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EDITORIAL

Groundwater Sustainability, Security and Equity: India Today and Tomorrow

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Groundwater Resource: Sustainability and Security

Water is the basic civilizational need for domestic use, food production, all economic and developmental activities. Water sustainability, security and equity are fundamental to the growth of civilization, and modern industrial life. UN (1977) charter also defines "Access to Water" as "a human, social, individual and collective right". Its virtues were known even to our ancients who took care to conserve this precious resource.

Rainfall is the mother of all water resources on earth. Although India receives an annual rainfall of 1100 mm, much more than the global average of 700 mm. Its highly nonuniform distribution in space and time, recurrent droughts and weather vagaries, pollution, and its unscientific exploitation render parts of the country water-stressed or even water-scarce leaving a question mark on its sustainability and equitable distribution (Fig.1). According to NITI AYOG nearly 600 million people in India are facing high to extreme water stress or lacking water security which is defined in UN-Water reports as "the capacity of a population to safeguard sustainable access to adequate quantities of water of an acceptable quality for sustaining livelihoods, human well-being, and socio-economic development, ………… and for preserving ecosystems in a climate of peace and political stability".

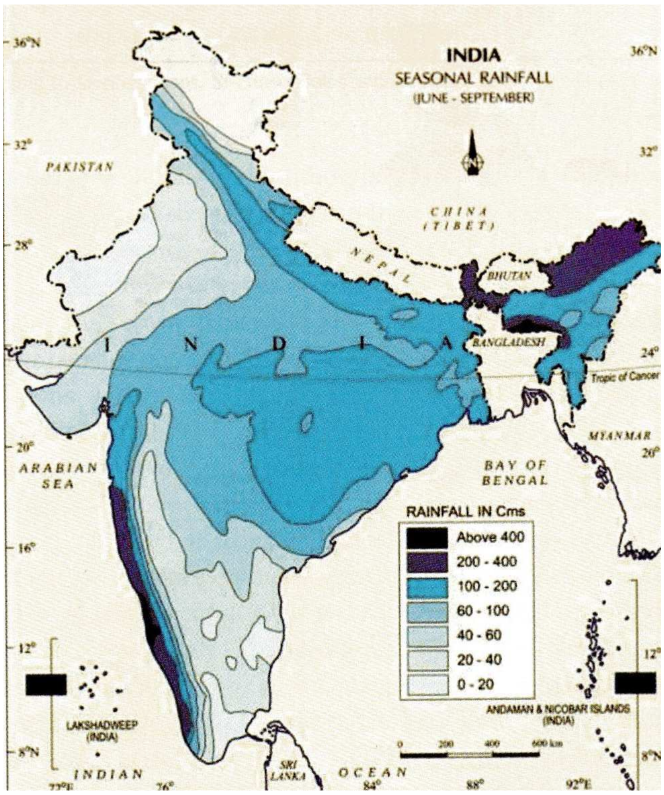

Fig.1. Seasonal rainfall of India (source: IMD).

Surface water and groundwater are two components of water cycle. Since sixties groundwater has been recognized in India as a sustainable resource rather than surface water. Groundwater can withstand 2-3 consecutive droughts, is ubiquitous in occurrence, annually replenishable, free from impurities and evaporation loss, and does not require large capital investments for its development. Nearly one-fifth of the country is arid to semi-arid, drought prone (rainfall <600 mm), suffering from endemic water scarcity where groundwater is the only dependable water source. Groundwater use in the country has since been steeply escalated contributing 66% of total irrigation, 85% rural water supplies and 20-80% urban water supplies. But 60% cultivable area in the country is still rain-fed and unirrigated dryland. With the projected growth of population demands of food grains production will double by 2050, and so also of drinking water, and hence the pressure on groundwater draft will be more, especially in drought prone rainfed areas. Already the stage of its exploitation has reached 60.08%. Hence groundwater, a 'replenishable but finite' resource, needs scientific management to ensure its sustainable development and equitable distribution, in short 'a water secure India'.

Today's Scenario: Resources Status & Challenges

An overview of groundwater regime reflects a highly uneven scenario haunted by various challenges. Widely variable geological, geotectonic, geomorphic, pedological and climatological set ups in India are responsible for spectacularly varying groundwater occurrence, movement, storage and development potentials (Fig.2). In the mountainous zone of the extra-peninsular region (Himalayas) in the north with abundant precipitation (2500->3000 mm) springs, mountain streams and autoflows in 'terai' are the only sources of water but the flows decline or dry up in summer. The Indo-Ganga-Brahmaputra alluvial plains with a pile of unconsolidated sediments, endowed with high rainfall (750-1600 mm) constitute potential groundwater

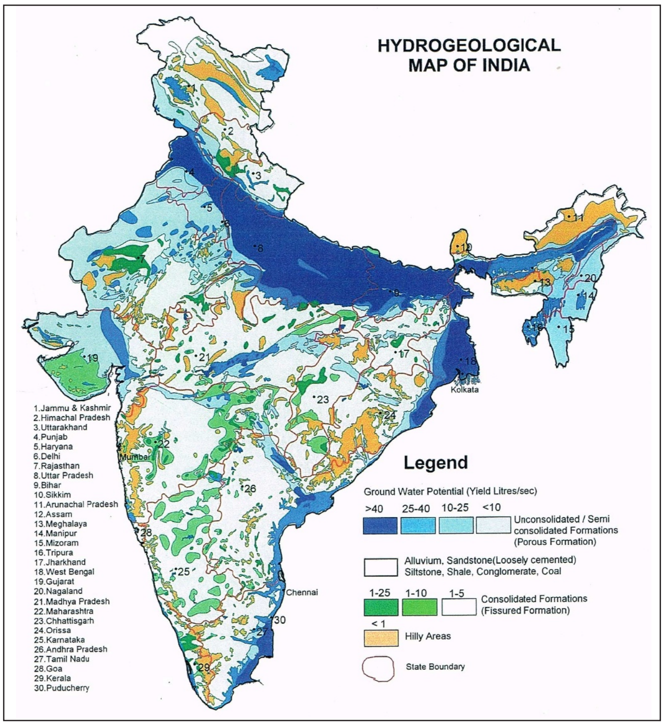

Fig.2. Hydrogeological of India (source: CGWB).

reservoirs (yield 50 - >250 lps) intensively developed. The Peninsular shield, a significant part being arid to semiarid, drought prone with low to moderate rainfall (<300-750 mm) is composed of tectonically disturbed, consolidated, low yielding (<1-10 lps) metamorphic, igneous, volcanic rocks, and compact sedimentaries along with moderate to low yielding semi-consolidated Gondwana sedimentaries in rift basins, and thin alluvial stretches adjoining the river courses. The potential coastal alluvial aquifers yield (50 - >250 lps) are often beset with sea water ingress.

The total annual extractable groundwater resource in India is 398. 08 BCM and the stage of groundwater extraction 60.08% (CGWB 2022). A picture of uneven exploitation emerges in the country (Fig.3) with several parts of the country overdeveloped (draft exceeding annual recharge), and several others in low to very low stage of groundwater extraction (<1 – 44%). Overdevelopment has led to desaturation of aquifers, declining water levels and well yields, drying of baseflows in streams, rising cost of water lifting and power consumption, declining agricultural production, as also acute scarcity of drinking water, triggering loss of employment and migration of people (Mem. 69, Geol Soc. India, 2008). Paradoxically, limited use of groundwater with excessive recharge from the irrigation system has resulted in rise of water table, and water logging reportedly in 5.8 MHa of major & medium canal commands which have eventually reduced soil fertility and agricultural production resulting in economic backwardness.

Groundwater pollution from high F (>1.5mg/L), As (>0.01mg/L), Fe (>0.3 mg/L), NO_3 (>45 mg/L), heavy metals is threatening its sustainability as source of drinking water. The pollutants are derived from geogenic sources or anthropogenic activities. Untreated industrial and municipal effluent wastes, landfills are also potential sources of pollution and waterborne diseases. Hardly 22% of waste waters are treated in India. Saline aquifers (EC > 1600 microsiemens/cm) are reported from the coastal areas of India, oceanic islands and some inland areas due to natural occurrence, tidal incursion or seawater ingress. As per UNICEF nearly 44 million people in India suffer from various water quality hazards.

Tomorrow's India: Need for Groundwater Governance

> ***"****The real water crisis facing the world is one of water management. Pressure on finite resource requires efficient and equitable allocation between the rising demands of different types of users and usage." (The Atlas of Water, Earthscan, London, 2004, p.92).*

What is needed is sustainable and hence disciplined groundwater development. Sustainable development has been defned as that kind of development that "meets the needs of the present without compromising the ability of the future generations to meet their own needs". This involves regulation of groundwater draft in overexploited areas through administrative, legislative, and various water conservation measures including water pricing; acceleration of its exploitation in areas with low stage of development including drought prone areas; stepping up hydrogeological surveys and exploration; conservation, and augmentation through conjunctive use and artificial recharge; monitoring and protection of resource from overexploitation and pollution. "Integrated water resource management………should be the main principle for planning, development and management of water resources" (National Water Policy, 2012). It is "a process which promotes coordinated development and management of water (*rainwater*, *surfacewater, groundwater)*, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising sustainability of vital ecosystems" (UNEP-DHI. IWRM in action. Water Policy, 2009).

New sources of water: Hydrogelogical surveys and exploration aided by remote sensing and geophysics should be accelerated especially in drought prone, hardrock, coastal and high relief areas to delineate yet unknown potential aquifers. Heliborne TMT surveys are the latest innovations used in high resolution aquifer mapping especially in hard rocks (Geol. Soc. India, Spec. Publ.. No.5, 2016). The country has now launched multidisciplinary National Aquifer Mapping & Management Program (NAQUIM).

Dynamic resource: Precise estimation of dynamic groundwater resources provides the foundation of its scientific development and management. Groundwater draft should not exceed its annual replenishment. The vast saline/brackish water resources available along

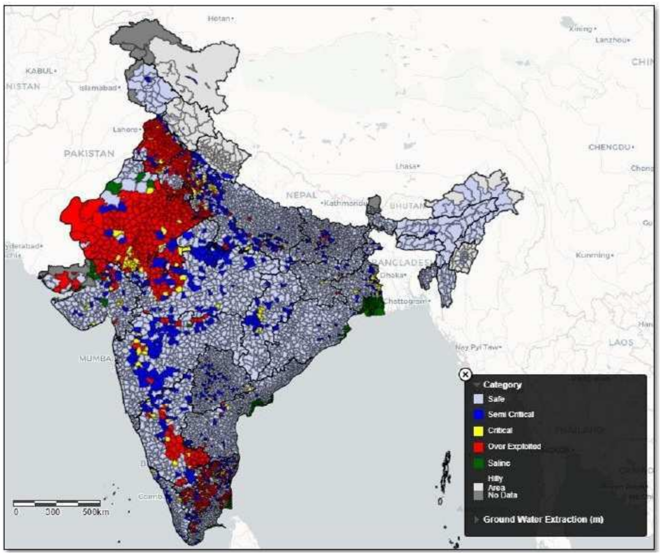

Fig.3. Stages of groundwater development in India, 2022 (CGWB).

the long coast of India should also be estimated for use in irrigation of salt-tolerant crops nafter blending with freshwater, in prawn culture and, salt industries.

Water management in rural areas: Integrated management of rainwater, surface water and groundwater along with watershed treatment, - water conservation, conjunctive use, rainwater harvesting, and artificial recharge with rainfed agriculture and drip/sprinkler irrigation can unlock enormous potential of the rainfed areas of the country ameliorating chronic water shortage (*JGSI*, March, 2015). Conjunctive Use of surface water and groundwater in the canal commands is the most efficient method of water conservation, which allows optimal use of total available water resources, rectifies aberrations in canal irrigation, increases irrigation intensity and agricultural production, and ensures drinking water security. Studies by CGWB & State organisations have brought out replicable models of conjunctive use in different hydrogeological and agroclimatic zones in the country. Further, rainwater harvesting and artificial recharge are recent innovations to enhance natural recharge rate replenishing depleted aquifers or creating subsurface storage under favorable hydrogeological conditions. These are implemented adopting traditional technology of water harvesting and moisture conservation practices as part of watershed treatment (CGWB 1996, 1998, 2012) such as terracing, contour bunding, percolation tanks, check dams, gully plugs, as also groundwater dams. CGWB has drafted a Master Plan for Artificial Recharge (2020) in the overexploited and water-deficit areas of India.

Water supply crisis in urban complexes: Urban India is engine of country's productivity and growth. By 2050 one-third of country's population may live in cities. But unscientific urbanization creates severe water shortage in cities as in Bengaluru. Cauvery and Arkavathy rivers, and lakes, both natural and man made are the primary sources of water , but are in dire straits. Groundwater, the supplementary source and lifeline of the city's water supply is overexploited precipitating severe water scarcity in summer. Rejuvenation of Arkavathy river and lakes, and recharging overexploited groundwater through rainwater harvesting, recycling of treated waste waters, plugging of transmission leakages and pricing of water may ameliorate the situation. Bangalore serves as a model of water supply planning and management for a smart city (Mem 79 and Spl. Publ., no.7, Geol. Soc. India, 2011, 2020).

Regulating draft through legislation: Most states have enacted groundwater legislation in some form to curb its overdraft and ensure its equity. But development of this common pool resource by millions of users through individual enterprise, and unrestricted right of the landowners to draw groundwater render legislative measures infructuous. However, groundwater legislation may be effective if supported by supply and demand management, and conservation measures with community participation. In the greater public interest, its use rights should be with the community.

Contaminant-free aquifer: Reverse Osmosis, Electrodialysis, LTTD technique for desalination, Oxidation-Coagulation-Coprecipitation method for arsenic removal, Nalgonda technique for defluoridation, use of organic fertilizers, biosorption, seawater intrusion controls, and STPs for sewage treatment are common mitigation measures for degraded groundwater quality. Artificial recharge and harnessing contaminant-free aquifers are cost-effective alternative methods (Mem 1, ISAG, Hyderabad, 2012). DRASTIC mapping allows tracing pollutant sources and movement for planning mitigation actions.

Global warming and water cycle: Impending climate change and global warming will affect hydrological cycle in the country with rise of annual mean temperature by 3°-5° C over the century, decrease in rainy days, increasing frequency of extreme events entailing increasing runoff, lessening groundwater recharge, melting of Himalayan glaciers drying up Himalayan rivers, increasing evapotranspiration and hence water consumption, and thus will increase pressure on groundwater. Sea level rise of 1m will inundate coastal areas, submerge oceanic island of Mali, and salinize the coastal aquifers. All these changes will affect cropping pattern, crop seasons, food grains output and drinking water availability (Natl. Sem. Green Earth, 2012, Dehradun). National Mission on Climate Change Mitigation Technology focusing mainly on water harvesting and conservation is a welcome step.

Know your aquifer, manage your aquifer: All the above strategic actions need a thorough knowledge of subsurface geology, hydrology and water balance calling for stepping up surveys, exploration, monitoring, modeling. Mathematical modeling enables understanding the groundwater system better and predicting its behavior in strained conditions. Reappraisal hydrogeological surveys and groundwater monitoring through 61,737 permanent observation wells across the country help in surveillance of groundwater regime against any deleterious effect of progressive groundwater development, and in exploring alternate development model. Further, information technology has allowed fast storage, analysis, and retrieval of voluminous data. Public awareness of aquifer overexploitation, conservation and pollution is essential for successful water management. All hydrogeological data are now available in the web site of the Ministry of *Jal Shakti* and depicted in the Digital Watershed Map of India (2006) even at the taluka level for wide public use.

Radhakrishna's 'Water Secure India'

"Water underground is more precious than even precious metals and minerals and requires to be systematically explored. Water is a crop, a resource to be cultivated, nurtured, stored, and harvested over long periods of time". Late Dr. B. P. Radhakrishna, legendary geoscientist of yesteryears, penned a series of articles on water management and conservation (*JGSI*, 1991, 1997, 1998, 2002, 2003, 2004, 2008). These articles give a glimpse of his futuristic vision of water management in arid and semi-arid, specially hardrock areas.

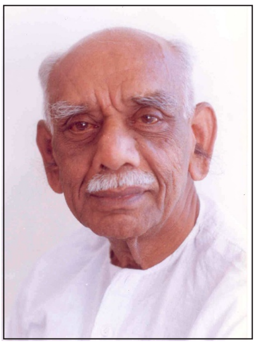

Fig.4. B.P. Radhakrishna, Messiah of Water Security.

Radhakrishna was a votary of indigenous solution to the water management problems based on local land and water endowments adopting traditional knowledge and practices.

Blueprint of Actions: Rainfall in India is limited to 90 days in a year. Radhakrishna called for runoff farming by erection of contour bunds and stone lines to check flow of water, growing rows of trees to catch rainwater to effect recharge (Fig.4). A major aspect of rainwater harvesting is construction of farm ponds which act as percolation tanks, and development of contour ditches and bunds to prevent rapid runoff. Our ancestors constructed large number of tanks in Telangana, Tamil Nadu, Karnataka which provided irrigation, and served to effect recharge to groundwater which was tapped by farmers in non-rainy months, as also in drought or rainfall deficit years through wells. Radhakrishna, advocated identification of regions of rapid runoff for its interception. He referred to 'rain nakshatras', the ancient practice of classifying rains into 13–14-day periods and urged for its fine tuning to 5–7-day classification with scientific analysis.

Radhakrishna viewed geological inputs as crucial in water conservation. Cadastral maps (scale 1:8000) showing individual land ownership, water table contours, geology, depth to water, groundwater structures, soil types and land use characteristics, as flat land suitable for irrigation, sloping land suitable for horticulture, and hilly land for afforestation will go a long way in educating farmers for water management. All these will help save moisture in soil and promote "transformation of drought prone areas into smiling agricultural fields". "Village" should be the focus of development. He suggested short courses to teach enthusiastic volunteers on communicating knowledge to the rural public making good use of video cassettes. Geologists and geomorphologists should develop area-wise thumb rules which may serve as 'Best Practices' for the people.

Water Warriors and Community: In the words of Radhakrishna, "What is required is good leadership at village level……Village community is the rightful custodian of water…………Group action at soil and water management aided by government support can achieve wonders." By combining technology with social actions rainwater can be made to provide maximum benefits to dryland farmers both through surface water storage and through aquifer recharge. Anointed by Radhakrishna as Water Warriors, Late Anil Agrawal, Sunderlal Bahuguna, Magsaysay Awardee Rajendra Singh, Anna Hazare organized conferences and '*pani yatras*' urging the society for mass movement for rainwater harvesting on a grand scale (*JGSI*, Feb 2002). Arvari River Basin in drought prone Alwar district of Western Rajasthan is a shining example of community driven integrated water management using traditional/ indigenous knowledge of water conservation. More than 8600 '*johads*' (check dams) were constructed in 1600 villages in the basin with community participation under the leadership of Tarun Bharat Sangh. The dead river Arvari was revived into a perennial water course within a span of two water- years. With availability of water farming and economic activities resumed, - economy flourished from penury to affluence. Arvari set a new model of water governance through setting up of Arvari River Basin Parliament making their own rules and laws for water management (Mem 82, Geol. Soc. India, 2008).

Sanitation and Clean Environment: Solid waste is a source of groundwater contamination. Most rural households still resort to open defecation. In cities 30% water in domestic usage is lost in flushing toilets. He highlighted the use of biotoilets and electric toilets to make the sanitary system waterless and odorless. He suggested converting human waste to fertilizer using latest technology." Tying ecological sanitation and field fertilizer use together will ensure non-pollution of water sources and a sustainable solution to management of human waste" (*JGSI,* April 2008).

Urban Water Management: Radhakrishna was seized with the plight of the slum dwellers and the poor of Bengaluru due to water shortage, who pay heavily to private water traders while the affluent indulge in its wasteful use. He insisted on preparation of ward wise atlas of water potential through microlevel surveys, census of borewells for precisely estimating groundwater draft and assessing health of aquifers, suspension of borewell drilling and rooftop rainwater harvesting as major steps for alleviating the water crisis.

Hydrogeological Research: Radhakrishna called for "increased attention to research on water harvesting, ….. conserving and reclamation as well as treatment and disposal of sewage…. This in turn needs an understanding of the flow paths of shallow and deep-seated groundwater in the heterogenous earth." He laid emphasis on Regional Aquifer System Analysis in the line of the United States, which is now a part of our National Program (*JGSI*, Oct 1990).

Radhakrishna was of the view that science of water management is a marriage of geohydrology with social science.

'Wake Up, India'

The country's status of water resources potential vis a vis projected demand for food and water security of the growing population is critical. Per capita availability of fresh water fell sharply from 5000 m^3/year in 1950 to 2300 m^3 in 1997 and may decline further to 1118 m^3/year or less in 2050 precipitating severe water scarcity especially in domestic water supplies (CWC 2012). The total water requirement of the country as on 2025 is estimated as 982.81 BCM while the ultimate utilizable water resources is 1082 BCM (Surfacewater 691 and Groundwater 391 BCM) (CWC, 2012). The situation has already worsened in several river basins, precipitating conflicts between riparian states. This combined with the impact of global warming sounds an alarm of critical situation in not-so-distant future. By 2030 all known aquifers are likely to be exhausted. Scarcity spawns inequitable distribution of resource with the poor worst hit, while the affluent indulge in wasteful use of water. In this scenario groundwater development and management have a major role to play. Highlighting the spirit of much needed water sustainability, security and equity "UN's Sustainable Development Goals (SDG) for Water and Sanitation by 2030" set the following principal aims as part of Participatory Water Security program of which groundwater is a key resource.

- Equitable access to safe drinking water for all.
- Reducing pollution, minimizing release of hazardous chemicals and materials, halving untreated wastewater and recycling and safe reuse globally.
- Increasing water-use efficiency and ensuring sustainable withdrawals and supply of freshwater to address water scarcity.
- Protection of water-related ecosystems, including forests, wetlands, rivers, aquifers and lakes
- Participation of local communities in improving water and sanitation management.

Supply and Demand management is at the core of groundwater management, – its security and equity. Atal Bhujal Yojana, Jal Shakti Abhiyan, National Water Mission, Atal Mission for Rejuvenation & Urban transformation, Swachchha Bharat etc, launched by Union Government are some ambitious endeavours in this direction.

Radhakrishna gave a clarion call for ushering in a new blue revolution matching in scope the green revolution which changed the face of India a few decades ago.