



Nanotechnology Application in Water Sector

From the beginning to end of the value chain : An Indian perspective



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First Study of its kind focusing on various
dimensions of innovation activity in India;
aiming at providing valuable inputs for S&T
and Innovation decision making.*

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1. Introduction

Nanotechnology like Information and Communication Technologies, Renewable resources, Biotechnologies is persuaded as a major wave of economy in 21st century and drives our 5th innovation wave of Kondratieff, an important building block of three cycle schema given by Schumpeter. In the last decade, nanotechnology entered the policy arena as a technology that is presumably well known promising candidate for solving important issues such as ensuring the quality and quantity of potable water for the world society in the 21st century.

Most of the studies till now mainly emphasis on the overall nanotechnology development but as a broad impact technology, nanotechnology penetrates various industrial sectors. In this bulletin we focused our analysis on thematic intervention of nanotechnology in water sector. It is a first kind of study which focused on nanotechnology applications in one sector and providing insight how it is developing in country like India through the lens of bibliometric indicators like publications and R & D programmes specific to water sector.

This bulletin gives the comprehensive overview of state of art technologies available for water purification, worldwide. It draws insight the recent contamination scenario of water and challenges ahead and how nanotechnology is developing in country like India across the water sector from the beginning to end of value chain to serve for Bottom of Pyramid society. It also addresses the potential nanotechnology risks and outlines risk data gap challenges for existing regulatory framework. In summary, we suggest some ways in which government agencies can move forward responsibly so that ultimately nanotechnology and its products can succeed in the eyes of developers, researchers, regulators and the public.

2. The current concern and the global picture: Water Crisis Causes

Water is not as abundant and readily available as it appears. Various reports published by World Health Organization put forward alarming facts about water availability. 17-19 million people in the world lack access to clean water. 3.4 million people die every year from water scarcity, sanitation and hygiene related problems out of which 99% death occur in developing countries¹. In South Africa alone 5.7 million people lack potable drinking water which adds to the hardship of their lives.

In India, 1.2 billion people live with a very minimal per capita consumption of 1820 cubic meter which was 5177 cubic meter in 1951². This decreasing trend of water availability hints to water crisis situations in coming future.

It has been reported that only 68% of Indian population has access to safe drinking water. 21% of communicable diseases in India are from unsafe drinking water³. India is ranked at 124th position out of 174 countries in terms of Environmental Pollution Index. This is really an alarming situation and the need of efficient actions can't be overemphasized further. It is essential to have a long term vision for water conservation and management. Main causes of this situation are:

17-19 Million people lack access to clean water.

99% water related deaths in Third World Countries.

Only 68 out of 100 people in India have safe drinking water

Different states are suffering from contamination of Arsenic, Fluoride, Nitrate and Iron

a. Population

The global population expansion or specifically in Indian context has been rapid for the past few decades. This growing population increasingly demands heavy industrialization. In the next forty years half a billion growth in population is expected. Heavy urbanization shifts have been observed by people moving from rural section to urban parts of the country. Out of 1.2 billion 377.1 million people live in cities and it has been predicted that in next two decades 225 million people will be added to this urban population⁴.

b. Water Resource Usage

It's not just the population alone. Water is not scarce, but the efficient methods to make it available are. 85% of Indian population depends upon water withdrawn from ground water reserves⁵. In ecological conservation point of view a minimal level of water should be available for sustainable growth in the water ecosystem including rivers, lakes, ponds and ground water. Most of the aquifers suffer declining water levels. Most of them are affected by heavy salt intrusion, surface water contamination and inadequate replenishment.

¹UNICEF, *Diarrhoea: why children are still dying and what can be done*.

http://www.unicef.org/media/files/Final_Diarrhoea_Report_October_2009_final.pdf, 2010.

²Research, A.G., *water and wastewater treatment opportunity in India*. 2011.

³Jha, A., K. Nagrath, and K. Vijaya Lakshmi, *Access to Safe Water: Approaches for Nanotechnology Benefits to Reach the Bottom of the Pyramid*. Final Technical Report May 2011. 2011.

⁴Balasubramaniam, H., *Treating india's wastewater: why inaction is no longer an option*. 2014 March.

⁵Research, A.G., *water and wastewater treatment opportunity in India*. 2011.

Major mining and thermo-electricity generation industries withdraw major fraction of water available in natural resources. For USA, in 2000 water withdrawal by thermo-electricity industry was 3% which is expected to surge up rapidly to 28-49% in 2030⁶ to cater the increasing energy demands. Such stresses on current water resources make it essential for us to reuse and recycle of waste water.

c. *Inadequate Waste Water Treatment Technologies*

Indian municipal water infrastructure has been under criticism for a very long time. Every heavy rainfall or natural catastrophe like Tsunami (2004) exposes the weak links in age old water channelling systems. Water treatment technologies have to evolve one step ahead of the demands.

Waste water quality has been degraded due to rapid industrialization in past 4-5 decades. Contaminated waste water can cause severe damage to ecology by eutrophication, GHG emission. The current treatment capacities are not sufficient enough, only 60% of Industrial waste water is treated while as low as just 26% of domestic waste water is treated. The following table shows the difference between our waste water generation capacities and treatment infrastructure availability⁷.

Table 1: Waste water generation and treatment, Source: Jindal ITF 2011⁷

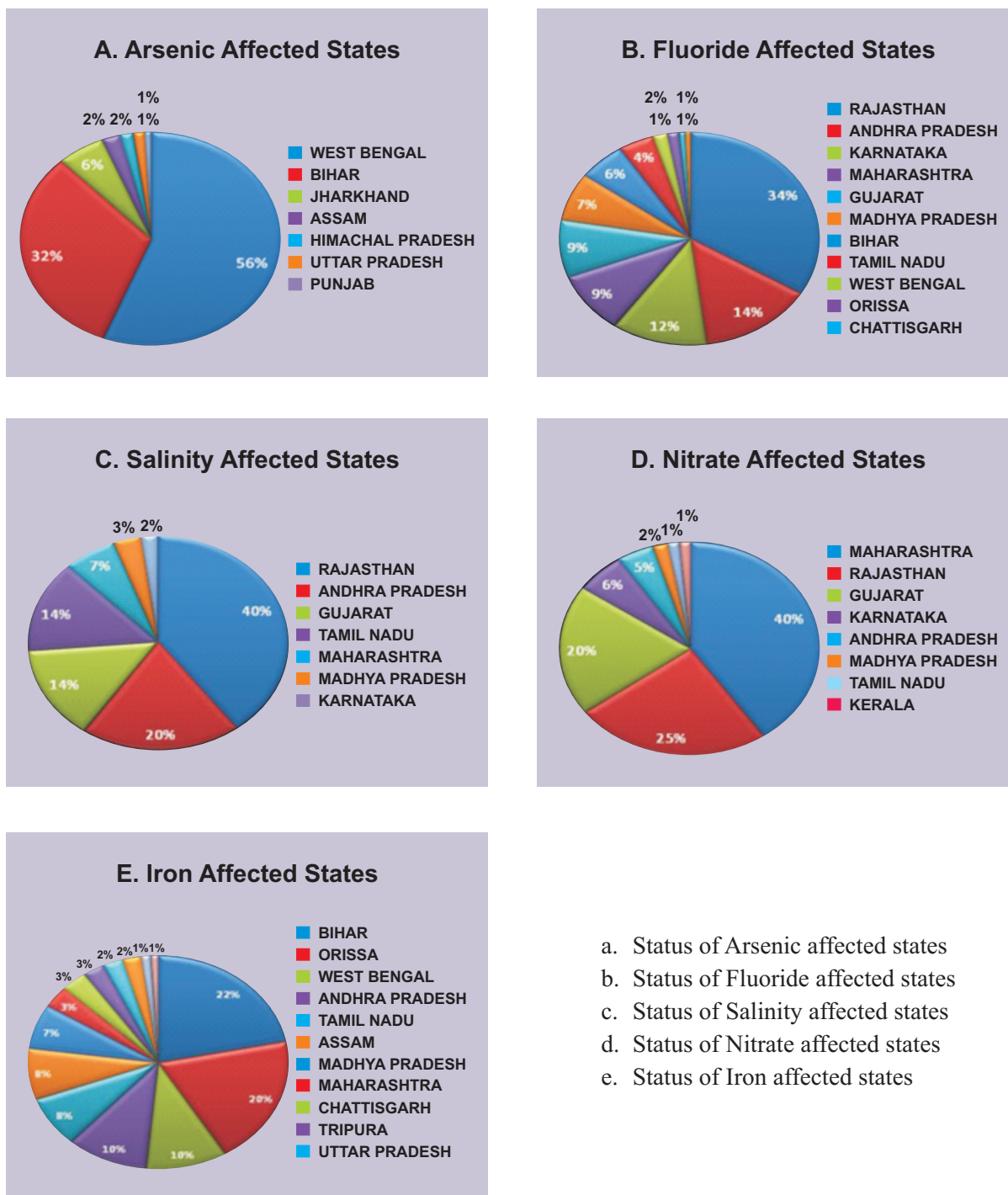
Period	Waste water generation (MLD)	Waste water treated (MLD)
2004-05	26254	7044
2005-06	29129	6190
2007-08	33000	7044
2008-09	38254	11787
2009-10	41131	13066
2010-11	51232	14484

⁶Sustich, R.C., *Introduction: Water Purification in the Twenty-First Century-Challenges and Opportunities*. Nanotechnology Applications for Clean Water, NY, USA, 2009.

⁷ITF, J., *Private Sector Participation in the Water and Waste Water Industry*. Innovative Technologies in Water Sustainability, 2011. March

As per the water analysis data report from Central Ground Water Board (CGWB) 2013⁸, the most of the states of India have shown contamination of Arsenic (As), Fluoride (F), etc.

Figure 1 : Contaminants Status in Indian states 2012-2013



- Status of Arsenic affected states
- Status of Fluoride affected states
- Status of Salinity affected states
- Status of Nitrate affected states
- Status of Iron affected states

⁸Central Ground Water Board, Ministry of Water Resources, Government of India. Annual Report, 2012-2013.

This emergent perception of an imminent water crisis in the country entail a pressing need for the best potential use of water as well as technological advances to augment the fresh water by various means like desalination process, water treatments, etc. Nanotechnology has the potential to provide a long term solution for water quality, availability and viability of water resources, such as through the use of advanced filtration materials that make possible greater water reuse, recycling, and desalinization^{9,10}.

Nanotechnology provides an answer to cost and efficiency problems. It proposes new functionality, products and systems as a promising technology in water and waste-water sector worldwide. Nanotechnologies will create immense environmental benefits in terms of water management and treatment by convalescing filtering, decontamination, desalination, conservation, recycling, analysis & monitoring of Sewerage system.

2.1 Potential of Nanotechnology in Water Treatment

Nanotechnology based application has many advantage their over conventional counterparts. Nanotechnology facilitates a very low level detection of contaminants and hazardous materials in water streams due to its intrinsic abilities. Toxin and contaminants levels vary with geographical variations but nanotech based sensors provide a wide range of sensitivity making it applicable in all kind of geological conditions and contamination types. Trace toxicity and refractory contaminants are major concern for conventional purification methods. Broadly nanotechnology materials are combined in conventional technologies to result into four kinds of technologies for multitude of purposes viz. Nanofiltration systems made of carbon nanotubes, zeolites, nanofibres and nanosponges; Nanocatalysts which can catalytically attack chemical contaminants and toxins to degrade them; Magnetic nanoparticles, they can remove metals like arsenic due to their innate interaction abilities and Nanoparticles that are used to develop sensitive sensors with enhanced detection abilities of molecular levels.

Nanotechnology can improve the desalination abilities of filtration membranes which can provide potable water at substantially low cost from brackish water or sea water. Nanotechnology has potential to treat acid mine drainage and other industrial effluents at very low cost.

In- depth analysis of BCC research (2011) has estimated the global value of nanotechnology products used in water treatment procedures of worth \$1.4 billion in 2010 and is projected to reach \$2.2 billion by 2015 showing 9.7 % increases at a compound annual growth rate (CAGR). The market is made up of two segments: established products (including reverse- osmosis, nanofiltration, and ultrafiltration membrane modules) and emerging products (nanofiber filters, carbon nanotubes). Established products were valued at nearly \$1.4 billion in 2010 and are expected to reach \$2.1 billion by 2015, at a CAGR of 9.2%. Emerging products were valued at \$45 million in 2010 and, with a CAGR of 20%, reaches \$112 million in 2015.

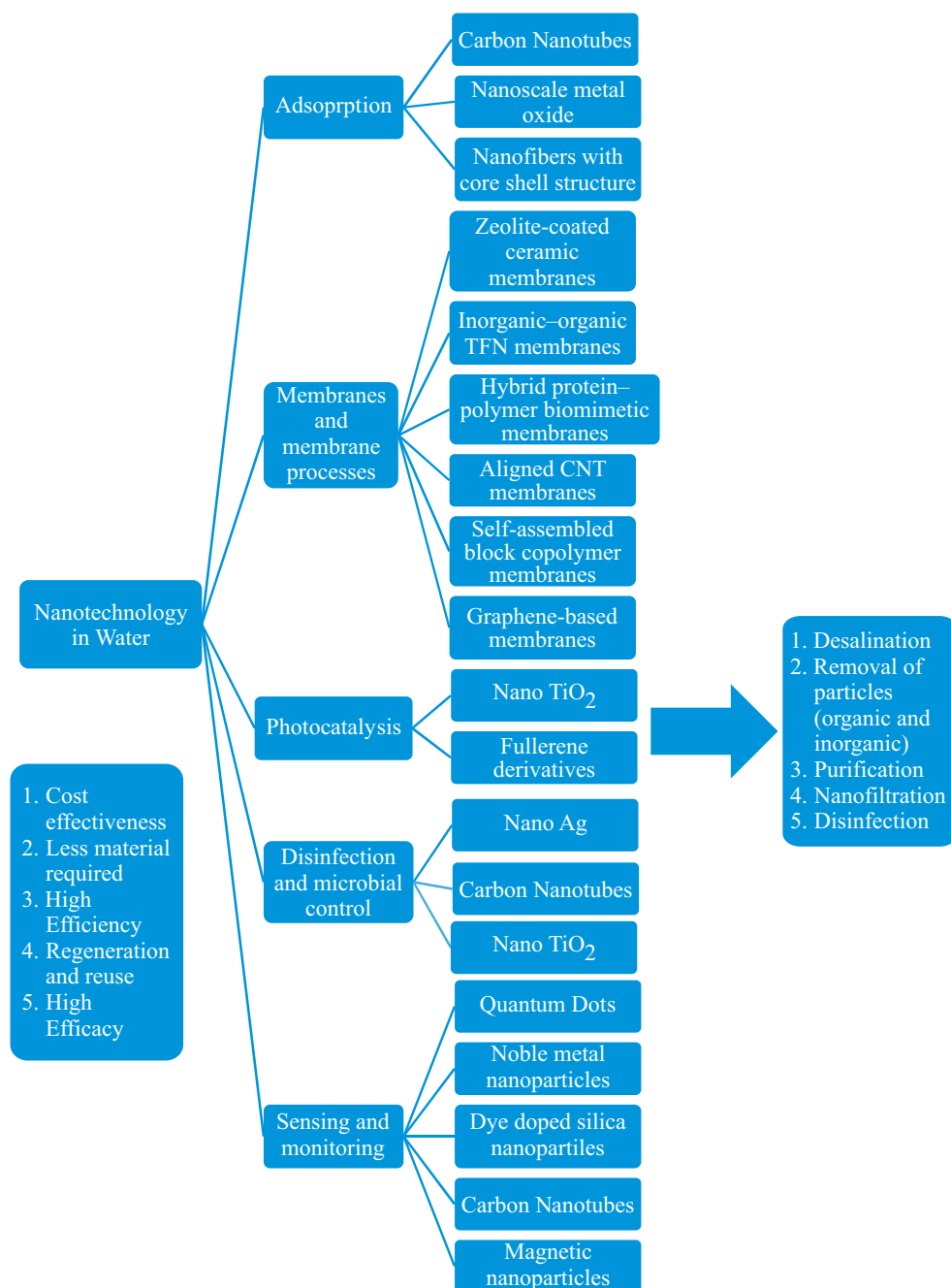
⁹Agarwal A. and Joshi H. 2010 *Application of Nanotechnology in the Remediation of Contaminated Groundwater: a short review. Recent Research in Science and Technology*, 2(6), 51-57.

¹⁰Rajan C.S.2011 *Nanotechnology in Groundwater Remediation. International Journal of Environmental Science and Development*, 2(3), 40-45.

2.2 Prominent Technologies available in water remediation worldwide

Some interesting membrane technologies are now emerging from developed and developing nations that are highly relevant to the needs of the developing as well as under developed countries.

Figure 2: Prominent Technologies available in Nano Water^{11,12}



¹¹Hoek E. M. V., Pendergast M. T. M. and Ghosh A. K. 2009 *Nanotechnology-Based Membranes for Water Purification*

¹²Qu X., Alvarez J. J. P. & Li Q., 2013. *Applications of nanotechnology in water and wastewater treatment. Water Research, Volume 47, pp. 3931-3946.*

3. Current state of Research and Development (R & D) Environment: An Indian Context

3.1 Nanotechnology R & D Environment

India has taken a major drive to create capacity and capability in Nanotechnology¹³. Department of Science and Technology articulated and implemented Nano Science and Technology Initiative (NSTI) in 2001 with an allocation of ₹60 crore (15 million USD). In 2007, this programme was further strengthened with another major initiative known as 'Nano Mission' with a budgetary allocation of ₹1000 crore (250 million USD) for five years.

This funding has been utilized to sponsor 90 research projects and create 19 Centres of Excellence (CoE). The CoE consist of eleven “Unit of Nanoscience” (UN) that pursue the basic research in several broad areas of Nano science and Technology whereas seven “Centres of Nanotechnology” is mainly focus on R & D in niche areas or in specific dimensions such as water remediation and purification (IIT, Madras).

3.2 Nanotechnology R & D Initiatives specific to Water Sector

In the eleventh plan period (2007-2012) more ambitious programmes and targets were set keeping in view different domains where nanotechnology can play a key role in enhancing the sector.

In the same period, water technology initiatives has carved out with an aim to provide affordable and indigenous safe drinking water using processes which uses nanomaterials and filtration technologies. Since the inception of the programme in 2007, 145 projects have been sanctioned by funding approximately ₹150 Crore¹⁴. The programme has been successful in terms of developing point of use drinking water system, field assessments of technology solution for metals of major concern like Arsenic (As), Fluoride (F), Iron (Fe) and desalinization of brackish water as well as sea water in different parts of India.

Recently in 2011 Department of Science and Technology approved a grant to Central of Excellence to open 8 Thematic Units of Excellence. It is important at this critical juncture to assess the status of research and innovation in nanotechnology in different industrial sectors in India.

By recognising the capability of India to develop innovation for bottom of pyramid, 12th five year plan (2013-2017) gave more emphasis in designing solutions to the challenges in water sectors such as membrane technologies and nanotechnology based sensors including biosensor¹⁵.

¹³Bhattacharya S., Shilpa and Bhati, M. 2012. *China and India: The Two New Players in the Nanotechnology race.*, 93 (I), 59-87.

¹⁴Department of Science and Technology. *Water Technology Initiative Programme*, 2007 <http://dst.gov.in/scientific-programme/t-d-wti.htm>

¹⁵Department of Science and Technology, *Nanomission Programme*, 2011. <http://nanomission.gov.in/>

Figure 3: Major Programmes/Initiatives on Nano Water Research during Five Year Plans



3.3 Nanotechnology Market

Intensive research in nanotechnology is going on to develop technologies to provide safe potable water from various resources. Most of the research institutes in India like IIT's, BARC, IISc are involved in developing nanomaterials and their integration into conventional treatment technologies. Table 2 list key nanomaterials developed by some premiere Indian research institutes¹⁶.

Table 2 : Nanotechnology Research in Various Research Institutes for Water Treatment.

Technology	Application	Institute
Fe-Oxide	As removal	IIT KGP India
Carbon Nanotube Filter	Toxin Removal	BHU India-Rensselaer Polytechnic USA
Carbon nanotube filters	Pathogen removal	BARC India
Gold Nanoparticles	Pathogen Detection	Agharkar Research Institute
Nanoparticle	Toxic metal detection and removal	IIT Bombay
Nanosensor	Low level toxin detection	IIT Delhi

4. Capturing Nano Water Research through Bibliometric Indicator : Publication analysis

A database of nanotechnology publications was compiled from the Thomson Reuters ISI Web of Science using a series of Boolean string searches. The Boolean strings were derived by author after going through related literature and in-depth study of the various articles, reports and news are as follow:

remediat* OR wastewater OR "waste water" OR "drinking water" OR drinkwater OR "drink water" OR "water purification" OR "ground water" OR groundwater OR soil OR "pollutant" OR "toxic compound" OR filtration OR desalination OR "water softening" OR "heavy metal*" OR photocataly* OR membrane* OR contaminat* OR arsen* OR zinc OR adsorption OR reduction OR C60 OR fulleren* OR CNT OR nanotube* OR iron OR ZnO OR magenti* OR nanocrystallin* OR "metal oxide*" OR gold OR copper OR dendrimer* OR lead OR oxidat* OR titanium OR TiO* OR silicon OR SiO* OR nanomembrane OR nanofiltration OR photodecomposition OR iron nanoparticles OR Graphene

Nanotechnology applications in water sector represent a field which is drawing attention of each advanced and emerging economies. In fact, innovation in nanotechnology in water sector has been at a core in many countries which can further be seen by research publications in this strategic area. We analysed the number of publications during 2000-2013, in this specific field.

¹⁶Jha, A., K. Nagrath, and K. Vijaya Lakshmi, *Access to Safe Water: Approaches for Nanotechnology Benefits to Reach the Bottom of the Pyramid. Final Technical Report May 2011*. 2011.

Figure 4: Top 10 Countries in Nano Water Research Publications (2000-2013)

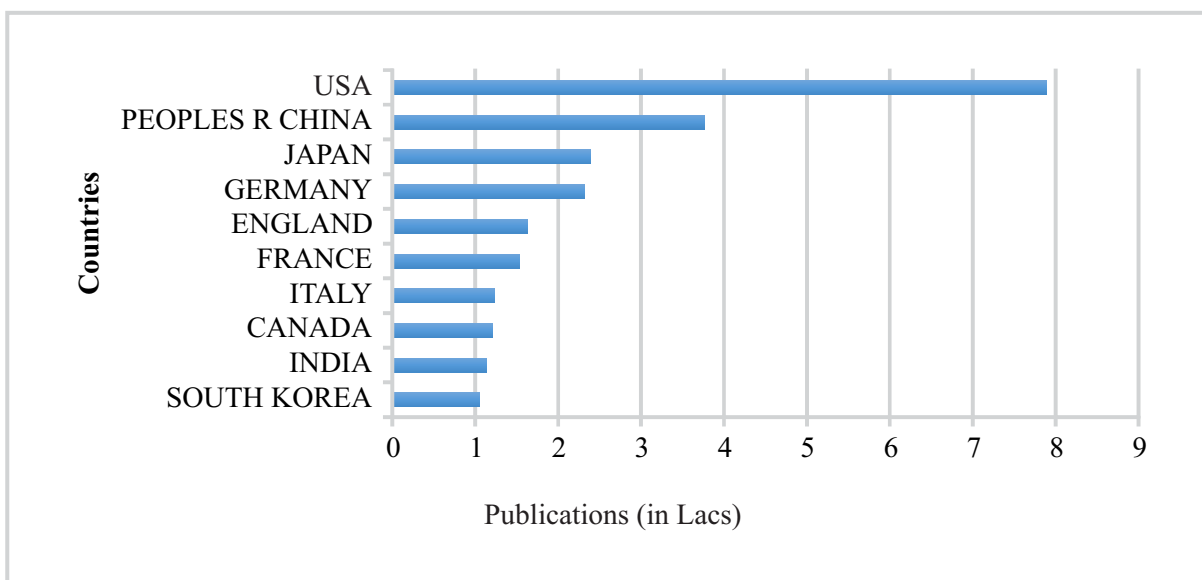


Figure 5: Publication trend in Nano Water Research in India (2000-2013)

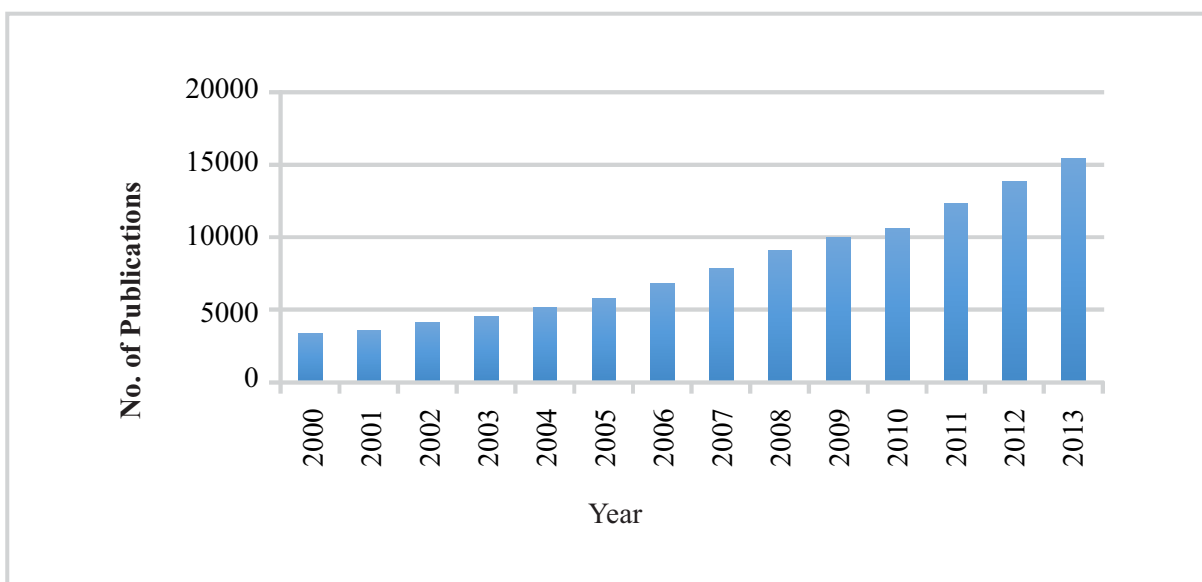
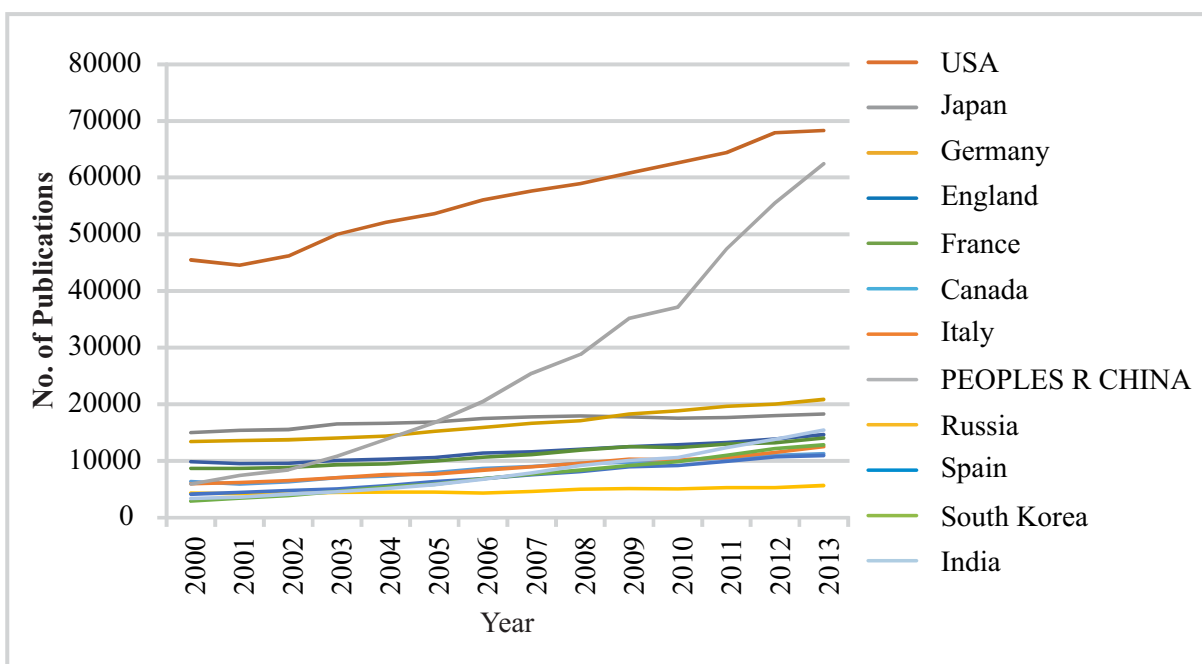


Figure 6: Global positioning of countries in Nano Water Research (2000-2013)

An examination of India's nanotechnology publications in water sector relative to global publication trends highlights the growth of nanotechnology for the period of 2000-2013. It is clear that nanotechnology water research has become a significant research discipline in India in this rapidly expanding and advancing research field. Figure 5 indicate fourfold increase and a continuous rise in nanotechnology publications in water sector applications since 2000 (3408) to 2013 (15421). India has much better reception of papers. Thus, this is one indication that Indian research is addressing important problems, advancing knowledge and making researchers take note of that. It can also be observed in fig 6 that the positions of top 10 players are changing since 2000 due to change in share of publications. China is continuously increase publishing in this field and surpassed the other comparator countries and became the one of the most prolific country by acquiring a global rank of 2nd in this field in year 2013. India is also showing the same trend and also surpassed its comparator countries since 2007 like Spain, Italy, France, England and South Korea and positioned itself among top ten prolific countries.

United States of America and China are most prolific countries in research publications in this area and India is also emerging as a key player in the global publications in this area. This indicates that India is capable to show its visibility among top ten countries. India positioned itself at 5th after leading countries like USA, China, Germany and Japan. It shows India is continuously working on pressing concerns for economic development and to develop sustainable path to achieve quality water. In 2000 India was on 15 position and in 2013 India is among the top 5 leaders. Overall if we look at the total publications from 2000-2013 India is able to make its visibility among top 10 countries (9th position).

Table 3: Top Institutes involved in Nano Water Research in India for the period 2000-2013

S. No.	Institute	Publications	Percentage of Total Publications
1.	Council of Scientific Industrial Research (CSIR) India	16785	14.88%
2.	Indian Institutes of Technology (IITs)	15696	13.92%
3.	Indian Institute of Science (IISc) Bangalore	4260	3.78%
4.	Bhabha Atomic Research Centre (BARC)	3798	3.37%
5.	Banaras Hindu University (BHU)	2296	2.04%
6.	University of Delhi	2110	1.87%
7.	Jadavpur University	2041	1.81%
8.	Anna University	1884	1.67%
9.	Aligarh Muslim University	1568	1.39%
10.	University of Calcutta	1287	1.14%

It has been almost more than 10 years since India took major drive to create an innovation climate for nanotechnology by providing substantial funding. As a result of this, several institutes, Centres of excellence in nanotechnology were established. They are continuously working on specific pressing concern. So it is an opportune time to assess the impact and influence of publications and researches have had on the field, as well as the greater scientific community. Citation count is a useful metric of scientific impact. It is the most common method for analysing the magnitude of scientific recognition of an individual article. We have seen that India is continuously publishing on nanotechnology application in water sector and is successfully receiving attention from their international counterparts. Table 4 presents lists of top 15 countries and number of influential academic journal articles drawn from the Web of Science index based on citation count in year 2013. India is able to position itself in top 15 countries and receiving good citations for publication. Although citation index is not a direct measure of quality or importance, it offers one form of quantitative assessment of scientific impact. This assessment contributes to the identification of trends, which illustrate the evolution of scope and focus of nanotechnology research.

Emergence of India among top 10 key players (9th position) in nanotechnology water research publications.

India also positioned itself among top 15 countries by publishing among top 1% cited nanowater papers in 2013.

Council of Scientific & Industrial Research & IITs both alone contributed approximately 40% of top 1% cited papers of India.

**Table 4: Countries having Top 1% cited paper of nanowater Research
Publication in 2013**

S. No.	Country	No. of Publications
1.	USA	1352
2.	Peoples R China	816
3.	Germany	333
4.	England	308
5.	France	210
6.	Japan	175
7.	Canada	175
8.	Australia	163
9.	Italy	154
10.	Spain	150
11.	South Korea	150
12.	Netherlands	144
13.	Switzerland	130
14.	Singapore	125
15.	India	80

Table 5: List of Prolific Institutes having top 1% cited papers of nanowater Research in 2013

Institute	No. of Publications
Council of Scientific Industrial Research CSIR India	15
Indian Institutes of Technology IITs	15
Indian Institute of Science IISc Bangalore	5
Indian Association For The Cultivation of Science IACS Jadavpur	4
All India Institute of Medical Sciences	3
Public Health Foundation India	3
WHO	2
University of Mumbai	2
Tata Institute of Fundamental Research	2
National Institute Pharmaceutical Education Research	2
Maulana Azad National Institute of Technology Bhopal	2
Jawaharlal Nehru Centre For Advanced Scientific Research	2

CSIR and IITs continuously taking lead in publishing effective publications in various *web of science* subject categories. In 2013, 80 papers were in top 1% cited papers of which 30 papers were from CSIR and IITs. Thus both of institutes contribute approximately 37% in quality research. Major subject categories in which Indian institutes are publishing are Chemistry Multidisciplinary, Medicine General, Nanoscience Nanotechnology, Environmental Science, etc. (Table 6).

Table 6: List of Prolific Institutes having top 1% cited papers of nanowater Research in 2013

S. No.	Web of Science Subject Categories
1.	Chemistry Multidisciplinary
2.	Medicine General Internal
3.	Nanoscience Nanotechnology
4.	Multidisciplinary Sciences
5.	Materials Science Multidisciplinary
6.	Pharmacology Pharmacy
7.	Physics Applied
8.	Physics Atomic Molecular Chemical
9.	Chemistry Physical
10.	Environmental Sciences

5. Policy Environment for Responsible Development of Nanotechnology in Water Sector.

There are several organisations involved in developing health & environment regulations for nanotechnology; the Ministry of Environment & Forest, the Ministry of Chemical & Fertilizers, the Ministry of Health & Family Welfare, and the Ministry of Labour and Employment. Ministry of Environment & Forests is playing lead role in implementing policies & programs relating to prevention & abatement of pollution in water and air. Over the years, number of laws has been enacted to achieve the objective of the Ministry of which, Water (Prevention & Control of Pollution) Act, 1974 was the first environment specific statute in the country. Environment (Protection) Act, 1986, Hazardous Wastes (Management and Handling) Amendment Rules, 2000, are other laws which deals in directly or indirectly with water pollution. Central Pollution Control Board, an apex body of MoEF is responsible to laydown standards for effluents discharged from the industries in order to prevent the pollution of water resources in the country. These standards are termed 'Minimal National Standards' (MINAS). The Ministry of Chemicals & Fertilizers regulates chemical, which means it can be charged with regulation of many nanomaterials. Finally, the Ministry of Labour and Employment regulates Labour Safety Standards, child and women labour policies and laws so it can play major role in determining factory & laboratory conditions for workers in nanotechnology labs. Besides that, Bureau of Indian Standards (BIS) has responsibility for standards of nanotechnology including safety standards. In India development of safety standards for nanotechnology & nanomaterials is in quite nascent stage. In general, BIS follows all the recommendations set by the (BIS 2014) ISO¹⁷.

¹⁷Bureau of Indian Standards. Retrieved from <http://www.bis.org.in/sf/nano.htm>.

In 2005, the ISO started a committee, ISO/TC229, which has four groups:

WG1: Nomenclature and Terminology (NT)

WG2: Measurement and Characterization (MC)

WG3: Health Safety and Environmental aspects of Nanotechnology (HSE)

WG4: Material Specification (MS)

India is active in formulating the ISO guidelines & standards. The major conduit between the ISO and the India BIS is the MTD33, a working group set up by the BIS to serve as the liaison to the ISO.

ISO has developed 42 standards for nanotechnology. These standards can be divided in four groups. Nomenclature and Terminology (NT) has 10 standards, Measurement and characterization (MC) has 15 standards, Health Safety and Environmental (HSE) has 13 standards and Material Specification (MS) has 4 standards.

Health and Safety standards are mainly dealing with the manufactured nanomaterials like Silver, Gold, Zinc oxide, etc for their characterisation, their potency and risk evaluation. Silver, Gold and Titanium dioxide are generally used to make water filter in India. ISO is also preparing Materials Safety Data Sheet (MSDS) for nanomaterials. It mainly provides the information about the procedures for handling or working with nanomaterials in a safe manner, and includes information such as physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill-handling procedures. BIS can use these standards to develop Indian standards for nanotechnology in water sector according to our country's environment¹⁸.

¹⁸ISO Technical Committee- Nanotechnology. (n.d.). Retrieved from http://www.iso.org/iso/standards_development/technical_committees/list_of_iso_technical_committees/iso_technical_committee.htm?commid=381983.

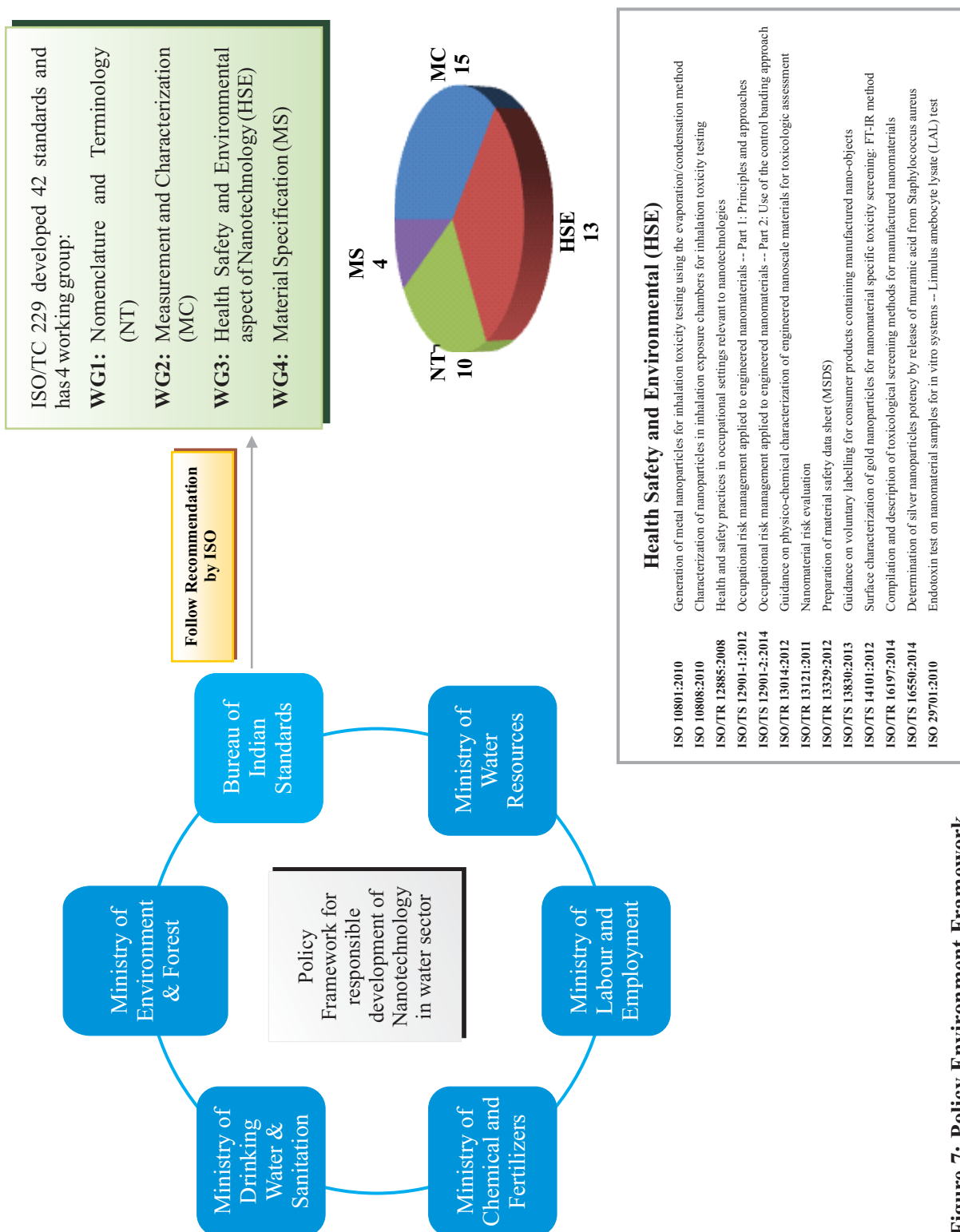


Figure 7: Policy Environment Framework

6. Risk gap and Existing Rules & Regulations

Nanotechnology shows great potential for applications in different sectors due to its novel properties. These extraordinary properties also trigger skepticism about nanotechnology adverse effects on human health & environment. As these properties may also appear on opposite side which means small amount of nanomaterial will have potent toxicity as compared to their bulk counterparts. However, due to lack of adequate data risk assessments for nanotechnologies and nanomaterials are extremely difficult. It is difficult to extrapolate study results done in controlled setting in labs to complex ecosystem.

Over the years lots of laws & regulations came for abatement of pollution. In India, Ministry of Environment & Forests (MoEF) implements policies & programmes relating to preventions & abatement of pollution in water & air. Water (Prevention & Control of Pollution) Act, 1974 was the first environmental specific enactment in the country. The Pollution Control Board at central with state came into being as a consequence of this act. In 1981, the air (Prevention & Control of Pollution) Act was enacted.

After the inception Water Prevention & Control of Pollution Act as first regulatory statute in 1974, the Air (Prevention & Control of Pollution) Act 1981 was enacted, followed by The Environment (Protection) Act, 1986, etc. The National Environment Policy also set main objectives to integrate environment concern in all relevant development processes. Current Water Prevention & Control of Pollution Act has definitive limitations and capacity to address nanomaterials. Before regulating nanoparticles Ministry have to demonstrate that nanoparticles have potential adverse effects on human health or the environment. Ministry also require to create water quality standards to dispose it in river stream or used as irrigation source in agricultural land, it must need to develop a database covering all known effects of specified nanoparticles in water. Limitations of current technologies for detection and monitoring nanoparticles in water create significant barriers in implementing and imposing various conventional regulatory standards. If a facility uses or manufactures nanoparticles and is discharging its waste water stream in water bodies, CPCB (An apex body of MoEF) could implement its authority to inspect the facility, obtain records, demand discharge monitoring and make reports to gain information on the nature of nanoparticle discharged.

No baseline data about nanomaterial release in different environmental compartments (soil, air & water)

Nanomaterials are still not treated as Hazardous waste

Materials Safety Data Sheet for nanomaterials.

Lack of Standards of nanomaterials to discharge in water stream

Definitive limitations and capacity of existing rules and regulations to address nanomaterials

No mandatory requirement for nanomaterials manufacturers to submit information and data sheets about nanomaterial production levels, type of nanomaterial produced, etc.

7. Issues that need attention from Policy Perspective

- Government helps to build a significant institutional network to support scientific & technology progress in Nanotechnology. Government need to embed new risk policy & regulation in existing legislative frameworks for responsible development of nanotechnology.
- It has been 15 years, since the inception of nanotechnology evolution in India, But policy environments for nanotechnology are lacking importance of risk research. Risk Project which emphasize on nanomaterial exposure& transportation, hazard mechanism on entry in environment & development of tool for risk assessment should be given in priority by Department of Science & Technology.
- More funding should be allotted to develop monitoring capabilities so that baseline data about nanomaterial release in different environmental compartments (soil, air & water) can be collected which will be helpful to anticipate and prevent potential environmental problems related to nanotechnology developments upstream, rather than reacting to them downstream. Therefore, development of infrastructure for nanosafety is an immediate requirement.
- Requirement to prepare Materials Safety Data Sheet for nanomaterials which can provide information such as physical data (melting point, boiling point, flash point, etc.), toxicity, health effects, first aid, reactivity, storage, disposal, protective equipment, and spill-handling procedures.
- Nanomaterials should also be treated as a hazardous waste. CPCB (An apex body of MoEF) should come forward to implement its authority to inspect the manufacturers' facilities, obtain records, demand discharge monitoring and make reports to gain information on the nature of nanoparticle discharged in water stream and other environment compartments (soil and air).
- CPCB and BIS should come forward to develop standards for nanomaterials discharge in water stream and presented in drinking water.
- Necessity in amendment of Current Water Prevention & Control of Pollution Act, 1974, The Environment (Protection) Act, 1986, Hazardous Wastes (Management and Handling) Amendment Rules, 2000, and other laws which deals directly or indirectly with water pollution as they have definitive limitations and capacity to address nanomaterials.
- In India, there are 300 companies out of which a significant portion of the companies involved in manufacturing nanomaterials, nano based products. Still there is no legislative mandate to provide data about the nature of nanomaterials produced & discharged/emitted during the manufacturing process. Central Pollution Control Board should take steps to implement regulations which require nanomaterial manufacturers to submit information and data sheets about nanomaterial production levels, type of nanomaterial produced and should also require the company to do in-house toxicity test and make them available to regulatory agencies and in public domain.
- There is also a generic requirement for labelling and identification of the nano based products by nanomaterial product manufacturers.
- Government should also couple regulatory framework for engineered nanomaterial with standardisation to promote environmentally benign practices.

Disclaimer : *The views in this bulletin are those of the author, and do not represent those of the CSIR - National Institute of Science Technology and Development Studies (CSIR-NISTADS)*

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