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Emerging Scenario of Nanobiotechnology Development in India

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Abstract:

The paper is an attempt to explore the emerging nanobiotechnology development in India. Nanotechnology and biotechnology is one of the most important emerging fields of science in the 21st century and their merging offers opportunities for novel solutions to needs in biology. The development of these two research fields are proving beneficial for both diagnostic and novel therapies such as drug discovery, drug delivery, gene, vaccine delivery, and tissue engineering in India. The main thrust of this paper is to trace out the overview of research and development (R&D) activities among different players in Indian nanobiotechnology sector. It contributes to policy making by providing new information on the commercialisation of nanobiotechnology product in India. The paper is based on information and data gathered through from various websites, annual report, and R&D projects by the different agencies in the field of nanobiotechnology research in India.

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Key words: Nanotechnology, Nanobiotechnology, R&D, India.

1. Introduction

Nanotechnology and Biotechnology are the two most of the promising technologies in the 21st century's. Nanotechnology deals with developing materials, devices, or other structures possessing at least one dimension sized from 1 to 100 nano meters. Biotechnology is defined as the application of science and technology to living organism as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services (OECD, 2005). This sector has generated great expectations in terms of demand for innovative diagnostic and therapeutic processes and opening new paths for research. Association of these two innovative technologies generates a novel technology that is nanobiotechnology and it can play a vital role in developing and applying many useful tools in the study of life.

Nanobiotechnology is the interface between nanotechnology and biology. This is a combination of three words: Nano is tiny, Bio is living things, and Technology is about tools. Nanotechnology provides the tools and technology platforms for the investigation and transformation of biological systems and biology offers inspiration models and bio assembled components to nanotechnology (Roco, 2003). The integration of nanotechnology with biotechnology as well as with information technology and cognitive science is expected to accelerate in the next decade (Roco and Bainbridge, 2002).

Nanoscale devices are 100-10,000 times smaller than the human cell. Because of their small size and larger surface area relative to their volume, nanoscale devices can readily interact with biomolecules such as enzymes and receptors on both the surface of the cell and inside the cell. By gaining access to various areas of the body, nanoparticles have the potential to detect disease at the micro level and deliver treatment (Navalakhe and Nandedkar, 2007). Advancement in

nanobiotechnology can proves beneficial for both diagnostic and novel therapies such as drug discovery, drug delivery, gene, vaccine delivery, and tissue engineering. The convergence of nanoscale science with modern biology and medicine is a trend that should be reflected in science policy decisions (NRC, 2002).

2. Indian Scenario of Nanobiotechnology Development

2.1. Department of Science and Technology (DST)

Department of Science and Technology (DST) is the nodal department for organizing, coordinating and promoting science and technology activities in India. It is the chief agency engaged in the development of nanoscience and nanotechnology in India. The Nanoscience and Technology Mission (NSTM) were established by the government of India during the 10th plan period (2002-2007) with an allocation of Rs. 60 crores (about 12 million USD) (GOI, 2002). During 11th plan period (2007-2012) this programme was upgraded through another major initiative known as 'Nano Mission' with a budgetary allocation of Rs. 1000 crore (about 250 million USD) for 5 years (GOI, 2007). Nano Mission aims to create the necessary innovation climate for nanotechnology in the country by strengthening basic research through funding support, creating centres of excellence, fund application oriented R&D projects, foster public private partnerships, organize international collaboration and provide effective education and training to researchers and professionals.

The 12th plan (2012-2017) focusses on promoting collaborative research involving national and international laboratories on technologies to produce nanoparticles and the latest characterization techniques, promoting R&D, public private partnership mode, establishing a well-equipped center of excellence for development and adoption of nanotechnology in the health sector (GOI, 2012). During the 11th five year plan (2007-2012) declared that nanobiotechnology applications for

drug delivery, molecular imaging medical diagnosis, biosensors, tissue engineering, bioenergy and biofuels, medical robotics, microbial prospecting for novel compounds, wound dressing, genes, and bioremediation etc. are other important thrust areas. Several other government funding agencies are also supporting the growth of nanobiotechnology research in India. The major funding agencies are Department of Biotechnology (DBT), Indian Council of Medical Research (ICMR), Department of Information Technology (DIT), Defence Research and Development Organization (DRDO), Council for Scientific and Industrial Research (CSIR), and Department of Atomic Energy (DAE) supporting the expansion of nanobiotechnology in India.

2.2. Department of Biotechnology (DBT)

Department of Biotechnology is one of the key stakeholders in nanotechnology development in India. It was set up primarily for the development of modern biology and biotechnology in India. It is trying to promote research in nanobiotechnology. It held consultations for roadmap on nanotechnology and its application in medicine and diagnostics as early as August 2004. In 2006, Minister of State for Finance had announced that the government would develop a nanobiotechnology policy (Economy Bureau, 2006). In 2006 the department has issued four calls for proposals relating to nanotechnology in the fields of agriculture, including nutrition and mitigating soil pollution, biology, nanobiotechnology, drug delivery systems and medicine for both fundamental research and technology development. There has been a focus on developing industrial products in public or private domains and create public-private partnerships for drug and biomolecule delivery.

2.2.1. R&D Projects Funding by the Department of Biotechnology in Nanobiotechnology

Department of Biotechnology has been engaged in promoting

interdisciplinary research, fostering innovations and promoting the development of translational research in various areas of Nano biotechnologies including developing new therapeutics, diagnostics for early diseases detection and imaging, designing and development of smart nanomaterial for tissue specific drug delivery, bio separation, tissue engineering, medical devices and implants, fabricating sensors for detection of chemical and pathogens in food and crop. In the year 2007-2008, 42 sanctioned projects were reported to be in the areas such as drug delivery and diagnostics, cancer therapy, water purification, environmental management, pesticide delivery, amongst others (DBT, 2008). During 2009-2010, 94 projects have been sanctioned in the last four years and some of the research highlights are as follows in table 4.

Table 1: R&D projects Sanctioned by DBT in the different organizations for promoting nanobiotechnology in India.

Centres/Institutes/Universities	**Technology/Application areas**
Amrita Institute of Medical Sciences, Kochi	Novel nano delivery carrier for systemic control and release of parathyroid hormone for the treatment of bone diseases
Institute of Pharmaceutical Sciences, Punjab University	Studies are under progress in the development of drug loaded solid lipid nanoparticles for treating cerebral tuberculosis
B. V. Patel PERD Centre Gandhinagar	Drug delivery and drug targeting using therapeutic nanoparticles
University of Madras, Chennai	Using quantum dots as a fluorescent label to detect cancer cells in place of conventional methods
Anna University, Chennai	Quantum dots and rods bio conjugates as target probes in imaging cancer cells
Tuberculosis Research Centre, Chennai	Protein engineering for self-assembly systems for applications in nanoscience and nanotechnology
Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore	Cellular interaction of nanoparticles, effect on epigenetics and thereby its role in gene expression: implications from drug delivery to diagnosis

University of Calcutta	Gold nanoparticles in drug delivery and diagnostics
Indian Institute of Technology, Guwahati	Nanoscale materials with therapeutic implications
University of Kerala	Bio conjugation of nanomaterials and their application in cancer therapy
National Chemical Laboratory, Pune	Biological synthesis of sophorolipids using yeast, their use as capping and reducing agent for the synthesis of nanoparticles
Aligarh Muslim University, Aligarh	Potential of nanoparticle encapsulated siRNAs in cancer treatment
University of Mumbai, Mumbai	Targeted nanoparticulate drug delivery system of doxorubicin for hepatic cancer using asialoglyco protein receptor mediated approach.

Source: DBT, 2012.

2.3. Indian Council of Medical Research (ICMR)

ICMR an autonomous body under the Ministry of Health and Family Welfare is engaged in R&D that seeks to address health needs of the nation. It invests in research that has been identified as national health priorities such as control and management of communicable diseases, fertility control, maternal and child health, control of nutritional disorders, alternative strategies for health care delivery, and control within safety limits of environmental and occupational health problems research on major non-communicable diseases like cancer, cardiovascular diseases, and drug research (ICMR, 2007). It has currently funded a few projects dealing with research on nanomaterial use for drug delivery in areas of tuberculosis, retinoblastoma and ophthalmic and toxicological and chemotherapeutic aspects of these nanoparticles.

2.4. Department of Information Technology (DIT)

Department of Information Technology (DIT) under the Ministry of Communication and Information Technology were set up with the agenda of making India a front runner in the

age of information revolution. Realising the potential of nanotechnology in information and communication technology, it launched a nanotechnology development Program in 2004. It had made an investment of 126 crore and sanctioned 18 projects by 2007. There are two centres of excellence have been created at Indian Institute of Technology (IIT), Bombay and Indian Institute of Science (IISc), Bangalore focusing on development of nano systems for healthcare and environmental monitoring, development of organic and biopolymer devices, acoustic sensors, among others. It has been created a facility and expertise centre at Council of Scientific and Industrial Research (CSIR)-Central Scientific Instrument Organization (CSIO) for development of bio-nano sensors for healthcare and agriculture application. Dip-Pen-Nano based nano patterning facility has been setup at CSIR-Central Electronics Engineering Research Institute for nanofabrication being used in application such as biosensor arrays, photonics and nano circuitry.

2.5. Defence Research and Development Organization (DRDO)

The mission of Defence Research and Development Organization to establish world class science and technology base to equip the country's defence services with internationally competitive systems and solutions. It has supported and engaged with research in the areas of nanomaterials, nanotubes and device development. Defence Materials and Stores Research and Development Establishment (DMSRDE), Kanpur under the DRDO has set up a nano material development, carbon nanotube manufacturing facility. One of the labs under DRDO has based on a Nanosensors developed at Indian Institute of science, Bangalore and developed a typhoid diagnostic kit that is 30 times more sensitive than earlier prototypes. Future plans of DRDO with national and international collaborations include establishing a laboratory focused on nanomaterial based medical devices.

2.6. Council for Scientific and Industrial Research (CSIR)

Council for Scientific and Industrial Research was set up under the Department of Scientific and Industrial Research (DSIR) as an autonomous body in 1942 to provide scientific, industrial R&D that maximises the economic, environmental and societal benefits for India. It has been supporting projects in the broad area of nanoscience and technology. In between 2003-2007 the research projects was based on chemical science and technology and material sciences. It has undertaken fabulous work in the health domain and has been instrumental in the development of drugs and pharmaceuticals. This has led to its interest in nanotechnology R&D in medicine and health. Under the 11th five year plan, a network project on nanomaterials and nanodevices in health and disease with Centre for Cellular and Molecular Biology (CCMB) as the nodal lab has been initiated. Rs 40 crore has been budgeted for this (CSIR, 2007).

Central Scientific Instruments Organization (CSIO) one of the constituent CSIR laboratories has developed a low-cost, easy to use, portable tuberculosis diagnostic kit based on nanotechnology. A few projects related to nanotechnology have also been facilitated under the New Millennium Indian Technology Leadership Initiative scheme **(**NMITLI). This scheme seeks to develop efficient public-private ventures for developing large scale projects of national importance or industrial significance.

2.7. Department of Atomic Energy (DAE)

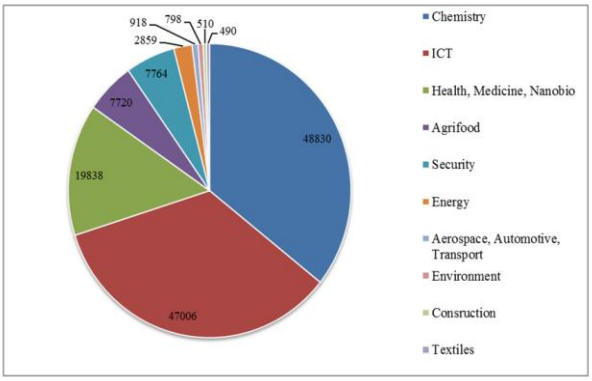
The Department of Atomic Energy is a multidisciplinary organization engaged in the development of nanotechnology. Its vision with respect to nanoscience and technology is to understand the behaviour of nanomaterials and cultivate methods for their fabrication and characterisation and then use this knowledge to create devices. It is working in the area of

lasers, radiation detectors, nanoscale motors and drug delivery systems. It supported basic research in chemical sciences and engineering sciences, including materials and surface engineering. It has planned an advance technology development program that it claims will form the backbone of product development in nanotechnology. The department is interested in biocompatible materials, super lattice of nanomaterials and drug delivery systems.

3. Patents and Publication Activities in Nanobiotechnology

R&D investments are indicators for the main inputs into science based innovation while R&D only covers one aspect of technological change and innovation. Publication and patent data provides complementary indicators for research and development activities although capturing intermediate outputs (OECD, 2008). Patents are the most important way in which researchers can protect the ideas or technologies they have developed. It reflects the ability of transferring scientific results into technological applications. It is also an essential for economic exploitation of research results and is thus central for any analysis which deals with economic potentials of a technology and the identification of most promising fields and actors in terms of persons, organizations or countries (Hullmann, 2006). Countries across the globe are now competing for competitive edge for leadership in the global market through technological growth and development. Patents are now seen as a powerful indicator of the status and competitiveness in the modern world. As a figure 1 provides sector wise nano related patent applications worldwide between 1992 and 2008.

Figure 1: Comparison of worldwide nano related patent applications in specific sectors between 1992 and 2008.



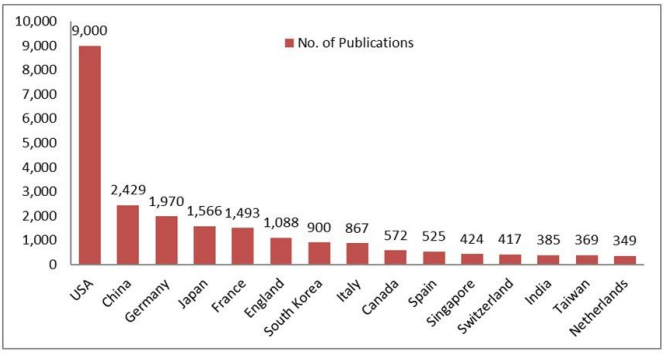
Source: Adapted from Brand, 2011.

The preceding figure shows the numbers of patent applications have broken down to ten specific application sectors. The energy sector shows the outstanding growth, the security sector as well as agriculture and food have greater contribution in patent numbers. Chemistry, materials and information and communication technologies (ICT) contribute with the largest sectoral shares. This is clearly due to the enormous importance of information technology and electronics as well as to the cross sectoral characteristics of nanomaterials and nano surface chemistry and their significance to numerous technical applications. Nano related biomedical applications including consumer products such as home detergents, cosmetics, and body care represent a third sector continuously contributing with more than 1000 annual patent applications.

In the International Patent Classification (IPC) health sector is divided into four subsectors based on the health section. These four subsectors are (i) dental care, (ii) drugs, (iii) diagnostic kits, and (iv) medical apparatus and medical care. As nanotechnology contains a variety of different technologies and the perspective of intellectual property the IPC does not yet have proper classifications to represent it. Only in version 7 did the IPC include class B82 referring to nanotechnology and it ranges only subgroup B82Y which specific uses or applications of nanostructures, measurement or analysis of nanostructures,

manufacture or treatment of nanostructures. B82Y 5/00 belongs to nanobiotechnology or nanomedicine, e.g. protein engineering or drug delivery. India has applied 21 patents in B82Y 5/00 nanotechnology class at USPTO in the Period 2000-2012 (Kumar and Desai, 2013). Figure 2 provides a list of the fifteen countries publications in the field of nanobiotechnology.

Figure 2: The top 15 countries in nanobiotechnology ranked by the No. of publications (1990-2008)



Source: Adapted from Tekeda et al., 2009.

The preceding figure shows the number of nanobiotechnology papers published by authors in each country. The USA shows a remarkable presence in nanobiotechnology while China has the second largest number of publications in nanobiotechnology. Other countries such as Singapore (11) have a high impact on nanobiotechnology publication and Switzerland (12) has a significant impact on nanobiotechnology publications, while Netherlands (15) appear to be devoted to nanobiotechnology. India has the thirteen ranks and contributes to about 2 per cent of the global publications in nanobiotechnology and maintaining a global competitiveness because of significant government funding, educational initiatives and academic collaboration. The top ten Indian institutes based on nanobiotechnology related publications are Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) Bangalore, Indian Institute of Science (IISc) Bangalore, Bhabha Atomic

Research Centre (BARC) Mumbai, Indian Association for the Cultivation of Science (IACS) Kolkata, National Physical Laboratory (NPL) New Delhi, Indian Institute of Technology (IIT) Kharagpur, IIT Madras, IIT Delhi, National Chemical Laboratory (NCL) Pune and University of Delhi.

4. Emerging Scenario of Nanobiotechnology Industry in India

Nanobiotechnology R&D and products in the Indian industry are still in the initial stages of development. Most of projects are moving through different stages of research and clinical trials from phase I to III and a few nano based drug delivery systems have already reached the market. The Indian biopharmaceutical industry is seeing business opportunities trends such as merger and acquisition, takeovers, collaboration, in-licensing, increase in R&D investment, innovations in healthcare and drug delivery as well as product penetration into the tier I to tier VI markets to make significant inroads into nanomedicine and nanodiagnostics (Nanowerk, 2012). Companies such as Lupin Ltd., Cadila Healthcare Ltd., Biocon Ltd., Dabur Pharma Ltd., Panacea Biotec Ltd., Piramal Life Sciences Ltd., Cadila Pharmaceuticals Ltd., Dr. Reddy's Laboratories Ltd., Natco Pharma Ltd., Shasun Pharma Ltd. and Venus Remedies Ltd., among others are working on nanomedicines or launched nanotechnology enabled therapeutics. Table 2 provides a list of some of the major nanobiotechnology based products commercialized by Indian companies and institutions.

The global value of total market for nanobiotechnology products is $19.3 billion in 2010 and is growing at a compound annual growth rate (CAGR) of 9 per cent to reach a forecast market size of $29.7 billion by 2015 (BCC, 2011). The market size for nanomedicine and nanodevices in India as of today is very small (Nanowerk, 2012). Centre for Knowledge

Management of Nanoscience & Technology (CKMNT) estimates that over a period of next 10-15 years the domestic nanotechnology market in this segment will grow up to US$ 1.6 billion at a Compounded Annual Growth (CAGR) of 47 per cent with the potential to reach US$ billion and India will be the fastest emerging player in the biopharmaceutical nanotechnology sector worldwide. Oncology, arthritis, diabetes mellitus, viral infections etc. are the potential areas where nanotechnology can have significant impact for the Indian biopharmaceutical industries in the future (Nanowerk, 2012).

Table 2: Some of the nanobiotechnology based products commercialized by Indian companies and institutions partnerships

S. No.	Company	Name of the product/technology	Source of Technology
1	Eucare Pharmaceuticals Private Limited, Chennai	Nano bioceramics for dental, orthopaedic and bone graft applications	NML, Jamshedpur
2	ABS Medicare Pvt. Ltd., Vadodara	A process for the manufacture of hydrogel wound dressing	BARC, Mumbai
3	Cadila Pharmaceuticals Limited, Ahmadabad	Nano sensor based typhoid detection kit	IISc Bangalore and DRDE Gwalior
4	Lifecare Innovations Pvt. Ltd., Gurgaon	Liposomal based amphotericin B formulation	PGIMER, Chandigarh
5	Velbionanotech, Bangalore	Bio-nano chip and DNA based drugs	In-house
6	Centre for Advance Research & Development (CARD), Bangalore	Nano blaster to blast cancer cells in the human brain	In-house
7	Bharat Biotech, Hyderabad	Nano particle loaded drugs for drug delivery	International collaboration (Novvax Inc., USA)
8	Panacea Biotech, New Delhi	Smart hydrogel nanoparticles for drug	In-house

		delivery systems	
9	Lifecare Innovations Pvt. Ltd., Gurgaon	Nanotechnology based drug delivery systems	University of Delhi
10	Dabur Pharma Ltd., New Delhi	Drug delivery systems for cancer treatment	University of Delhi
11	Bilcare Limited, Pune	Anti-counterfeiting security technologies for drugs	In-house
12	Tata Chemicals Limited, Mumbai	Biosynthesis of gold nano triangles	In-house
13	Bharat Serums and Vaccines Limited, Mumbai	Nano emulsions (Injectable NDDS)	In-house
14	Natco Pharma Ltd., Hyderabad	Nanotech based generic version of breast cancer drug (Abraxane)	In-house

Sources: Collected from websites and annual report of the companies

4.1. India's International Collaborations

There are several mutual collaborations emerges in nanoscience and technology agreements between India and other countries. These Initiatives for joint R&D have made-up prominently with Indian institutes engaging in projects of similar kind in the United States, Europe, Japan, Taiwan and Russia. The science and technology departments of Brazil, South Africa and India have entered on a trilateral initiative to developed collaborative programmes in nanotechnology based drug delivery systems. The International Science and Technology Directorate (ISAD) of the Council of Scientific and Industrial Research (CSIR) that aims to support cooperation between CSIR and international institutions has facilitated workshops and collaborative projects with international partners like South Africa, South Korea, China, France, Japan in the area of nanoscience and technology.

Another forum for international collaboration is the Euro-India Net set up under the Six Framework Programme (FP6) between Europe and India to encourage collaborations

between scientists in the area of nanotechnology. In 2006, a joint Indo France Symposium on Nanotechnology held allowed discussions on basic nanoscience research as well as applications of nanotechnology in areas of medicine. A memorandum of understanding has been signed between India and UNESCO to establish a regional center for education and training in biotechnology where one of the focus areas is on nanobiotechnology. The United Kingdom has joined hands with India to establish a joint Nanotechnology Working Group to speed up the development of new technologies. These initiatives between India and the UK will help create an environment that incentives cooperation.

India has also taken initiative to establish standards on various aspects related to nanotechnology including terminology, metrology and health and safety practices and it develops standards like Bureau of Indian Standards (BIS) at the International Standards Organization Technical Committee, ISO/TC 229 on nanotechnology. Nanotechnologies Sectional Committee, MTD 33 was constituted in BIS in 2007 to enable participation at the ISO initiative and to formulate national standards in the field of nanotechnology. The MTD 33 has created in parallel to the ISO four national panels on terminology and nomenclature, measurement and characterization, health, safety and environment as well as on materials specification (Deshpande, 2011).

4.2. Challenges for Nanobiotechnology Industry

The Indian nanobiotechnology sector is subject by the drug delivery. It exposes greater interest towards the therapeutics, vaccines, nutracetuticals and bone scaffolds, sensors and biomarkers. Other areas are diagnostic and health consumer that open the interest in cosmetics, sunscreens, antibacterial, antiseptic, antimicrobial coatings, water purification systems. The techniques for nanobiotechnology therapies are extraction and characterisation of nanotechnology for business goal.

Patenting is an important factor that determines what gets commercialised and by whom. Nanobiotechnology sector is an initial stage of development and this stage is meaningful to identify the critical barriers in the commercialisation process. This sector is facing shortage of human resources as in most of the institutes and only few scientists are engaged in research. Lack of venture capital is identified as one of the important barriers in the commercialisation.

The country needs strict legislation in this field it involved many issue related to nanotechnology development and there should be a clear cut IPR regime. India lacks strong national policy and has affected the development of the sector. Regarding government funding is concerned there is a general opinion that India lacks adequate government funding and there is a need of more funding. In addition, public sector R&D institutions and several companies in India are researching on nanomedicine, especially in the development of newer drug delivery systems against cancer, diabetes, fungal infections, and viral infections and for gene therapy. The pharmaceutical, biotechnology and biomedical companies in India are concentrating on nano based platforms for developing therapeutic and diagnostic modalities. There is a possibility of India being a global player in the nanotechnology in coming future. If these challenges are overcome, the nanobiotechnology market will develop into a sustainable component of the Pharma biotech industry.

5. Regulatory Actors of Nanotechnology Applications

Department of Biotechnology focuses essentially on nanobiotechnology based research and most of the nano research funded by the Department of Scientific and Industrial Research (DSIR) refer to materials and metals and chemicals. Institutes and laboratories under the Council for Scientific and Industrial research such as the Central Drug Research

Institute and the Indian Toxicological Research Institute are engaged in crucial and specialised research fundamental for nanotechnology governance. The Ministry of Health and Family welfare (MoHF) is involved in governance of nanotechnology applications in health sector through its Directorate General of Health Services, under which the Central Drugs Standard Control Organisation (CDSCO) is situated. Institutionally MoHFW is in charge of prevention and control of health related hazards.

The Ministry of Environment and Forest (MoEF) deals with environmental impacts or hazards originate from a new application. Department of Pharmaceuticals, Ministry of Chemicals and Fertilizers are engaged with advanced studies and research in pharmaceutical sciences including toxicology. They also have the order for conducting programmes on drug surveillance, community pharmacy and pharmaceutical management. The Ministry of commerce an important actor in protecting intellectual property rights in the field of nanotechnology. It is responsible for addressing the complexities of nanotechnology in the current patent legislation.

The role of international level organization such as World Health Organization (WHO) is to develop, establish and promote international standards with respect to food, biological, pharmaceutical and similar products. The International Risk Governance Council (IRGC) is an independent international organization. It is set up with the objective of helping the different stakeholders in understanding and management of emerging global risks that have an impact on human health and safety, the environment, economy and society at large. The International Organization for Standardization (ISO) is the premier international organization and fairly actives in engaging with aspects of material standardization of nanotechnology in health sector.

6. Conclusion

Nanobiotechnology development in India is at a foundational stage and powerful effort would be needed on the part of research organisations and industry to successfully engage with such technologies. The multidisciplinary field of nanobiotechnology is bringing the science of the small device closer and closer to reality. 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 and it is possible that nanomedicine in future would play a crucial role in the treatment of human diseases. There are many multinational biopharmaceutical companies planning to launch their nanotechnology based products or invest in R&D operations in India. These multinational companies are setting up through joint research and collaboration and in-licensing or out- licensing agreements with the Indian companies. These key factors provide full opportunities for Indian players to explore various paths in the nanobiotechnology sector.

The Government of India has been encouraging the growth of the sector by funding nanobiotechnology projects under various programs of DBT, DST, DSIR and ICMR. Other stakeholders such as universities, research institutes, and private firms are also emerging as important players in this area. It has played a major role for developing the nanobiotechnology research ecosystem in undertaking leading programs, major investments, development of model curriculum, initiating joint university industry projects, establishing centre of excellence and enhancing laboratory facilities, developing human resources and building international collaborations.

Other important issues are strong implications for a technology to develop such as governance and regulatory structure, involvement of actors, stakeholders and linkages

among them. It is essential to identify the roles for different actors and stakeholders. India has taken initial steps in addressing standardisation issue and it develops standards like Bureau of Indian Standards (BIS) and CSIR-NPL (National Physical Laboratory). The role of international forums such as the IRGC, ISO, WHO in taking the lead in setting guidelines in the establishment and implementation of international standards and in facilitating a network of information and monitoring for adoption in domestic policies becomes important in India. Finally, there are numerous products forthcoming and some of the products are running in the market. So, it is essential to construct a standardize policy framework for this emerging technology to protect from any destructive effect on society across the globe.

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