Global investments in the field of nanomedicine and nanotechnology drive the scientific innovations at nano level. This paper identifies the factors of Indian Healthcare which promotes (pull) and suppresses (push) the growth of nano medicine research in India. Pull factors such as shift in healthcare collaborations, strong information technology platforms, budding innovations in the field of nanomedicine and interdisciplinary approach in India’s scientific output are the potential drivers of nanomedicine research in India. Push factors highlighted the inefficiency in healthcare regulation, novel versus Generic mind and lack of political will to invest in nanomedicine research. These acknowledged push and pull factors can be helpful during health policy reforms and to plan research and development investments in India.

**Keywords:** Nanomedicine, push factor, pull factor, India, healthcare

**UDC:** 620.3 (031)

**Introduction**

Nanomedicine in India is still in infant stage, comparing with other. Research and development in science field are shifting from macro perspective to micro and now innovations are made at nano level. Nanomedicine is one of the applications of Nanotechnology involved in the monitoring, repair, construction and control of human biological systems at the molecular level, using engineered nanodevices and nanostructures. Nanotechnology’s harmful effects on human beings and the environment should be monitored and regulated at early stage. Concept of push and pull factors has its deep roots in migration theories (SciDev Net, 2010; AAG 2011; GIS for History, 2008; Ntumba and Shiang-Lih, 2011).

In context of Indian healthcare, potential factors (push factor) which could inhibit the growth of Nanomedicine research and factors (Pull factor) which acts as driver to enhance nano research are highlighted in this paper. The objective of this paper is three fold, first fold reviews developments of Nanomedicine around the world, second will try to figure out push and pull factors of Indian healthcare which can influence the growth of Nanomedicine research and third part explains the possible ideas to encourage research in Nanomedicine based on the factors identified. Nanomedicine applications are useful to prevent and treat the acute and chronic ailments that prevalent globally and early diagnosis, cancer therapy, nano diagnostics, regenerative medicine, nano sequencing of DNA, cosmetics, drug delivery systems, and Prosthetics are possible (Moni, 2009; Freitas, 2006; ICE, Undated; CORDIS, 2005).

**Methodology**

For the data and analysis scientific journals were retrieved in research databases. Riviste on-line and PUBMED were used frequently. PUBMED in built databases such as MeSH and Boolean Operators were used to find the terminologies and articles. Websites of
corporate authors, periodicals and Articles in the field of nanotechnology was retrieved for the information about recent developments in the field.

**Nanomedicine around the world**

Major cast and investors in Nanotechnology and Nanomedicine includes United States, Taiwan, Japan, South Korea, United Kingdom, China, European Countries, India and Russia. World’s governments spend around US $ 10 billion every year on Nanotechnology Research. The positive impact of Nanotechnology is inevitable in the field of health and other fields where it has been deployed (Cientifica, 2011). Innovations in Nanomedicine which imprinted the success in various research fields are as follows.

**Nano Tweezers**

Nanotweezers are used to pick and move individual cells with the help of its sensitive grip without any damage, and used as a probe to study the mechanical properties of tissues and biological materials inside the living organisms. This application is very useful to create microscale and nanoscale devices which could be helpful in treating and diagnosing the health defects at genetic and cellular level (Inman, 2008).

**Targeted drug delivery - for cancer and ischemic heart disease**

Nano medicine is a trend setter of targeted drug delivery. Conventional treatments of cancer such as irradiation and chemotherapy drugs lack specificity in targeting the tumor cells also damages the healthy tissues with undesirable side effects. Nano medicine overcomes these issues (Ventola, 2012). In recent year's tumor targeted nano medicines are deployed to identify and kill tumor cells in the body (Lammers, Hennink and Storm 2008; Bar, Yacoby and Benhar, 2008).

To enhance the bioavailability of drugs at the point of action, the drugs are carried using the nano carriers which are biocompatible and biodegradable in nature. In a recent study, Carbon and Silica nano particles used as carriers to deliver the drug in treating ischemic heart disease. These nano carriers are proved to be non toxic and easily removed from the body. Results shows that the clinical outcome of the patient improved and the targeted drug delivery is safe and efficient (Glagaduza, Korolev, Sonin, Postnov, Papayanet et al., 2010).
Furthermore scientists’ also developing self assembling molecular nano stents - a device which can support arteries physically - and many other devices which can probe the plaque which causes stroke (ICE, Undated).

**Nanomedicine applications in regenerative medicine**

Regenerative medicine is a broad interdisciplinary science that attempts to restore lost, damaged, or aging cells and tissues to a state as close as possible to its native architecture and function. Strategy in regenerative medicine is injecting the bio compatible nanoscaffolds into the body. This scaffold is made up of thin fibrous protein and other compounds. Before injecting, nanoscaffolds are combined with living cells or bioactive molecules which help to replace and regenerate the damaged tissues, bones or cells in the site of action (NYT, 2012).

A research study performed for bone regeneration by scientists using nanoscaffolds, in this case Nanoscaffolds are combined with nano hydroxyapatite (nano-HA), collagen, electro-spun silk, anodized titanium and nano structured titanium surfaces which imitate the same structural and composition like natural bone. Outcome of the study showed the positive response in the formation of bone (Macarena, García, López-Ruiz, Bustamante et al., 2012; Bouliaiez, Alvarez, Ramirez, Marchal et al., 2011).

**Other Medical Application of Nanotechnology**

Other than above applications, Nanomedicine is applied in HIV control, Dentistry, nutritional sciences, surgical oncolgy and many other non health related fields as well.

![Table 1. Other applications](source: Adopted from (Raffa et al., 2010)]

<table>
<thead>
<tr>
<th>Application</th>
<th>Medical use</th>
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<tbody>
<tr>
<td>Nano-electro transducers</td>
<td>Electro-stimulation therapies</td>
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<tr>
<td>MRI contrast agents</td>
<td>Imaging of tumours and molecular Imaging</td>
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<tr>
<td>Nano-bio sensors</td>
<td>In vitro and in vivo diagnostic</td>
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<tr>
<td>Nano-bio-generators</td>
<td>Dispense with need for power supplies in powered implants</td>
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**Push and pull factors of Indian healthcare which could influence nanomedicine research**

**The push factors**

Novel versus Generic: Competition between generic and novel ideas is widespread among the Indian researchers and healthcare professionals in the field of science. India’s health system and drug policies molded the practice of manufacturing generic medicines over the new drugs. The efforts of research field are deployed for making generic drugs and biosimilars, instead of novel techniques in emerging sciences like nanotechnology and others. In addition to support this idea Dr. Abraham of Nichi-In Center for Regenerative Medicine (NCRM) says, “When compared to the developed nations, we did not start basic research in nanomaterials well in advance and due to lack of such original technologies in materials, processes and methodologies we need to depend on already patented materials and methodologies to accomplish end-product developments,” (BMJ, 2011; BioSpectrum, 2011).

Inefficient regulation: Healthcare regulation somehow failed to hold the veins of coordination between the private researchers and public health organizations, no common goal is shared between public and private. Presently most of the prevention interventions are carried out by publicly funded health organizations. Sometimes they fail to buy the
new drugs from private research organizations for prevention interventions because the drugs are not cost effective and it is expensive for public. The motivation of doing research in private organizations could also be affected by the lack of demand in the market and the lack of coordination from public health organization. Pricing regulation on the new technologies and drugs should be considered to overcome this situation.

Policy makers fail to frame policies which could coordinate the activities of both private research and public health organizations. After completing the pre clinical trials of a new nano drug, Drug Controller General of India (DCGI) needs several years to understand about the drug, as the drug is new and takes time to grant the approval for conducting clinical trials (phase I), thereafter it takes several years to market the drug. Sometimes healthcare regulator fails to act on time, authorities from R&D sector demands strong regulation on rapid authorization of market approval of new drugs and intellectual property IP protection in Nanomedicine and nanotechnology (BioSpectrum, 2011).

Political Will: There is lack of political will in funding the research and development projects in country; it is transparent by reviewing the Five year plans prepared by planning commission of India in order to develop the economy (Planning commission, 2010).

Significant efforts and investment made by government is more inclined towards agriculture, poverty alleviation, economic liberalization, increasing the productivity level of industries by upgrading its technology and education.

In spite of this situation, Ministry of science and technology are making efforts to establish a strong research base in Nanomedicine and nanotechnology through various departments and establishing NSTI - nano science and technology initiatives (DST, 2006)

**The pull factors**

Historical science base: As a part of knowledge based economy India has immense potential human resources for doing nanomedicine research. Trend analysis of the researches done and papers published in India for a decade reveal the diversity of the country’s scientific output, in the fields of Microbiology, pharmacology & toxicology, chemistry, physics, agricultural science and tropical medicine. Research in nanotechnology is emerging in many universities and research Institutes. Professional courses on Nanoscience and nanotechnology are started in many state and central level Universities (Adams, King and Singh, 2009).

Little Drop of Innovation: Since 2003 research institutes in India started developing nano drugs against Tuberculosis, Cancer, Viral Infections and gene therapy. Even though the nano drug research in the country is not up to the level of expectations, there are some budding innovations in nanomedicine made by private players. India’s first Nano drug is called ‘Fungisome’ - the life saving drug innovated using the limited technology available in the country to treat deadly fungal infections (BioSpectrum, 2011).

Information technology (IT): IT base in the country is well established. Technologies are tailor made on demand and many international projects are running throughout the country’s IT infrastructure. Use of IT resources in health is not new, e - health applications in the country are more successful compared with neighbors. To avoid the technology failure in field of nanomedicine, technologies can be developed based on the need assessment of nanomedicine research, capability, effectiveness and applicability. After assessment of the country’s epidemiological data, technologies can be scaled up for nanotechnology.

To be more cost effective, healthcare system can deploy the existing pool of information technology in the country to improve nanomedicine research, instead of importing the technologies from abroad (Lewis, Hodge, Gamage, and Whittaker, 2012).

Efforts in collaborations: Collaborations in research are less in Indian healthcare nowadays. But previously more research was performed in collaboration with USA,
France, Netherlands and Australia. Now there is a geographical shift in scientific research collaboration from “west to east”.

Nowadays the collaboration trend is shifting towards eastern world countries such as Japan, China, Taiwan, South Korea and Singapore. Beyond the scale of achievements in science, Indian Universities and research centers organize conferences and seminars on nanomedicine and nanotechnology at global level in vision of enhancing its participation and scientific collaboration of nano research. Second World conference on nanomedicine and drug delivery was held at Kerala, India in 2011 (Adams et al., 2009; Ninan, Thomas, George, and Sebastian, 2011).

**Few ideas to enhance the research in nanomedicine**

Based on the essence of push and pull factors above, India is putting huge efforts to change its identity from knowledge based economy to research driven economy. Firstly, well-built political support is needed for all nanotechnology research organizations in terms of support, investment and regulation. Research driven companies should pull up their product pipelines with the new and novel drugs instead of the generic; it enhances the focus of researchers in scaling up the nanomedicine research.

Adopting interdisciplinary approach is quite common in all research areas; it will help in getting new ideas in nanomedicine field. Collaborations within the country and outside should be increased in the field of nanomedicine and strong policies/protocols should be prepared and implemented for proper disposing practices for nano wastes. More research is needed to study the Impact of nano particles on humans and the environment.

**Conclusion**

Nanomedicine research is flourishing in many European countries, USA, Japan, and in other developing economies. Push factors of Indian healthcare system such as narrow focused public funding for research activities, existence of generic more than novel ideas among the research pool and inefficient healthcare regulation and drug policies could inhibit the growth of nanomedicine research in India. On the other hand there are few pull factors, which promotes nanomedicine research. Overall India has a great potential and resources for scaling up nanotechnology in the country. India can prosper in Nanomedicine research if appropriate health and research policies are implemented with continued political support and efficient international collaborations.

**References**

AAG, 2011. “Migration conceptual framework: Why do people move to work in another place or country?” AAG Publications, March


Cientifica, 2011. Global funding of Nanotechnologies and its impact, Cientifica Market Reports, July

CORDIS, 2005. European technology platform on NanoMedicine, CORDIS Projects Vision Document, September

DST, 2006. “Proposal for nanoscience and nanotechnology mission,” Department of Science and Technology Press release, December


