BARC Q&A

Tête-à-tête with

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The points in the interview were shared as answers to an email questionnaire by Dr. K. Tirumalesh of RC&IG, BARC.

With India's over dependence on groundwater, what strategies can ensure sustainable usage of water for present and future?

At the national level, groundwater is increasingly becoming the backbone of India's water security. It caters to nearly 65% of irrigation needs, 85% of rural drinking water demand, and supports growing urban and industrial use. This widespread reliance, while vital to socio-economic development, has also led to significant stress. Ensuring sustainable use of this invisible lifeline is not just a technical necessity, but a national imperative.

India's groundwater utilization patterns are shaped by diverse geological, climatic, and socio-economic contexts. Therefore, a balanced approach which encompasses blending demand management, supply augmentation, regulation, and community participation is essential.

On the supply side, replenishment of groundwater resources through artificial recharge structures, watershed management, and revival of traditional systems is crucial. The Jal Shakti Abhiyan and Amrit Sarovar Mission are already creating thousands of such structures across the nation. Additionally, re-using the water generated from treatment of wastewater can significantly curtail the need for tapping new groundwater resources.

On the demand side, micro-irrigation, crop diversification, and precision agriculture offer scalable solutions. The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) and incentives for water-smart farming are steps in the right direction.

Institutionally, programmes like the Atal Bhujal Yojana and National Aquifer Mapping (NAQUIM) are empowering communities and stakeholders with tools to understand aquifer behavior and prepare Water Security Plans at the Gram Panchayat level. Tools like IN-GRES have brought transparency and scientific rigor to groundwater estimation.

Only through this integrated and inclusive strategy can we ensure groundwater remains a secure, equitable, and resilient resource for generations to come.

With increasing urbanization, do you think India has a robust policy framework for managing water demand in cities? What reforms are urgently needed to avoid any near-future eventualities and "zero water-day" situations?

India's rapid urbanization is emerging as one of the most pressing challenges to water security. By 2036, nearly 40% of the country's population is expected to reside in urban areas, thereby significantly increasing the demand on already strained water resources and infrastructure. While notable strides have been made in recent years, urban water management in India must evolve further to meet this growing pressure.

Multiple ministries are working collaboratively to address the issue. The Ministry of Housing and Urban Affairs is spearheading the Jal Jeevan Mission (Urban), which aims to ensure 100% household tap water connections and promote the reuse of treated wastewater. Under AMRUT 2.0, cities are developing Water Balance Plans and upgrading water supply and sewerage infrastructure. The Smart Cities Mission is incorporating advanced technologies such as smart metering, real-time monitoring, and automated leak detection to enhance water efficiency. The Ministry of Jal Shakti is leading the Jal Shakti Abhiyan, focusing on rooftop rainwater harvesting, water body rejuvenation, and aquifer recharge. Simultaneously, the Ministry of Environment, Forest and Climate Change is promoting wetland conservation and regulating environmental flows

…Presently, there's a shift towards integrated and sustainable water resource management in India, combining traditional wisdom with modern strategies. Yet, overcoming the legacy challenges requires holistic planning, community participation, and resilient infrastructure that can adapt to climate and demographic pressures…

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to protect urban ecosystems. To make cities truly water-resilient, an Integrated Urban Water Management (IUWM) approach is being promoted, linking surface water, groundwater, stormwater, and wastewater systems. Water pricing reforms and metering are being introduced to incentivize efficient use while safeguarding affordability for vulnerable populations.

India possesses the policy framework, institutional capacity, and technical tools necessary for transformation. What is needed now is stronger convergence across agencies, effective enforcement, and widespread public participation.

How has the Indian National Water Policy evolved over time, and what changes are necessary for future water security, with reference to both drinking and irrigation water demands?

India's National Water Policy (NWP) has evolved significantly over the past few decades, reflecting the country's changing priorities and growing understanding of water as a finite and shared resource. The maiden policy, formulated in 1987, was focused primarily on the development and utilisation of water resources through construction of large-scale infrastructure projects such as dams, reservoirs, and canal systems. This aligned with the national objective of achieving food security and supporting industrial growth in the post-independence era.

The revised 2002 policy marked an important shift by acknowledging the need for participatory irrigation management, conjunctive use of surface and groundwater, and water pricing as a conservation tool. The 2012 policy represented a more integrated and forward-looking approach. It introduced the concept of Integrated Water Resources Management (IWRM), emphasized ecological flow requirements, climate resilience, and water-use efficiency. Importantly, it brought groundwater into sharper focus and recognised it as a common-pool resource. India's National Water Policy is a dynamic guideline. As water challenges become more complex, policy framework will continue to evolve, in order to guide the stakeholders for initiating appropriate actions in a timely manner. Of late, there is an increasing shift from supply-side approaches to demand management, community participation, decentralized governance, and science-based planning. Emphasis is growing on treating water as a common public resource, ensuring equitable access, and promoting water security for all.

How are extreme rainfall events impacting water resources, and what approaches can develop climate-resilient water systems, particularly considering the receding Himalayan glaciers that feed major rivers?

Extreme rainfall events, marked by their unpredictability, intensity, and frequency, are becoming more common due to climate change, with profound impacts on India's water resources. On one hand, sudden downpours lead to urban and riverine flooding, damage to water infrastructure, and reduced groundwater recharge as runoff flows rapidly. On the other hand, prolonged dry spells and shifting monsoon patterns are contributing to droughts, crop failures, and declining reservoir levels. These twin extremes have potential to destabilise India's historically monsoon-dependent water systems. In parallel, the receding Himalayan glaciers which feed major rivers like the Ganga, Yamuna, Brahmaputra, and Indus pose an even greater long-term risk. Glacial melt initially increases river flows but will eventually lead to reduced base flows, especially in the dry season, severely affecting water availability for millions downstream.

In response, India has begun integrating climate resilience into water resource planning. Under the National Hydrology Project, real-time hydro-meteorological data is being used for flood forecasting and reservoir operation. The Namami

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Gange programme is incorporating ecological flow monitoring to protect river health amid changing flow patterns. Many states are increasingly adopting Water-sensitive Urban Design and building rainwater harvesting and recharge structures under schemes like Jal Shakti Abhiyan and Amrit Sarovar. To address infrastructure safety, the enactment of the Dam Safety Act, 2021 has established a comprehensive regulatory framework for monitoring, inspecting, and maintaining dams in the country critical in a time of rising hydrological variability.

Additionally, glacier monitoring stations and snowmelt models are being developed in collaboration with agencies like the IMD, NRSC, and CWC. India is not just preparing for future climate impacts it is actively managing the challenges already unfolding, by blending traditional water wisdom with modern science, and embedding resilience into its water governance systems.

How important is restoring natural surface water bodies and incorporating traditional water conservation methods into modern management systems, particularly in the context of climate change?

Restoring natural surface water bodies and integrating traditional water conservation methods into modern management systems has become increasingly critical, especially in the context of climate change and water management. Natural systems such as ponds, tanks, lakes, wetlands, and floodplains serve as vital buffers against extreme weather events. They regulate floods by absorbing excess rainfall, support groundwater recharge, maintain base flows in rivers, and moderate local microclimates. However, rapid urbanization, encroachment, siltation, and pollution have severely degraded many of these ecosystems across India.

Equally important is the revival of traditional water harvesting systems. These systems were historically designed to suit local geo-climatic conditions and were managed collectively by communities. They provide a template for decentralized, low-cost, and climate-resilient water management. By integrating these systems with modern science through GIS mapping, hydrogeological surveys, and data-based planning they can be rejuvenated as part of mainstream water policy.

India's First ever Water Body Census has been completed by the Government wherein physical features along with the geo coordinates of water bodies have been recorded. Government initiatives like the Amrit Sarovar Mission, Jal Shakti Abhiyan, MGNREGA-based water conservation works, and urban lake rejuvenation under Smart Cities initiative are already enabling large-scale restoration.

Incorporating traditional wisdom with modern techniques offers a hybrid approach that is not only sustainable but also socially inclusive and ecologically sound. As India builds resilience against climate risks, such nature-based solutions must be recognized as central to achieving long-term water security and environmental sustainability.

How do you rate the success of programs like Jal Shakti Abhiyan and Atal Jal Mission in reviving overexploited areas and conserving water resources?

The Jal Shakti Abhiyan (JSA) and Atal Bhujal Yojana (Atal Jal) represent two of the most transformative initiatives undertaken by the Government of India to address groundwater stress and promote sustainable water management, particularly in overexploited and water-stressed areas. Both programs, while distinct in their approach, share a common goal community-led water conservation, built on data-driven planning, convergence of resources, and behavioral change.

The JSA, launched in 2019, followed a campaign-style model focusing on five key interventions rainwater harvesting, renovation of traditional water bodies, reuse of water, afforestation, and

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awareness. Its success lies in the convergence it achieved across ministries and schemes, leveraging the implementation strength of programs like MGNREGA, PMKSY, and AMRUT. It revived lakhs of water bodies and structures, improved groundwater recharge, and fostered a nationwide movement of "water warriors," particularly under the 'Catch the Rain' campaign. Importantly, it made water conservation a mass movement, extending beyond just the government machinery to involve citizens, NGOs, and local institutions. Recently, Hon'ble Prime Minister of India has launched "Jal Shakti-Jan Bhagidari (JS-JB)" initiative under the Jal Shakti Abhiyan to promote community-driven water conservation and groundwater recharge across the country.

The Atal Bhujal Yojana, with its focused implementation in 80 water-stressed districts across seven states, has added depth to this movement. It introduced a bottom-up, community-centric approach where over 8,000 Gram Panchayats have prepared Water Security Plans based on aquifer-specific data and scientific guidance. With more than 1.2 million stakeholders trained, including farmers and women, Atal Jal has successfully fostered ownership at the grassroots level. Early results show promising outcomes, including improved groundwater levels in over 1,300 Gram Panchayats, adoption of efficient irrigation practices, and better awareness about aquifer behavior.

Together, these programs have marked a shift from reactive crisis management to proactive aquifer stewardship. While challenges remain such as scaling beyond pilot districts, ensuring long-term behavioral change, and institutionalizing groundwater governance the foundation laid by JSA and Atal Jal is robust. They demonstrate that empowering communities, backed by technology and convergence of schemes, can indeed lead to measurable improvements in India's water-stressed landscapes.

Contaminants like arsenic, fluoride, nitrate and salinity along with other emerging pollutants are affecting millions of people in India. What would be the most impactful approach to tackle water contamination effectively in both urban and rural areas?

Water contamination in poses a serious public health and environmental challenge. Tackling this issue requires a multi-pronged, area-specific and technology-backed approach with strong institutional support. Recognizing the importance of systematic intervention, the Ministry of Jal Shakti has prioritized regular groundwater quality monitoring as a core activity. To enhance standardization and reliability, a detailed Standard Operating Procedure (SoP) has been recently issued to streamline groundwater quality assessment practices nationwide.

In rural areas, the most impactful solution lies in community-level water purification systems, such as Community Water Purification Plants (CWPPs), which provide access to treated water at low cost. The Jal Jeevan Mission (JJM) has made water quality a top priority. The National Water Quality Management Framework with a network of over 2,000 water testing laboratories has made accessible to the public quality services with Field Test Kits distributed at the village level. In highly contaminated zones, alternative safe sources, such as deeper aquifers or treated surface water, are being identified and integrated into piped water supply systems. Technologies like reverse osmosis (RO), ion exchange, activated alumina filters, and electrocoagulation are being deployed based on contaminant type and feasibility.

In urban areas, the emphasis is on upgrading sewage and industrial effluent treatment infrastructure, enforcing Zero Liquid Discharge (ZLD) norms, and preventing illegal discharge into water bodies.

As part of technological innovation, the Central

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Ground Water Board (CGWB) has developed specialized well construction techniques to access arsenic-free aquifers in the Indo-Gangetic plains. Over 500 such wells have been successfully constructed and handed over to state governments for public use, along with knowledge transfer for further replication. Similarly, designing of wells to minimize fluoride contamination have been developed and implemented in fluoride-affected areas.

Education and awareness are also critical ensuring that communities understand the risks of contaminated water and are empowered to participate in local water safety planning. With convergence between Jal Jeevan Mission, Swachh Bharat Mission, and Namami Gange, and strong leadership from both the Centre and States, India is moving towards a future where access to safe and clean drinking water is not a privilege, but a universal right.

Nuclear techniques have been significantly contributing to energy security, health security and food security. How do you see the prospects of Isotope Hydrological techniques in providing deeper insights into complex hydrological issues and helping in designing sustainable water resources development and management for India?

Nuclear techniques, particularly isotope hydrology, are emerging as powerful tools in addressing complex water-related challenges and supporting sustainable water resource development in India. While nuclear science has long contributed to the nation's energy, health, and food security, its application in the water sector through stable and radioactive isotopes offers unique understanding of hydrological systems.

Isotope techniques help in tracing the origin, age, movement, and recharge sources of groundwater, especially in regions with complex geology or where conventional methods are limited. India, with its highly diverse hydrogeology, growing dependence on groundwater, and mounting pressure from climate variability, stands to benefit significantly from wider adoption of these techniques. Isotope hydrology can precisely distinguish between shallow and deep aquifer systems, identify zones of natural recharge, and determine interactions between surface water and groundwater, which is essential for integrated water resource planning. It can also help track pollution pathways, evaluate the sustainability of springs, and validate artificial recharge interventions thereby supporting better policy and infrastructure decisions.

Recognizing the growing importance of isotope hydrology in water resource assessment and management, the ministry has initiated isotope hydrological projects in collaboration with Bhabha Atomic Research Centre, DAE. Concerted efforts are also being made with the help of BARC for training of manpower on isotope hydrology, technical collaborations and developing new isotope methodologies to solve real-time problems persistent in India. National Institute of Hydrology (NIH) and the Central Ground Water Board (CGWB) have recently procured advanced Isotope Ratio Mass Spectrometers (IRMS) for precise isotopic analysis of water samples. These state-of-the-art instruments enhance the ability to trace groundwater origin, age, recharge zones, and contamination pathways with high accuracy.

To further strengthen data integration and collaboration, CGWB has developed a dedicated web-based software platform that enables upload, visualization, and download of isotope-related data. This user-friendly digital system serves as a common platform for information sharing, fostering coordination among researchers, groundwater professionals, and policymakers. By bringing isotope data into a centralized repository, the Ministry has taken a significant step towards promoting transparency, collaboration, and scientific rigor in the field of groundwater resource management.

As India advances toward data-driven and climate-resilient water governance, isotope hydrology can

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play a pivotal role in ensuring our groundwater security and aquifer sustainability quietly but decisively, much like groundwater itself.

In India's federal structure, how can Centre-State cooperation be optimized for sustainable water management, and what critical policy shifts must happen today to positively transform India's water scenario over the coming decades targeting "Access to clean drinking water and sanitation for all"- UN Sustainable Development Goal-6 as a part of Aatmanirbhar Bharat (self-reliant India) by 2047?

In a country as diverse and vast as India, water governance is inherently complex made more so by the fact that water is a State subject under the Constitution, while many water-related challenges and solutions transcend state boundaries. Therefore, optimizing Centre-State cooperation is not just desirable but essential for achieving sustainable water management and meeting the targets of UN Sustainable Development Goal-6 (Clean Water and Sanitation for All) by 2047, in alignment with the national vision of Aatmanirbhar Bharat.

In recent years, Centre-State collaboration has significantly strengthened through key flagship initiatives. The Jal Jeevan Mission stands out as a model of decentralized execution, where the Centre provides funding, technical support, and monitoring tools, while states plan and implement the delivery of tap water supply to every rural household. Over 140 million functional household tap connections have been provided under this mission, transforming the rural drinking water landscape. Similarly, the Atal Bhujal Yojana empowers States to take ownership of groundwater management by preparing community-based Water Security Plans in over 8,000 Gram Panchayats across seven states.

To ensure data transparency and informed decision-making, the Centre has established the National Water Informatics Centre (NWIC) as a centralized platform to host, visualize, and share water-related data with States and other stakeholders. NWIC, through the India Water Resource Information System (India-WRIS), enables seamless data integration across departments and promotes real-time monitoring of reservoirs, river basins, and groundwater levels. The recently developed IN-GRES platform for groundwater estimation is another example of Centre-State technical collaboration under a unified digital framework.

Furthermore, regulatory mechanisms have been formalized through updated Groundwater Regulatory Guidelines by CGWA, which have been adopted and customized by many State Ground Water Authorities (SGWAs). These include area-specific water extraction charges, mandatory recharge obligations, and promotion of water-use efficiency. Inter-state cooperation is also evident in the Ken-Betwa Link Project, which represents a coordinated water-sharing agreement between Madhya Pradesh and Uttar Pradesh under central facilitation.

Major national missions like Namami Gange, PMKSY, Swachh Bharat Mission, and Jal Shakti Abhiyan are all designed as centrally supported but state-led initiatives, where funding, planning, and execution are done collaboratively.

These coordinated efforts reflect a significant shift from fragmented water management to a more integrated, collaborative and digitally enabled approach, paving the way toward India's commitment to SDG-6 and the national vision of Aatmanirbhar Bharat by 2047.

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