



WATER R&D IN INDIA: TRENDS AND INTERVENTION

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Highlights

- Out of total extramural research funding only 1.97% of the fund is allocated for water research.
- DST funds the largest extramural research grant for water followed by MoWR, UGC, DBT and MOEF.
- Mismatch between our policy expectations and research outcome in the water sector exist. R&D fund management strategies should be revised.
- Universities attracting more extramural research funds than the R&D institutes.
- Amongst publicly funded R&D institutes, CSIR emerges to be the leader attracting 44.9% of R&D extramural funds followed by research institutes under MOWR and ICAR

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This Policy Bulletin has been prepared under ISTIP project (funded by CSIR) by Dr. K. Mandal and Priti. Authors are affiliated to CSIR-NISTADS.

1. Introduction

India with the world's second largest population of 1.21 billion (as per 2011 census report) is under the threat of severe water scarcity has already been cited by several reports. Water scarcity has gripped several states of India as groundwater levels continue to deplete at an alarming rate. Mercury levels are rising and large parts of the country are experiencing severe droughts. A fast growing economy on one hand and a large agricultural sector on the other have stretched the country's supply of water even thinner. Severe water shortage had already led to a growing number of conflicts across the country, with 90 % of India's territory served by inter-state rivers. India's supply of water too is rapidly dwindling primarily due to mismanagement of water resources, although over-pumping and pollution are also significant contributors. Climate change is expected to worsen the situation by causing unpredictable weather. Recognizing the severity of the problem, the twelfth five year plan on water have proposed a paradigm shift which brings in a complete change in the principles and approaches for water management in India across various sectors-a move away from a narrow engineering-construction perspective towards a more multidisciplinary understanding of water with central emphasis on the goal of resilient eco-systems, a focus on the principle of subsidiary.

The working group report of the twelfth five year plan recognized the fact that Research and Development in the water sector has been a weak area as evident from the pace at which new and appropriate technologies have been developed/introduced in the sector in the

past¹. Consensus was attained in the group for need of more technological options to be evolved through R&D process; the group had renowned experts working in the water sector.

At this critical juncture, it is important to develop an understanding of what has or is actually happening in terms of R&D in the water sector in the country. This bulletin gives a broad overview of the R&D scenario in the water sector. It attempts to address issues and facts that are critical to the R&D related aspects in the sector, such as: what are the emerging trends in technology development in the sector? Who are the key players of technology development in the sector? What are the challenges and gaps for technology development in the sector?

2. The water predicament in India

Indian geography as well as topography varies considerably as we move from region to region. Therefore, the nature and extent of water crisis is multifaceted. Problems across states range from low per capita availability, low storage capacity, surface run-off on account of nature of geological terrain to sea water intrusion in coastal areas. Additionally, the utilization of the created facilities is far from optimal as the water sector in India suffers from: (a) relatively low water use efficiency and (b) increasing gap between the created irrigation potential and the utilized irrigation potential.

Furthermore, the crisis related to water quality, both biological and chemical contamination has been widespread. Problems of arsenic and fluoride due to over exploitation of groundwater resources which was initially traced in Uttar Pradesh and West Bengal have now spread to Assam, Bihar, Chhattisgarh, Jharkhand and Maharashtra. India also has a huge waste generation problem; untreated sewage being directly released into rivers and other surface water bodies causes the bacteriological contamination. Agricultural runoff adds to the pesticide contamination of the water sources. Industrial chemicals such as cadmium and nitrates which are either seeping into the ground and polluting the groundwater or their indiscriminate release into the surface water is polluting the surface water thereby adding to the quality issues which has recently started gaining attention. Box 1 gives an indicative picture of the nature and extent of water quality problems in India.

Lastly, sewage and effluent treatment is insufficient in India. A recent bulletin² reveals that only 60% of industrial waste water is treated while as low as just 26% of domestic waste water is treated. Lack of proper facilities to treat wastewater therefore enhances the water quality related problems and adds to the water crisis.

¹Report: Working committee report on 12th plan (2012), Ministry of Planning Commission, India, P. No. 144-189

²M. Bhati & et. Al (2015), ISTIP Policy Bulletin No. 6, NISTADS, India

Box 1. Water quality status in India: Facts and figures

- The annual silt load reaching the north-Indian rivers ranges from 4 to 98 hectare meters per 100 sq km of catchment area. The highest silt load occurs in the Teesta (98.4 ham/100km²).
- Cases of extreme values are relatively limited in number, but certain reaches of important rivers have become polluted because of discharge of untreated domestic and industrial effluents into the rivers. The length of river reaches with BOD higher than 6 mg/l is 2800 km in Maharashtra and 1200 Km in Uttar Pradesh.
- Excessive fluoride in drinking water is a major concern in the States of Haryana, Rajasthan, Gujarat and Andhra Pradesh. The permissible limit is only 1mg/l, whereas its concentration in some locations exceeds 30 mg/l.
- 10 million people (approx.) are affected by Arsenic pollution of drinking water in the Gangetic plains. The problem is more acute in Murshidabad, Nadia, North and South 24 Parganas, Malda and Bardhaman districts of West Bengal. Recent reports indicate the presence of high arsenic levels even up to Kanpur in Uttar Pradesh.

Source: Water resource management, Indian National Academy of engineering page <http://inae.in/research-studies/#Water Resources Management>

3. *Role of technology in solving the impending water crisis*

The impetus for the water technology development stems from the specific needs of the country. It also stems from the role that water plays in the country's development plans, as well as the importance of water issues and policies. Right from users and stakeholders of water technology, including government agencies, industry, R&D institutes and universities all have a role in water technology development. Water technology development is multidisciplinary in nature that spans many areas, including environmental engineering, chemical engineering, civil engineering, geosciences, microbiology, meteorology, and materials sciences. Water technologies are needed to:

- Provide sufficient water supplies for domestic, agricultural and industrial use.
- Support national self-reliance in water-related R&D and reduce dependence on foreign technology.
- Improve the price/value efficiency of water production and treatment.
- Develop a domestic water technology industry that could contribute to national economic performance and provide employment opportunities.

Technological development in water sector could be broadly classified into four areas of highest priority for meeting the needs. An overview of the areas and sub areas can be found in table 1³, which indicates the kind of technological interventions that are required to address the increasing need for water resources due to expanding population. India is blessed with the availability of vast shorelines and therefore desalination could be a future weapon to combat the future water requirement and therefore demands utmost attention. Based on India's topography, there is need for advanced technology to address remote areas water necessities.

Table 1: The technology areas of highest priority as exists worldwide

Water Resources Management	Drinking Water Treatment	Waste Treatment	Water Desalination
Water Conservation	Membrane Treatment	Biological Treatment	Thermal Desalination
Water Reuse and Recycling	Chemical Treatment	Biological Membrane Treatment	Membrane Desalination
Groundwater Recharge	Ionic Exchange	Chemo physical Treatment	Hybrid Desalination
Rain Harvest	Disinfection	Advanced Treatment	
Cloud Seeding	Filtration		

Source: Report: Strategic priorities for water technology programme, Kingdom of Saudi Arabia, Ministry of Economy and Planning (Doc. No. 12P0001-PLN-0001-ER01), <http://www.kacst.edu.sa/en/research/Documents/Water.pdf>

The irrigation infrastructures in India are also not operating at desired efficiency. Efficiency of surface water projects has been assessed to be about 30-40%, which can be increased up to 60% by adopting efficient management practices, proper maintenance and modernization of existing infrastructures, command area development, participatory irrigation management and efficient irrigation and agricultural practices. Similarly, the efficiency of ground water facilities can be increased from the present level of about 65% to about 75%. This measure alone can save considerable water to meet the major portion of demand supply gap⁴.

The efficiency of water use in agriculture can be improved with choice of most appropriate cropping pattern and the specific crop variety most suitable for the region from the view of water availability. At the same time measures for moisture conservation are also very effective means of improving water use efficiency. System of Rice Intensification (SRI) is fast catching up in southern states as a method of agriculture practice for reducing water consumption by about 29-30% and yield increases by about 30-40%. There is definite need for focused research and studies

³Report: Strategic priorities for water technology programme, Kingdom of Saudi Arabia, Ministry of Economy and Planning (Doc. No. 12P0001-PLN-0001-ER01), <http://www.kacst.edu.sa/en/research/Documents/Water.pdf>

⁴Strategic plan for Ministry of water resources, Government of India, (2011)

directed towards improving efficiency in water use. The National Mission for Sustainable Agriculture has laid emphasis on this aspect. At the technology level, the key principles for improving water productivity at the field, farm and basin levels are: (i) increase in the marketable yield of the crop for each unit of water used, (ii) reduction of all outflows (ex. drainage, seepage and percolation), and (iii) increase in the effective use of rainfall, stored water and water of marginal quality. New irrigation technologies that will improve field level water application efficiencies will be critical components of the demand-side management⁵.

Ministry of Water Resources (MoWR) sanctioned Farmer Participatory Action Research Programme (FPARP) at 5000 demonstration sites at a cost of Rs. 24.46 crore. This programme is taken up in 25 States/UTs of the country with the help of 60 Agriculture Universities/Indian Council of Agricultural Research Institutes / International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Water and Land Management Institutes (WALMIs) and Non-Government Organizations (NGOs) to increase yield and income per drop of water. Water saving technological interventions were demonstrated on various crops such as paddy, wheat vegetable, gram and maize in various states. The performance of these technologies under FPARP were compared with the conventional method of irrigation in terms of percentage increase in water saving, yield and income as a result of the programme. Water saving has been indicated in wheat from 5% to 66.67%, vegetables 23.3% to 40%, paddy 25% to 55%. Increase in yield for wheat was ranging from 7.3% to 43%, vegetables 10% to 23% paddy 10% to 62%. Increase income for wheat 4.91% to 30%, vegetables 11% to 15.38% and Paddy 6% to 44%⁶.

4. Stakeholders and their commitment to water technology development

Traditionally, water resources schemes and programs are multidisciplinary in nature and are executed by various ministries/departments of both the central and state government. Such schemes and programs are formulated based on the activities respective ministry or department undertake as in Table 3. The stakeholders for the water technology development include related ministries and government agencies who act as the funding bodies, the public funded R&D institutes under respective ministries/departments, universities, civil society organizations and the private sector. Table 2 gives an outline of the stakeholders and role played by them as evident worldwide in cases of successful technology development.

⁵Strategic plan for Ministry of water resources, Government of India, (2011)

⁶Strategic plan for Ministry of water resources, Government of India, (2011)

Table 2. Stakeholders and their role in water technology development

Stakeholders	Function
Ministries and Government Agencies	Formulate policy and programs on technological development in the water sector
	Program management and coordination
	Provide input to program on government R&D needs
	Providing financial resources
	Reduce regulatory and procedural barriers to R&D and innovation
	Support R&D in universities, research organizations and industry in PPP mode
	Developing infrastructure and necessary conditions for R&D and innovation
Universities	Create new basic and applied scientific knowledge
	Train students in science and engineering
	Host and participate in Technology Innovation Centres
	Participate in collaborative projects, national and international
Public Funded Government Research Organization	Create new basic and applied scientific knowledge
	Host and participate in Technology Innovation Centres
	Participate in collaborative projects, national and international
Civil Society Organizations	Operational and implementation projects
	Successful transfer of technology from lab to land
	Dissemination and diffusion of technology in remote areas of actual need
Private Sector	Develop and commercialize products & processes resulting from the program
	Communicate company needs to program
	Support and participate in collaborative R&D projects
	Support and participate in the Technology Innovation Centres

Source: Compiled by author

b) Key ministries involved in financing for technology development in the water sector: Centre and State

As well-known, in India investment on research and development is largely made by public sector and the water sector is no exception to it. A large number of scientific agencies /departments / ministries of the central government provide funding support to R&D in the form of intramural or extramural projects with the aim of building research capability and infrastructure in the water sector. Captivatingly, multiple ministries, departments and agencies (as in Table 3) are involved in promoting R&D on water. Amongst all the ministries and departments, Department of Science and Technology (DST) is the largest extramural R&D funder followed by Ministry of Water Resources (MoWR), University Grant Commission (UGC), Department of Biotechnology (DBT) and Ministry of Forest & Environment (MOEF) Fig 1. The National Science & Technology Management Information System (NSTMIS), a division of the DST maintains the database of all extramural R&D projects funded during the period from 2000 – 2011 by all central government ministries, departments/ agencies to various

universities and public R & D organization. An in-depth analysis of all such projects reveal out of a total of 32929 extramural R&D projects funded by several ministries over the last 10 years across several disciplines only 1503 projects related to R&D on water. When estimated based on the amount of R&D investment, it is found that out of all the extramural research funding only 1.97% of the fund was allocated for water research, which is meager.

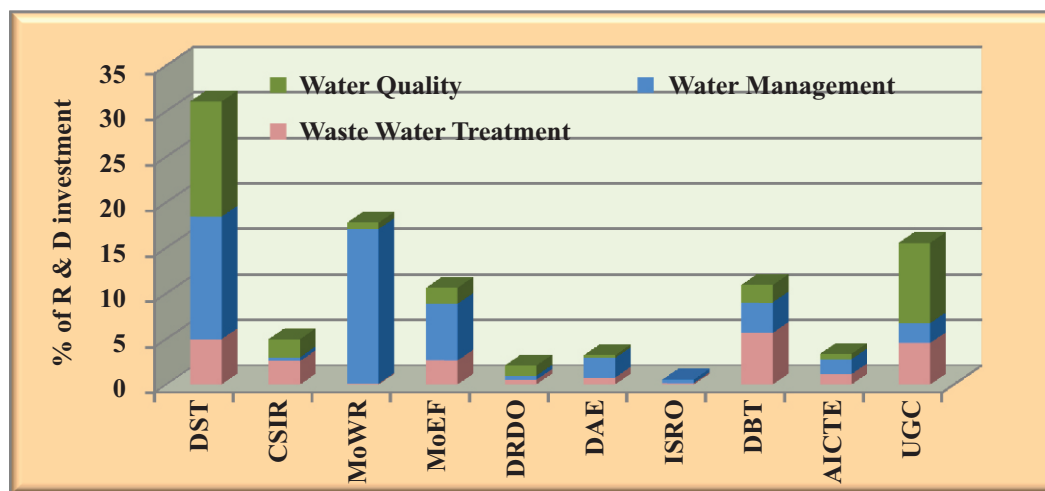
Table 3: Central government agencies involved in the water sector vis-à-vis their activity

Activities	Ministry / Department	Programme/Research Organizations
Overall Policy Issues, Assessment of Water Resources, Major and Medium Irrigation, Minor Irrigation, Ground Water and Flood Management	MoWR	CWC; CWGB; CWPRS; NIH; WALMI; GFCC; NWDA; Respective river boards
Rural Drinking Water	MDWS	NRDWM; SBM; NGP
Urban Drinking Water	MoUD	CPHEEO / JNNURM
Industrial Water	MoUD/MoCI	
Hydropower Development	MOP	CPRI
Inland Navigation	MOT	
Environmental Issues	MoEF*	CPCB/ WQSA
Overall Planning for Water Resources Development and Fund Allocation	Planning Commission (Former)	
Watershed Development	MOA / MoEF/ MORD	IWMP;TDET; NWDPA; BVY; DoLR
(a) Water planning for Agriculture, (b) Micro Irrigation (c) Management of Water related Disaster (Drought)	MOA / MoWR	ICAR; IARI; MMI; WTC; CADWMP; FPAR P; CAZRI; CRIDA; ICRISAT
Management of Water related Disaster (Flood)	MOHA	NDMA
Water technology Initiative	MoST	CSIR, DBT, DST

Source: Author Compilation from Comprehensive Mission Document of National Water Mission (2011)

BVY: Bhoomi Vikash Yojana; **CWC:** Central Water Commission; **CWGB:** Central Water Ground Board; **CWPRS:** Central Water Power Research Station; **CPHEEO:** Central Public Health and Environmental Engineering Organisation; **CPRI:** Central Power Research Institute; **CPCB:** Central Pollution Control Board; **CAZRI:** Central Arid Zone Research Institute; **CRIDA:** Central Research Institute for Dryland Agriculture; **CADWMP:** Command Area Development and Water Management Programme; **DoLR:** Department of land resource **GFCC:** Ganga flood control commission; **ICAR:** Indian council of agriculture research; **IARI:** Indian Agriculture Research Institute; **JNNURM:** Jawaharlal Nehru National Urban Renewable Mission ; **NIH:** National Institute of Hydrology; **NWDA:** National water development agency; **NRDWM:** National Rural Drinking Water Mission; **NGP:** Nirmal Gram Poruskar; **MOUD:** Ministry of Urban Development; **MOCI:** Ministry of Commerce and Industry; **MoA:** Ministry of Agriculture; **MMI:** Major and Medium Irrigation; **NDMA:** National Disaster Management Authority; **IWMP:** Integrated Watershed Management Programme; **TDET:** Technology Development and Extension Training; **NWDPA:** National Watershed Development Programme in Rainfed areas; **MDWS:** Ministry of Drinking Water and Sanitation; **MOP:** Ministry of Power **SBM:** Swachh Bharat Mission; **MoEF*:** Ministry of Forest & Environment & Climate Change; **MoT:** Ministry of Transport; **MOHA:** Ministry of Home Affairs ; **MoRD:** Ministry of Rural Development ; **WLMI:** Water and Land Management Institute; **WQSA:** Water Quality Assessment Authority; **WTC:** Water Technology Center;

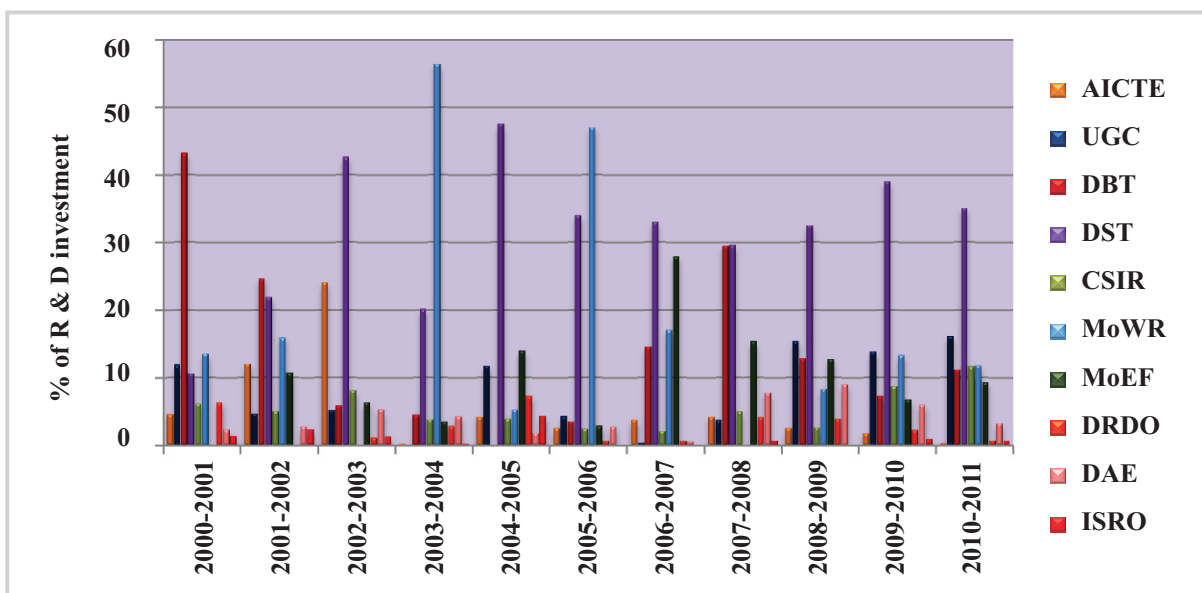
Fig.1 Funding by respective Government agencies in broad sectors of water R & D over the last 10 years



Source: Author's compilation from <http://www.nstmis-dst.org/Extramurel.aspx>

A prior study by Mandal et al 2013 reflects that allocation of funds for R&D on drinking water by the then Department of Drinking Water had remained somewhat bizarre⁸. Similar trend is observed in case of allocation of funds for water R&D by most of the agencies (Fig 2). No linear trend is observed and it appears that funds have been allocated in a rather arbitrary manner without a prioritization plan.

Fig 2. Trend of R&D expenditure on water by respective ministries and departments at constant price (base year 2004-05) over the last 10 years



Source: Author's compilation from <http://www.nstmis-dst.org/Extramurel.aspx>

⁸Mandal. Kasturi & etal (2013), "R &D for Drinking Water in Rural India", India Science and Technology, Cambridge University Press India Pvt. Ltd. , Vol No. 2, P. No. 410-414

At state level, the state S&T councils play a very minor role with some exceptions where the state feels the need of technological intervention in the sector. Table 4 gives an idea of the R&D initiatives undertaken by several state S&T councils.

Table 4: R&D initiatives undertaken by state S&T councils and their collaborative partners

State S & T Council	Collaborative R & D	R & D Area
Assam	Pilot demonstration of ceramic membrane based iron removal plant in Assam in collaboration with CGCRI, Kolkata Developing water and soil testing kit in collaboration with Department of Chemistry, Cotton College, Guwahati	Utility analysis of some aquatic plants in removing heavy metal pollutants from the aquatic bodies of Assam. Integrated studies of major wetlands of Goalpara District of Assam using remote sensing and GIS techniques
Andhra Pradesh	Establishment of water purification system based on reverse osmosis technique with technical support from CSMCRI, Bhavnagar, Gujarat	To improve water quality through water purification system based on reverse osmosis technique
Chhattisgarh	Rainwater harvesting, artificial recharge in four watersheds of Chhattisgarh supported by public health engineering department, govt. of Chhattisgarh.	Ground water conservation and management
Gujarat	Nano-Mission, minor research projects funded to state university & colleges	Waste water treatment
Himachal Pradesh	WASH project funded by the Federal Republic of Germany; Establish centre for monitoring glaciers; Research projects funded primarily to state university & colleges	Roof top rain water harvesting made compulsory in all buildings Conservation and management of wetlands in Himachal Pradesh
Karnataka	Karnataka Israel programme for industrial R & D (KIRD) : technology for water & waste water management in rural and urban areas	Ground water study, assessment of drinking water potential, rain water harvesting
Kerala	Research projects funded primarily to state universities & colleges	Environmental monitoring programme on water quality

State S & T Council	Collaborative R & D	R & D Area
Madhya Pradesh	Digital database of lithology, geomorphology and structure and derivation of groundwater prospects layers under National Resource Information System programme of Department of Space; Research projects funded primarily to state universities & colleges	Watershed development, ground water potential zone mapping
Punjab	Wetland conservation programme in collaborations with MoEF; Research projects funded primarily to state universities & colleges	Wetland Conservation at Harike, Roper and Nangal.
Puducherry	Coastal zone management	Introduction of precision farming
Rajasthan	Establishment of water purification system based on reverse osmosis technique with technical support from CSMCRI, Bhavnagar, Gujarat Research projects funded to primarily to state university & colleges;	Ground water quality mapping, watershed development & soil conservation
West Bengal	Development of bio-reactors to combat arsenic pollution in drinking water is at its final stage of demonstration in collaboration with the department of botany, Calcutta university; Research projects funded primarily to state universities & colleges.	Waste water treatment, wetland development, arsenic pollution abatement

Source: Author's compilation from websites of all state S&T Councils

a) Schemes and Programs

National Water Mission is one of the eight missions identified by the National action plan on climate change (NAPCC) which plans to ensure integrated water resource management helping to conserve water, minimize wastage and ensure more equitable distribution both across and within states. The Mission aims to develop a framework to optimize water use by increasing water use efficiency by 20% through regulatory mechanisms with differential entitlements and pricing. It seeks to ensure that a considerable share of the water needs of urban areas are met through recycling of waste water, and ensuring that the water requirements of coastal cities with inadequate alternative sources of water are met through adoption of new and appropriate technologies such as low temperature desalination technologies that allow for the use of ocean

water⁹. This includes enhanced storage both above and below ground, rainwater harvesting, coupled with equitable and efficient management structures. The following goals have therefore been identified based on the national water mission.

- Comprehensive water data base in public domain and assessment of the impact of climate change on water resource
- Promotion of citizen and state actions for water conservation, augmentation and preservation
- Focused attention on vulnerable areas including over-exploited areas
- Increasing water use efficiency by 20%
- Promotion of basin level integrated water resources management

Achieving such ambitious goals undoubtedly requires technological interventions. Mentioned below are some major programs of the Central Government intended to boost technological development in the sector.

Water Technology Initiative was a major program of the DST under Technology Development Scheme, started in 2007 with the aspiration to promote R&D activities aimed at providing safe drinking water at affordable cost and adequate quantity. The scope of this program covered the entire value chain of R&D; from water oriented basic and applied research, pre competitive technology development, technology based classification & assessment of technology options, pilot demonstration of technology leads etc. It also envisaged to nurture enabling activities such as human and institutional capacity building in form of fellowships, training of water managers, promoting centers of excellence for water research.

Later, a Technology Mission WAR (Winning, Augmentation and Renovation) for water was developed in 2009 on the principle that timely, urgent, cost effective, socially viable and sustainable techno-management solutions are required for solving problems of water scarcity out of a Supreme Court direction to the Government of India to constitute a Committee of Eminent Scientists and provide all resources necessary to address and solve the problem of water scarcity in the country through recourse to research and technology. The program was then carefully planned as evident in table 5.

A large number of water related R&D projects are also conducted within the purview of the Natural Resources Data Management System (NRDMS) – an S&T program of DST launched with the objective to demonstrate and promote the use of spatial data technologies for local level planning under diverse terrain conditions and promote S&T inputs for framing policies related to spatial data technologies¹⁰.

⁹Comprehensive Mission Document of National Water Mission (2011), Ministry of Water resources, India , Vol 1 (2011), <http://wrmin.nic.in/>

¹⁰Technology Mission War for Water, <http://www.dst.gov.in/>

MoWR provides financial assistance to promote research in the field of water resources engineering by way of grants to academicians/experts in the universities, IITs, recognized R&D laboratories, water resources/ irrigation departments of the central and state governments and NGOs under its R&D programme. Research proposals of applied nature as well as basic research are considered for MoWR support. The MoWR constituted six Sub-Committees to examine all related aspects in the sector:

- a. Policy and Institutional Framework;
- b. Surface Water Management;
- c. Ground Water Management;
- d. Domestic and Industrial Water Management;
- e. Efficient Use of Water for Various Purposes; and
- f. Basin Level Planning and Management.

With a view to actively associate the reputed academic institutions associated for specific studies related to impact of climate change on water resources, MoWR has also decided to establish “Professorial Chairs”. Indian institute of technology (IIT), Roorkee and National Institute of Technology (NIT), Srinagar are associated with studies in respect of Indus basin. IIT Kanpur and NIT, Patna has been assigned with the responsibility of research and studies related to Ganga basin. IIT, Guwahati and IIT, Kharagpur will contribute in assessment of impact of climate change in respect of Brahmaputra basin. MoWR has also assigned studies to Indian Institute of Sciences (IISc), Bangalore in respect of impact of climate change in rainfall and water resources of peninsular river basins. Depending upon the specific requirements, more institutions could be associated¹¹.

MDWS also promotes R&D in the field of rural water supply and sanitation as one of the support activities. Areas of research include: Water resources exploration, assessment & exploitation related technology development, technology development for improvement in water extraction techniques like improvements in hand pumps designs, solar pumps/ hydraulic rams, improving energy efficiency for reducing operation and maintenance (O&M) costs for projects using conventional power, water scarcity reduction and related technology development like artificial recharge, control of salinity ingress etc, improvements in distribution network of water supply projects for reducing water losses including unaccounted losses, technology for water quality enhancement for rural areas, development of water quality kits, development of appropriate rural sanitation technology.

Council of scientific & industrial research (CSIR), one of India's largest publicly funded research organization also carries on research on water and has identified drinking water as one of its niche area of research. CSIR 800, a major project which aims at providing a better life to 800 million

¹¹Comprehensive Mission Document of National Water Mission (2011), Ministry of Water resources, India , Vol 1 (2011), <http://wrmin.nic.in/>

people in the country by bringing solutions in the area of health, agriculture, and energy recognizes water as a niche area

Table 5: Approaches planned for finding out viable solutions for water related challenges in the WAR for water program of DST

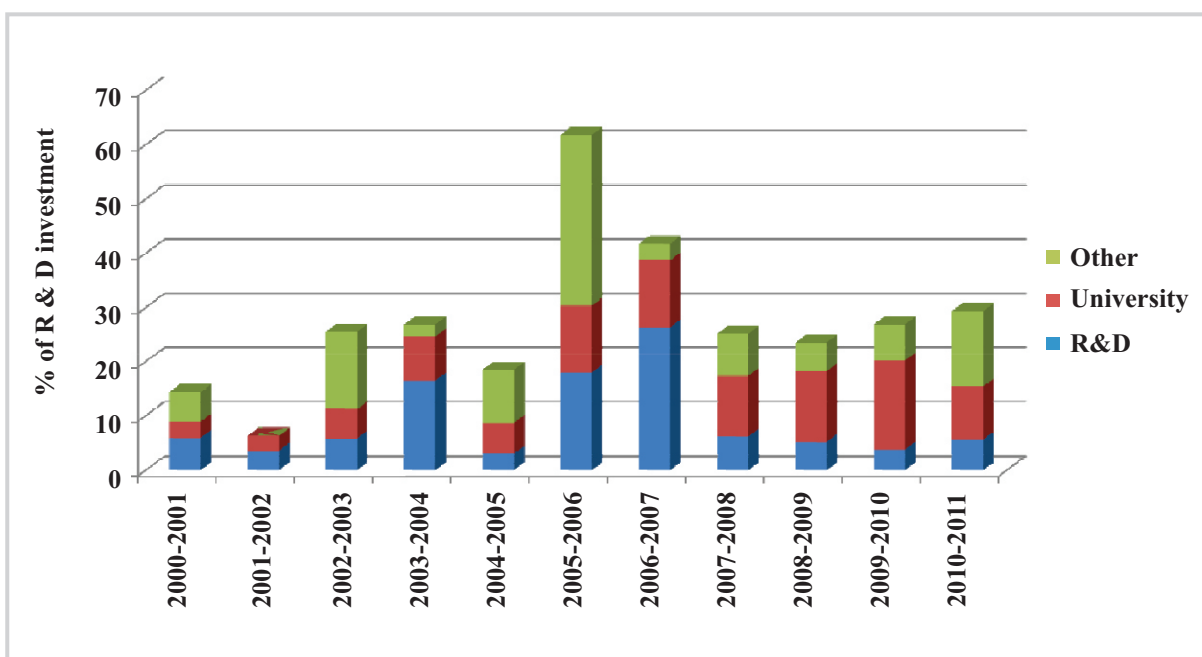
Function	Activity Required	Priority Actions
Mapping the scale, scope and seriousness of the problem in select regions	Mapping a wide range of water related real life challenges in different social environment based on real life data	Data collection. Quantification of water challenges. Assessment of impacted population. Enrolment of the community in selecting likely solutions.
Priority profiling and setting	Study of water challenge related problems and their socio economic impact	Selecting criteria for priority selection based on feasibility of solutions and their impact potentials.
Spotting and scouting feasible solutions from national and international technology sources	Global and wide national search seeking expression of interest	Global and National advertisement for expression of interest to provide viable solutions to selected water challenge.
Expert study and evaluation	Scientific and technical assessment and quantitative ranking of offered solutions	Interactions with technology providers and offers of solutions.
Matching of solution with problems in real field locations	Research and analysis of offered solutions for solving the selected specific problem	Extensive research and bench study for solution selection.
Resource planning and flow arrangements	Project planning and implementation document for every single site	Fund mobilization and allocation for intervention in each location.
Pilot under trial examination under real life conditions	Enrolment of the community leaders for rooting the selected solution(s)	Internalizing a study group for every solution selected for pilot trial.
Data analysis and scope for applications of technical solutions	Expert assessment and economic and social viability analysis	Cost and social viability ranking of solutions found out.
Finalization of selection of options of technical solutions for each water related challenge along with site specificity	Finalization of solution methodologies for each type of water challenge for subsequent replication	Finalization of research report on solutions found out.

Source: <http://dst.gov.in/scientific-programme/plan-document.pdf>

a) Key agencies involved in water R&D

Over several decades of developmental investments and democratic public governance that existed in India, a intricate network of organizations undertaking R&D in water have evolved. They include public funded research institutes, central and state universities, deemed universities, IITs, institutes of national importance, colleges and few private entities. The present study reveals that the universities are attracting more extramural research funds than the R&D institutes (fig 3). The reason behind may be since the universities generally do not have any intramural research fund, they are bound to be competitive and draw more funds. This kind of undertaken R&D on water generally is very much individual scientist centered, who out of his own interest keeps the ball rolling. Such kind of R&D does rarely come out with tangible output with regard to technological development. This is validated by the trend of R&D investment of all the agencies put together which does not establish a pattern of growth. Careful observation has showed that very less repetition of funding research projects of similar nature or to the same project investigator had taken place (with the exception of few training programs and water quality assessment related studies due to natural disaster like Tsunami); whereas for successful technological development continuous support is a necessary element.

Fig 3. Trend of allocation of funds related to water R&D to Universities, R&D institutes and others at constant prices by respective ministries and departments over the last 10 years



Source: Author's compilation from <http://www.nstmis-dst.org/Extramurel.aspx>

In the university system, state universities are more active in attracting funds (38%) followed by state colleges (Fig 4). A report has shown that IITs rank fourth worldwide as a leading water technology laboratory in terms of research publications¹². Amongst publicly funded R&D institutes, CSIR emerges to be the leader (Fig 5) attracting 44.9% of R&D extramural funds followed by research institutes under the MOWR and ICAR. All these departments and agencies work on different aspects of water management and treatment as shown in Table 6. Out of the 38 research laboratories of CSIR, 22 are engaged in water related R&D across diverse areas in the sector and over the years have developed a commendable basket of technologies (Table 7) but had not been so very successful in commercialization with a few exceptions. It has also been observed that both the universities and research institutes have undertaken more research in the area of water quality. Further analysis has also revealed that majority of the research proposals from the university system has been measurement or assessment of water quality whereas the national laboratories have concentrated on technology development. On the contrary, global trend of publications shows R&D in the area of wastewater treatment is maximum (42%) followed by water treatment and water management¹³ but as in Fig 1, R&D in the area of wastewater treatment is minimal in India. On the whole, either our planning exercise based on the required technological needs is not sufficient or have not been implemented as a result we have not been able to harness much from the water technology development related initiatives to the extent that it is desired. Technology is not a standalone system as reflected in some of the success stories in Box 2 and 3 which gives an idea how an integrated approach works in the field.

Fig 4 Share of research grant in water R&D in the university

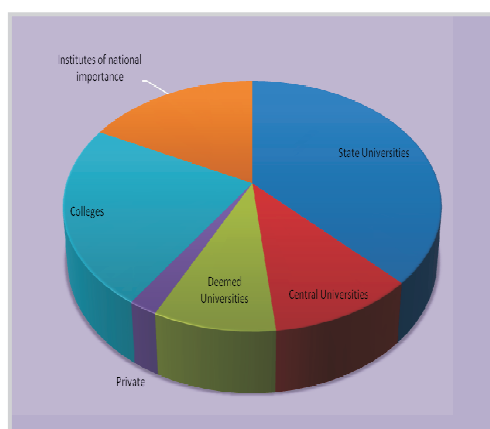
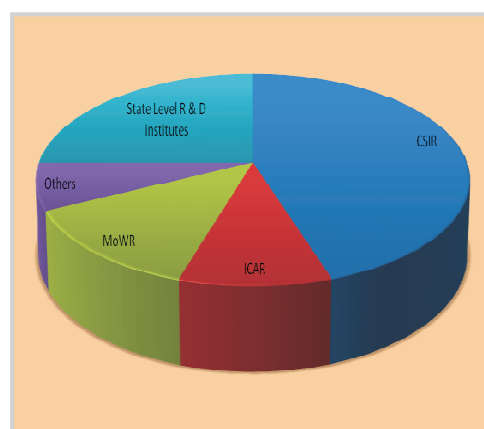


Fig 5 Share of research grants in water R&D in publicly funded national and state level R&D Institutes



Source: Author's compilation from <http://www.nstmis-dst.org/Extramurel.aspx>

¹²Strategic priorities for water technology programme, Kingdom of Saudi Arabia, Ministry of Economy and Planning (Doc. No. 12P0001-PLN-0001-ER01), <http://www.kacst.edu.sa/en/research/Documents/Water.pdf>.

¹³Strategic priorities for water technology programme, Kingdom of Saudi Arabia, Ministry of Economy and Planning (Doc. No. 12P0001-PLN-0001-ER01), <http://www.kacst.edu.sa/en/research/Documents/Water.pdf>

Table: 6 Premier public funded research organizations with their thrust area of research

Ministry/ Organization	Area	Sub Area	R&D Labs
CSIR	Water Quality	Purification technology(Nano filter, Ceramic membrane, Electrochemical method) For Arsenic, Iron, fluoride removal	IICT, ITRC, NML, AMPRI, CECRI, IICT, CSMCRI, CGCRI
	Waste Water Treatment	Sensor technology	IGIB, NEERI
		Water reuse and recycling (Bioelectricity, biodegradable plastics, biogas generation, chromium recovery)	IICT, NEERI CECRI
Biotechnological applications		I T R C , C P P R I , N E E R I , N M L , C S M C R I	
Electrochemical method (Arsenic)		NML	
Ion Exchange method		CSMCRI	
Adsorbent (Goethite)		IIMT	
Phyto -remediation		NBRI	
Treatment technology (Membrane reactor, In situ chemical oxidation, Bio sequestration, Masonry bricks)		NCL NGRI, NPL, NEIST	
Water Management	Aquaculture technique	CEERI	
	Assessment and monitoring (Arsenic)	ITRC, CPPRI, CIMFR	
	Modelling (Ground water, Artificial recharge, Modular house hold Sanitation Device),	NGRI, NIIST	
	GIS and Remote Sensing (Rural Water)	NISTADS	
ICAR	Water Quality	Treatment technology (Bioremediation Process)	CMFRI
	Water Management	Aquaculture Technique	CIFA
		Watershed development	CIBWA
		Groundwater dynamics	CRIDA
		Irrigation (DSS)	CAZRI, WTC
MoWR	Water Management	Hydrological data base	CAZRI
		Training programme	CWRDM
		Decision Support System (Agriculture Water Management)	CWRDM, NIH
		GIS and Remote sensing (Ground water Resources, watershed)	NIH
		Crop planning and Irrigation development	NERIWLM, WLMI

Source: Author's compilation from <http://www.nstmis-dst.org/Extramurel.aspx>

Table 7: Basket of technologies depending on water quality related problems developed by CSIR laboratories

Problem	Technological Solution
High Arsenic in water	Ceramic membrane based arsenic removal technology (CGCRI), Sand based technology (NML) Chemo-de arsenification (NEERI)
High Fluorides in water	RO based technology and waste treatment (CSMCRI), Electrolytic de-fluoridation (NEERI), Chemo-de-fluoridation (NEERI)
High iron contents in water	Ceramic membrane based iron removal technology
Brackish water (high TDS/salinity)	Ceramic membrane based iron removal technology (CGCRI), Hand Pump attachable removal unit (NEERI), NEERI-ZAR, Red clay based 'Terafil' unit (IMMT)
High saline (brine) water in coastal areas	RO membrane based technology (CSMCRI)
Presence of water borne pathogens such as, bacteria and viruses	TFC RO membrane based technology (CSMCRI)

Source: http://www.indiawaterportal.org/sites/indiawaterportal.org/files/Water%20Technologies_NEERI_2010.pdf accessed dated 31st March, 2015

The private sector has also been a part of bringing in technological interventions in the sector. Most of them have global alliances as shown in table 8. Public Private Partnership for water projects is a recent phenomenon and has been emerging as a successful way of promoting investment in the sector. The Vizag industrial water project in collaboration with Larsen and Toubro, the Hubli Dharwad treatment plant in collaboration with CGE, France and the Jamshedpur and Mysore City Corporation projects in collaboration with the TATA's are some such initiatives. The boxes on success stories further reflect on how such partnerships could bring in solutions for the people.

AMPRI: Advanced Materials and Processes Research Institute; **CECRI:** Central Electrochemical Research Institute; **CGCRI:** Central Glass & Ceramic Research Institute; **CPPRI:** Central Pulp & Paper Research Institute; **CIMFR:** Central Institute of Mining & Fuel research; **CSMCRI:** Central Salt And Marine Chemicals Research Institute; **CMFRI:** Central Marine Fisheries Research Institute; **CIFA:** Central Institute of Freshwater Aquaculture; **CIBWA:** Central Institute of Brackish water Aquaculture; **CWRDM:** Centre for Water Resources Development & Management; **DSS:** Decision Support System ; **ICT:** Indian Institute of Chemical Technology; **ITRC:** Industrial Toxicology Research Institute; **IGIB:** Institute of Genomic and Integrative Biology; **IMMT:** Institute of Minerals and Materials Technology; **NBRI:** National Botanical Research Institute; **NML:** National Metallurgical Laboratory; **NEERI:** National Environmental Engineering Research Institute; **NCL:** National Chemical Laboratory; **NGRI:** National Geophysical Research Institute; **NPL:** National Physical Laboratory; **NEIST:** North East Institute of Science and Technology; **NIIST:** National Institute for Interdisciplinary Science and Technology; **NISTADS:** National Institute of Science, Technology & Development Studies; **NIH:** National Institute of Hydrology; **NERIWLM:** North Eastern Regional Institute of Water & Land Management;

Table 8: Indian private sector players vis-à-vis their global alliances in the water sector

Company	Global Alliances
VA Tech WABAG	Wabag Germany
Degermont India	Joint Venture with Degremont, France
Doshi Ion	Joint Venture with Veolia Solutions, France tie up with Kinetico Inc USA for filtration, softening and Denin System
Ion Exchange India	Joint Venture with waterleau, Belgium
Driplex	Partnership with Best water group Austria and Lanxes, Germany
Paramount	Pilkenwood water, UK for oil water separation; Koch glitch, UK for Bio-tower Plastic media
Thermax	Wehire Umwelt Gmbh-Technology for treatment of hard to treat effluents GE Water- Ultra filtration and MBR technologies for India- Reverse Osmosis membranes

Source: http://www.moital.gov.il/NR/rdonlyres/990D9FE4-B289-4FD3-8051-9D358DAE4997/0/Water_and_Waste_Water_Treatment_Opportunity_India_report_160811.pdf

Success stories of improving water services through technological intervention

Box: 1

Gujarat shows a chronicle combination of huge investment in water infrastructure through intervention of innovative technological tools and modification in water policies. Gujarat has only 2% of the country's water resources for 5% of the country's population. Topography across the state is varied Three-fourths of the area is unsuitable for ground water withdrawal due to rocky terrain and coastal regions. The supply of water is limited and the state has a history of droughts. Gujarat has made serious efforts in all-important areas of the water sector such as source augmentation, source management and distribution management. It has implemented several schemes under the Sardar sarovar project, Sujalam sufalam yojana and multivillage rural water supply schemes.

Gujarat has showcased that how technological initiative to improve water supply for domestic consumption and irrigation have to be complemented by grassroots people's participation in management and distribution of water. The community managed water supply programme in Gujarat has proved to be a model for the entire country. It has shown how small innovations, such as micro-water harvesting, can make a large impact on agricultural production. Sardar Patel Participatory Conservation Project (SPPWCP)

involves construction of check dams and village tanks or ponds by a designated beneficiary group, with technical and financial assistance from the district office is a burning example. More than 350,000 check dams and village tanks or ponds were created in the last eight years, providing direct benefit to over 13 million people in rural Gujarat. Gujarat has also created the Gujarat Green Revolution Company Ltd. (GGRC) to popularize the adoption of drip irrigation among farmers. GGRC offers highly subsidized loans to farmers and has simplified the administrative procedures. Creation of a state-wide drinking water supply grid, schemes for water recycling and the Gujarat water regulatory commission bill which has been drafted are some of the institutional innovations in progress.

Box: 2

One of India's early successes in continuous water supply was the pilot project in the three north Karnataka cities of Hubli-Dharwad, Belgaum, and Gulbarga. The 3-city Karnataka project was structured as a management contract with the private sector being responsible for developing an 'improvement plan', procuring and managing contractors for carrying out works as envisaged in the plan, and O&M of the new system. Urban local bodies (ULBs) in the three cities in Karnataka, along with the Karnataka Urban Water Supply and Drainage Board (KUWSDB) and the Karnataka Urban Infrastructure Development Finance Company (KUIDFC) were the contracting authority for the project. A performance based management contract that linked 40 per cent of the payments against achieving project milestones was a key instrument in driving project efficiencies. Project funding was provided by the World Bank (76 per cent) and the Government of Karnataka (23 per cent), with KUIDFC as the nodal agency. The focus of the project was to improve water service management, by cutting leaks and losses in the distribution network, to enable continuous water supply with the available water resources. For the first time, a private sector participation initiative with demonstration of continuous water supply was taken up in the identified zones of the three ULBs. Veolia Eau-Compagnie Generale Des Eaux, a French 10 billion company that manages water supply systems in 80 countries was selected as operation and management consultant through global bidding. The company used its international expertise to design, install and commission water pipelines from the Renukasagar reservoir, about 45 km from Dharwad city. The existing pipelines were replaced with High density poly ethylene pipes to supply water in the demo zones. The company also laid a separate pipeline for Hubli from the water treatment plant at Aminbhavi, which ensured supply of water with decent pressure to the city. Five demonstration projects in select wards of these three cities were completed and water was available round the clock

Policy Suggestions

Development of strategic technologies that are essential for future growth is a necessity which one cannot ignore and water is one amongst them. For this, our development policies have to be holistic in nature as they often impact more than one sector at the same time. Demand/supply dynamics of any one sector cannot be the sole factor in devising policies as they impact those in another and vice versa. Keeping this in mind the following issues may be considered to boost technological development in the water sector.

- The government department and agencies often perceive that the water crisis is to be solved through management approach and technology has minimal role to play. However, countries like Israel have proved that it requires more than management. We need innovative and realistic solutions that are cost effective along with our regulatory and governance abilities. Therefore there is a need to bring in a change in mind set and therefore the approach of solving the impending crisis.
- Indian R&D system is more interested in high tech areas rather than meeting day to day challenges which are not top priorities for research and innovation. It is evident from the fact as out of the total R&D extramural fund only 1.97% went for water related studies. Indian research system has to be more for the bottom of the pyramid. It has to learn from traditional and indigenous knowledge systems and should work on refining them and bring localized resource based technological solutions at economical and competitive costs for the community. The scientific community must meet the needs of poor people. In the water sector, we need to devise technological solutions which are preventive in nature rather than being curative, e.g controlling pollution at the source rather than treating the polluted water.
- There is urgent need to increase investment in water related research studies. New models of funding water R&D should be devised. Currently funding is project based which most of the time is for a period of 2-3 years. Effective technology development requires financial support over a consistent period of time. Instead of all government research funds being distributed to the budget of different scientific departments, creating a new National Research Fund for the water sector could be effective. Identification of niche areas of technology development that is required should be undertaken and therefore generate a clear demand on the need and support of the nature of R&D based on such needs.
- R&D projects on water based on multi-centric studies should be encouraged. A framework needs to be developed with a vision for taking up R&D for the next 5-years. It felt that more studies on social aspects of water technology, e.g. Governance and conflict resolutions in water and sanitation sector should be included.
- All our policy documents of water have given stress to waste water treatment and water reuse. On the contrary the allocation of funds to such area is the least. So, fund

management strategies should be revised such that there is no mismatch between our policies expectations and research work.

- India requires multidisciplinary centers of excellence to tackle big issues like water system response rates to climate change, coupled forecasting of intense precipitation and floods, medium-range weather forecasts for agricultural water management and water contamination. Such centre's would also train the next generation of researchers to use holistic approaches. The Indian Institute of Science, Bangalore, has established such a centre this year. This step should be emulated nationwide with funding from government and private industry.
- Ministerial level tie-ups with R&D institutes of repute for evolving suitable technologies based on their requirement is desired. There should be specific funds allocated for replicating good technologies.
- Build technology partnerships with states and central ministries through new models of technological solutions, design, development and delivery. R&D projects as public private partnership projects should also be encouraged. Integrating the efforts of related organizations, which is a program management prerequisite for successful technology development and diffusion to be encouraged.
- Benchmarking our research organizations with global institutes of repute in the sector should be initiated and taking lessons from them should work on lines that are our country specific. Facilitate R&D collaboration between universities, R&D institutes and industry, expanded international collaboration. Research proposals from different research institutions or combinations of institutions and universities in network mode should be encouraged, periodic reviews of progress of research should be done and further improvement to be strictly monitored.
- Technology hubs need to be set up for development of new technologies and benchmarking of available technologies to provide a transparent picture of benefits to the private entrepreneurs. These hubs would also provide incubation facilities to inexpensive new technologies for attracting private participation. Hydro-hubs in Singapore and Irrigation Technology hubs in Israel could be the models the country could adopt.
- Regulatory framework for effective technological development in the sector needs to be strengthened
- Environmental services should be prioritized to tackle climate change as well as other problems related to water and therefore also attract entrepreneurs into the sector in tackling problems of the sector. This could perhaps bridge the gap between technological invention and diffusion and promote commercialization as in India much of the water related research is still at laboratory stage or a prototype had been developed at the most.

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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