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Prospects of Nanotechnology Development in the Health Sector in India

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Abstract

Nanotechnology has been regarded as a science and technology based innovation and is recognized as a promising new growth innovator of the 21st century. It offers a range of possibilities for healthcare and medical innovation, including targeted drug delivery systems, extended release vaccines, diagnostic and imaging technologies, and antimicrobial coating. These innovations have become a major focus not only for government policy initiatives and investment, but have also heralded for both nanomedicine and pharmaceutical industries. This paper explores theemerging nanotechnology development in the health sector in India. The paper also contributes to policy making by providing new information on the commercialization of nanotechnology in the health sector.The paper also analyses the potential and challenges in the development of rapidly growing nanotechnology research in the health sector in India. It also highlights the regulatory players involved in nanotechnology in the health sector in India. The paper is based on both primary and secondary research. The information is based on personal communication from eight Indian pharmaceutical firms involved in nanotechnology research and development (R&D) in the area of health sector.

Keywords: nanotechnology; nanomedicine; health; R&D, India.

1. Introduction

The application of nanotechnology to the screening, diagnosis, and treatment of disease, known as nanomedicine is an emerging field that has the potential to revolutionize individual and collective health care in the 21st century (Adelaideet al., 2012).

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At the beginning of this century, health, science and technology were identified as basics for social and economic development as set out in the United Nations Millennium Development Goals (United Nations, 2002).Nanotechnology is defined as the design, characterisation, production and application of structures, devices and systems by controlling shape and size at the nanometre scale (The Royal Society and the Royal Academy of Engineering, 2004). The nanometre scale is usually set at 1 to 100 nm and nanotechnology makes use of the new properties of materials at this scale that differ from those at a larger scale.

The greatest impacts of nanotechnology are taking place in the context of healthcare and medicine and this arena of nanotechnology is generally referred to as nanomedicine and sometimes broadly called bionanotechnology (Vo-Dinh, 2007). The global value of the 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 (Nanowerk, 2012).

In today's global economy, the industry faces enormous pressure to deliver high quality products to the consumer while maintaining profitability (Bawa and Johnson, 2008). It must continuouslyreview how to improve the success rate of new potential drugs while reducing research and development (R&D) costs as well as cycle time for producing new drugs especially new blockbusters.The cost of developing and launching a new drug to the market are widely variable, may be upwards of 800 million US dollars. Typically, the drug appears on the market some 10 to 15 years after discovery (Reuters, 1999, Bawa and Johnson, 2008).

Annual R&D investment bydrug companies has risen from $1 billionin 1975 to $40 billion today, while annualnew drug approvals have remained flat at between 20-30 drugs (Adelaideet al., 2012). There is a critical need to alter research approaches and business models and it is not surprising that drug companies today are turning to the miniaturization and nanotechnology to enable faster drug target discovery and drug development (Bawa et al., 2008).

Nanotechnologybased pharmaceuticals offer potential solutions to fundamental problems in the drug industry, ranging from the poor water solubility of drug compounds to a lack of target specificity. In time, nanotechnology should reduce the cost of drug discovery, design, and development (Bawa et al., 2008).Both private and public research efforts worldwide is developing nano products aimed at improving health care and advancing medical research. Some of these products have entered the marketplace, more are on the verge of doing so, and others remain more a vision that a reality. In the coming years, significant research will be undertaken in various areas of nanomedicine generating both evolutionary and revolutionary products (Bawa, 2007b).

In this backdrop, the paper is divided into six sections. Section one presents the introduction ofnanotechnology in the health sector. Section two deals with the structure of nanotechnology development in the health sector in India. Section three presents the Indian nanotechnology firms in the health sector. Section four analyses the emerging scenario of nanotechnology in the health sector. Section five deals with the policy and institutional environment for nanotechnology in the health sector in India and finally section six deals with discussion and conclusion.

2. Structure of Nanotechnology Development in the Health Sector

Nanotechnology in the health sector has involvedvarious scientific agencies providing support for creating capacity and directing applications to the sector. It has been possible due to the involvement of various stakeholders such as government involvement, academia, research organizations, industry and international collaborative network.

2.1.Government

Department of science and technology is the nodal department for nanotechnology development in India. It initiated and implemented the Nano Science and Technology Initiative in 2001 and it was launched as a mission mode program in the 10th plan period (2002-2007) with an allocation of Rs. 60 crores (about 12 million USD) (GOI, 2002). During the 11thplan 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 five years (GOI, 2007).

The Union Cabinet has approved for the second phase of the nano mission in the 12th plan period (2012-2017) at a total cost of Rs. 650 crores (GOI, 2012). During the 11thfive year plan (2007-2012) declared that nanotechnology 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 nanotechnology research in the health sector in India. The major funding agencies are Department of Biotechnology (DBT), Indian Council of Medical Research (ICMR), Department of Information Technology (DIT), Defense Research and Development Organization (DRDO), Council for Scientific and Industrial Research (CSIR), and Department of Atomic Energy (DAE) supporting the expansion of nanotechnology in the health sector in India.

2.2. Academia

Universities and engineering colleges are adopting nanotechnology in their course curriculum at the degree level, specialized M. Tech programme and doctoral programmes. Institutes like Indian Institutes of Technology (IITs) are a group of fifteen autonomous engineering and technology oriented institutes of higher education established and are actively involved in nanotechnology research in the health sector in Indi. Some of them are centre of excellencein this field and have specialized units for nanotechnology research. IITs are also offering courses at the M. Tech level and different departments have PhD scholars pursuing doctoral research in this area.Indian Institute of Science (IISc)has grown to become India's premier centre for research and postgraduate education in science and engineering.

IISc centre of excellence in nanoelectronics focuses on research and education in the areas of nanoscaleelectronics, devices, technologies, materials, micro and nano-electromechanical systems, bio-electronic interfaces, and integrated small scale systems.

2.3.Research Organizations

Publicly funded research organizations have been the major stakeholder in developing the knowledge capacity in nanotechnology development in the health sector. Department of Biotechnology (DBT) is one of the key stakeholders in nanotechnology development in the health sector in India.Council of Scientific and Industrial Research (CSIR) has been supporting projects in the broad area of nanotechnology R&D in medicine and health. Defense Research and Development Organization (DRDO) has supported and engaged with research in the areas of nanomaterials, nanotubes and device development. One of the labs under DRDO has based on a Nanosensors developed at the Indian Institute of Science, Bangalore and developed a typhoid diagnostic kit that is 30 times more sensitive than earlier prototypes. National Institute of Pharmaceuticals Education and Research (NIPER) is actively involved in biomedical research and application. It is undertaking research and nanotechnology for targeted drug delivery and nanomedicines.

2.4. Industry

Associated Chambers of Commerce and Industry in India (ASSOCHAM), Federation of Indian Chambers of Commerce and Industry (FICCI) and the Confederation of Indian Industry (CII) are three major industrial associations involved in the promotion of nanotechnology in India. CII started its own nanotechnology initiative in 2002 to create a supporting environment for industry through knowledge exchange missions, awareness programmes, workshops, market research and other range of services. Under this initiative CII in partnership with the DST organizes nanotechnology conclave annually starting from 2006 to facilitate collaborations between industry and institutes. A number of private sector actors have started investing in nanotechnology activities in the health sector. Some big companies such as Nicholas Piramal and Reliance Life Sciences have planned to develop nanotechnology based drug delivery systems.

2.5. India's International Collaboration

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 to allow 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 for 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 in 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 material specification (Deshpande, 2011).

3. Indian Nanotechnology Firms in the Health Sector

Firms are the key actors in innovation and production and it is characterized by specific learning process, capabilities and organizational structures as well as by beliefs, expectations and goals. It is connected in various ways through market and non-market relationships (Nelson and Winter, 1982; Teece and Pisano, 1994; Dosi et al., 2000). There has been some recent interesting nanotechnology developmentin the health sector in India. Private companies began investing in the R&D laboratories at university and government institutions. Numerous nanotechnology applications in the healthcare that are either currently on the market in India or are planned to be marketed over the coming years. Key companies include Dabur Pharma Limited, Bilcare Research Ltd,Prakruthik Health care, Shasun Pharmaceuticals Ltd and Nanoparticle Biochem, Natco Pharma, Richmond Chemical Corporation, Vascular Concepts, and Lifecare Innovations Pvt. Ltd. are leading firms in India which are active in the different areas of nanotechnology research in the health sector.

3.1. Dabur Pharma Limited

Dabur Pharma Limited is a leading Indian company in the field of nanotechnology. It is engaged in cancer research and a manufacturer of anticancer drugs. This nanoscale drug delivery system is India's first indigenously developed nanotechnology based chemotherapy agent.The company headquarter is in Ghaziabad, Uttar Pradesh, India. It operates in more than five countries and distributes its products worldwide.Dabur manufacturing operations are in India, Africa and the United Arab Emirates.

It has collaborated with University of Delhi's, the chemistry departments for the nanotechnology based drug delivery systems. The company has two patents for the drug delivery systems and formulation and started nano based research in 1997.It has developed nanotechnology products and recently launched in the markets. Product name is Nanoxel; it is an anti-cancer drug paclitaxel. It was the first time that a nanotechnology based pharmaceutical product was being commercialized outside of the United States (US). It has recently received the United States Food and Drug Administration(USFDA) approval for its generic paclitaxel, and file for European and US approvals for Nanoxel.The clinical trials for the same will be first conducted in Europe and a few Asian countries.

3. 2.Bilcare Research Limited (BICL)

Bilcare research Limited is a public pharmaceutical packaging company in India. It is basically based in Pune and expanded globally in the US, Europe and Asia. It is working in the field of security technology and developed a nanotechnology based anti-counterfeiting solution called NonClonable. It operates a modern manufacturing and research facilities in India, Singapore, United States of America and United Kingdom with its global centre of excellence in Pune and has regional offices in Brazil, Germanyand China. The research and development centre in India has approved by the Department of Scientific and Industrial Research (DSIR), Ministry of Science and Technology. Its manufacturing and research facility in Singapore has awarded pioneer enterprise by the Government of Singapore. The company has 32 patent applications globally, 9 patents granted and over 136patents filings worldwide for novel packaging materials, processes, systems and technologies addressing counterfeit, compliance and the other risks of the healthcare domain.

A NonClonableID technology that comprises unique materials based fingerprints which are difficult to copy and can track and trace products, thus restricting counterfeiting of pharmaceutical products. This technology covers anytime, anywhere authentication and track and trace technology for people and products. The applications of NonClonableID across different sectors like pharmaceutical, heritage assets, agrochemical, high value goods, document security, security and ID cards, currency security, medical compliance, fashion and luxury goods property registration etc.It has awarded by ChemTech Foundation India, on 14th February 2009 conferred the prestigious Pharma Bio 2009 "Innovation of the Year" award on this technology. It is a first company to have filed Drug Master Files (DMF's) with USFDA for its entire product range of specialty packaging materials. It has quality certifications including International Organization for Standardization (ISO) 9001:2000, 14001:2004; Occupational Health & Safety Advisory Services (OHSAS) 18001 and Current Good Manufacturing Practice (cGMP) certification.

3.3. Prakruthik Health Care Pvt. Ltd. (PHCPL)

Prakruthik Health Care Private Limited is an Ayurvedic company in India. It is based in Hyderabad and playing a key role in developing the nanotechnology based healthcare solutions in India. It is working in natural therapeutic medicine and has taken initiatives in the fields of nano healthcare, nano Cosmeceuticals and nano agriculture and horticulture.

Nano healthcare is coming out initially with three products N-detox, N-Jeev and En-Tube Capsules.It is licensed by the drug licensing authority, Department of Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homoeopathy (AYUSH), and the Government of Andhra Pradesh, India. It is supported in its research initiatives for total Ayurvedic health solutions, by Varun Herbals Clinic, Delhi,and aScientific & Industrial Research Organization (SIRO) company, Department of Science and Technology, Government of India. It has collaborations with Indian Institute of Chemical Technology (IICT), Hyderabad.The company aims to market its products in nine Indian states of Andhra Pradesh, Karnataka, Tamil Nadu, Gujarat, West Bengal, Orissa, Maharashtra, Punjab and Rajasthan in addition to export markets such as Singapore, Malaysia, Thailand and African countries.

3.4.Natco Pharma Limited

Natco Pharma Limited is a Hyderabad based pharmaceutical company in India. It is engaged in manufacturing and marketing pharmaceutical substances and finished dosage forms for Indian and international markets. It began operations in 1984 in Andhra Pradesh, India. It has launched Albupax, a nanotechnology drug for treatment of breast cancer. It is the first generic version of the international brand - Abraxane® of Abraxis Bioscience Inc., USA. The company has 66 Indian patents and international patents granted, and 41 Indian and 85 international patent applications filed. It entered into an agreement with Dr. Reddy's Laboratories Limited to jointly develop and sell generic cancer products on a profitsharing basis. The deal covers oral and injectable drugs, including paclitaxel, the generic form of Abraxis Bioscience's breast cancer drug Abraxane. It will exclusively supply the drugs to Dr. Reddy's Ltd. and Dr. Reddy's will sell globally.

3.5. Richmond Chemical Corporation

The Richmond Chemical Corporation is a USA based chemical and biosciences company.It is working on drug delivery systems based on nanotechnology and researching into systems for treatment of Alzheimer's disease. It is dedicated to thedevelopment of nanodevices for life science applications such as targeted therapeutics and drug screening, and nano analysis of biological systems using single molecule imaging and force spectroscopy.

Richmond Chemical Corporation's India office is located in the city of Hyderabad, Andhra Pradesh to facilitate collaborations with Indian and Chinese research institutes. It conducts sourcing and distributions of fine and specialty chemicals, both domestically and internationally. For the lab facilities, Richmond Vivek Laboratories (RV Labs) is the Indiabased synthetic organic chemistry a unit of the Richmond Chemical Corporation located in Hyderabad.

3.6. Vascular Concepts Limited

Vascular Concepts Limited is a Bangalore based leading company engaged in the design, development and manufacture of endovascular medical devices that address the treatment of arterial diseases. Arterial diseases include Coronary Artery Diseases (CAD) and peripheral vascular diseases (relating to the arteries that are located outside the heart). The group develops its own technology based patent portfolio of intellectual property and includes 28 patents in the United States.

The company has manufacturing collaboration with Eucatech AG of Germany, where all its devices are manufactured to the European standards. It has developed first generation stainless steel coronary stent systems ProLink LP and ProLink SV for smaller coronary vessels. The second generation of products includes a state of the art nanotechnology coating on stents developed between Vascular Concepts and a US company, which has granted an exclusive worldwide license on platinum, activated coronary stent system Propass. It has introduced its drug eluting coronary stent systems Pronova. It patented drug eluting stents, with a combination of sirolimus and cyclosporine are undergoing preclinical trials in the Netherlands.

3.7. Lifecare Innovation Pvt. Ltd.

Lifecare Innovation Private Limited is an Indian biotechnology firm. It is situated in Gurgaon, Haryana. The company engaged in research, development, manufacturing and marketing of healthcare products and specializes in controlled release pharmaceuticals employing an array of technologies of novel drug delivery systems (NDDS). The first product FUNGISOME is developed in India by combining liposome and nanotechnology delivery of Amphotericin B to target fungal or Leishmania cells. It is used for the treatment of life threatening systemic fungal infections and Kala-azar.

It has collaboration with the Council for Scientific and Industrial Research, Pretoria, South Africaled consortium for clinical development and commercialization of a sustained release PLG (poly DL-lactide-co-glycolide) anti-TB product. The in-house R&D lab of the company is approved by the Department of Science and Industrial Research, Government of India. The promoters of the company have filed 14 patents, including under the Patent Cooperation Treaty (PCT). It has set up a centre of excellence in Lucknow in anovel drug delivery system based involving liposomal and nano drugs.

3.8. Shasun Pharmaceuticals Limited

Shasun Pharmaceuticals Limited is an Indian pharmaceutical company. It is a Chennai based firm. The company has formed a new 50:50 joint venture (JV) with Nanoparticle Biochem Inc. (NBI) which is partly owned by the University of Missouri, USA. This new joint venture has worked for development of nanoparticles for use in therapy and medical diagnostics. The joint venture has developed a radioactive gold nano construct based therapeutic agent,S-NBI 29for treating solid tumours. The joint venture plans to come out with a gel like application for wound healing, delivered through nanofibers.In India it has collaborated in both research and clinical application of nanoparticles in different areas with different hospitals and institutes. Hospitals in India and at the University of Missouri, USA could be among the first to initially test the drug in pilot level clinical trials offering the benefit of cancer patients. It has more than 40 patents.

The potential of the use of this technology is treating various solid tumours, including the oral cancer, head and neck, prostate and pancreatic cancers. According to the World Health Organization, prostate cancer affects 4.6 out of every 100,000 Indians, compared with 104.3 per 100,000 in the US. In India, 85% men seek treatment when the cancer is in an advanced stage, compared with 15% in the US. The prostate cancer market was estimated to reach $7.7 billion by 2015 from $5.2 billion (PTI, 2010).

4. Emerging Scenario of Nanotechnology in Health Sector

This section is based on an on-line survey. The questionnaire was sent by e-mail to the leadingscientists, policymakers and entrepreneurs engaged in nanotechnology development in the health sector in India.

4.1. Focus Areas of Nanotechnology Research in the Health Sector

During the survey, it is found that Indian nanotechnology in the health sector is dominated by the therapeutics. This is exposed,the greater interest towards the drug delivery mechanisms, vaccines, bone scaffolds, Sensors and biomarkers. Other areas are diagnostics and health consumer that revealed the interest incosmetics, sunscreens, antibacterial or antimicrobial coatings and water purification systems. In response to the questions regarding preference in the health sector, most of the respondents shown their inclination towards the development of strategies and techniques for nanotechnology therapies in comparison to extraction and characterization of nanotechnology as potential or business goal.

4.2.Collaboration Pattern of the Firms

In order to inquire about the collaboration, it is found that most of the institutes/firms have some kind of collaboration with others and preference for collaboration depends upon the nature of the organization and it varies according to their mandate. Indian firms are spin-off from foreign firms and most of the firms prefer collaboration with the public institutes. It also showed their interest in private hospitals inthe clinical trials. The survey also tried to investigate the challenges of collaboration and exposed that most of the firms believed that lack of shared vision and organizational structure are the main challenges of collaboration followed by other factors like maintaining access to additional funding and increase competition between the groups. Lowering R&D and human resource managements ranked a second followed by market access and government connections. Only a few indicated collaboration with the suppliers as important and to a certain level.

4.3. Challenges to Commercialization

The Indian nanotechnology industry is at an initial stage of development. The survey has revealed that the Indian nanotechnology in the health sector is facing shortage of human resources.

The response pointed to the fact that in most of the institutes only few scientists are engaged in nanotechnology research in the health sector.One of the entrepreneur opined that the lack of enabling technologies is most important barriers for the nanotechnology in India. Lack of venture capital is also identified as one of the important barriers in the commercialization.Some of the firms feel that there should be a clear cut intellectual property regime. Ethical issues did not figure as critical barriers in the development of nanotechnology research. Some of them expressed that India lacks clear 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 for more funding.

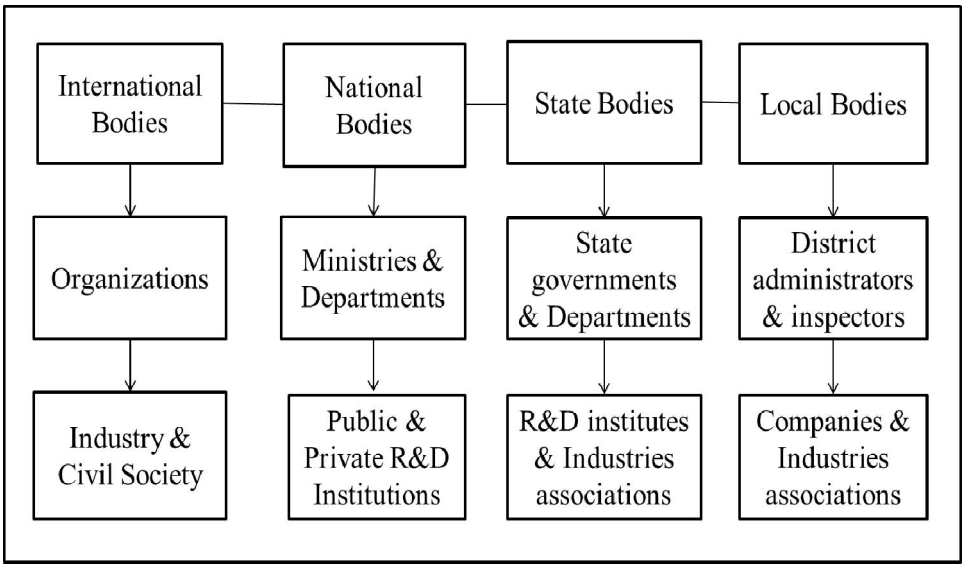
4.4. Potential of Nanotechnology inHealth Sector

Nanomedicine has bright growth prospects in India with its related research being carried out in various academic and scientific institutions. The undergoing research in the field of nanomedicine mainly explores its application to provide targeted drug therapy, diagnostics, tissue regeneration, cell culture, biosensors and other tools in the field of molecular biology. Public sector R&D institutions, various 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 like fullerenes, nanotubes, quantum dots, nanopores, dendrimers, liposomes, magnetic nanoprobes and radio-controlled nanoparticles for developing therapeutic and diagnostic modalities.

5. Regulatory Players in Nanotechnology in the Health Sector in India

The Regulatory framework for nanotechnology development in the health sector in India involves a host of players and institutions, including research bodies, promotional agencies, planning bodies, nodal ministries, other ministries, regulatory agencies, implementing agencies etc. performing different functions. As a figure 1 shows the regulatory framework of nanotechnology applications in the health sector India involves various players at various levels.

Figure 1: Regulatory Players in Nanotechnology in the Health sector in India



Source*:* Authors own compilation

The preceding figure describes the regulatory players in nanotechnology policy in the health sector works at various level players which influence the design and implementation of the regulation.The role of international level organizations such as the 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.

The important players in the national health research system are the DBT, ICMR, DST and CSIR. Ministry of health and family welfare (MoHFW) is in charge of prevention and control of health related hazards. The MoHFW has been indeed engaged with nanotechnology, but that has been primarily by way of the research on nanotechnology applications in the health sector by ICMR. It supports toxicological studies relating to nanoparticles in health applications through the ICMR.

It involved in governance of nanotechnology applications in the health sector through its Directorate General of Health Services (DGHS), under which the CDSCO is situated. The Central Drugs Standard Control Organization (CDSCO), state controllers and inspectors together regulate the import, manufacture, distribution and sale of drugs in India.There are four other organizations involved with developing health and environmental regulations for nanotechnology in India: the Ministry of Environment and Forest, the Ministry of Chemical and Fertilizers, the Ministry of Health and Family Welfare, and the Ministry of Labour and Employment.

The Drugs and Cosmetics Act of 1940 gives this ministry the power to regulate drugs and cosmetics, which means that any nanoparticles found in these sectors will be regulated by the Ministry of Health and Family (Subramanian et al., 2012).Indian National Science Academy (INSA) seems to be the only government scientific body that has a clear mandate to liaison between science and humanities.It is set up a specific committee on ethical issues involved in nanotechnology applications in the health sectors. Other civil society organizations such asThe Energy and Resources Institute (TERI) focuses on understanding the regulatory issues and the challenges posed by nanotechnology in the health sector in India.

An overview of the nanotechnology research focus in the health sector in India exposes that research with respect to risks associated with nanotechnology has been lacking. Its applications might have the potential to pose diverse Environmental, Health and safety (EHS) risk to consumers and the public. A few toxicological studies have been supported by various agencies for R&D. Cost and risk intensive area of nanotechnology is a difficult ground to enter not only for application or commercialization but also research and development. It is necessary to develop a short, medium and long term plan for creating innovative capacity in nanotechnology. Creation of risk analysis, assessment and management centre, need for anticipatory and adaptive governance, programme coordination and funding required from the top governance level should be at a priority level.

6. Conclusion

It is observed that though the Indian nanotechnology development in health sector is in emerging stage.There is a clear indication of rapid growth and the co-evolution of technology and institutions is yet to emerge.

The private and public research laboratory has engaged as the dominant players and pharmaceutical firms are playing a major role in this sector. Most of the pharmaceutical firms are engaged in drug delivery system rather than diagnostics and health consumer related nanotechnology research. Linkages are important for the sectoral growth. On examination of linkages, it was found that, firms, research laboratories, and hospitals have developed linkages with each other along with international collaboration. There are many challenges to commercialisation of nanotechnology research in India such as lack of enabling technologies, lack of venture capitals and relatively inadequate funding. It seems that given the nature of composite technologies involved, there is a greater need felt for R&D and training collaboration.

For shaping futures for a balanced growth of this sector, the institutions in India will have to be geared towards greater coordination, promotion of greater knowledge flows at national as well international levels.Government and industry must pay greater attention to emerging public concerns of nanotechnology of nanomedicine (environmental, ethical, societal and health issues) in order to prevent any public backlash. Acceptance of nanomedicine will largely depend upon trust in government oversight of ethically sound R&D and commercialisation. Only then will the public be more engaged in and aware of nanomedicine, leading to its wider adoption in society.

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