence of International Guidelines for the changing agronomics has been affecting the systematic growth of the Nanosector. There is an urgent need to assess the risk assessment and risk management factors prior to the implementation of regulatory guidelines. The department of Biotechnology has drafted the guidelines to validate the permissible level of nanoparticles dose within safety limits. The need of the hour will be more in-depth research away from the clinical trials so that Nanotechnology can really be a boon not only for advanced economies but also for the emerging economies across the globe.

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