Water

Water – gaps, opportunities and hope for tomorrow

Water is both local and global, just as carbon dioxide. However, while number of water molecules on the planet is roughly constant at 33.4 x 10^{45}, total CO_2 continues to rise. The magnitude of water, represented this way appears small, although it is massive, measuring 1.386 billion km^3 or in other words, a billion, billion tons. Nature circulates water from one form to the other – soil to sea to air. Eventually, the Earth is nourished by rain, its principal way of regeneration. Ecosystem on the land survives only because about 0.5% more water falls on land as rain than the amount evaporates from it. This excess water is taken to the sea through various ways and the process makes the land bloom. Our wealth is largely due to this nourishment. The foregoing makes it obvious that the singular ingredient that enables civilisation is water.

The context: India has just 4% of the global freshwater resources but ~18% of the world's population. The country, which was largely rural years ago, has *en-masse* become urban in the past two decades. The urban population has risen from 28% in 2000 to 33% in 2016. With a growth rate over 6% in gross domestic product (GDP), the most populous countries, such as India and China, are increasing their chemical, pharmaceutical, agrochemical, automotive, petrochemical, semiconductor, and many other outputs, which will eventually "enrich" our ecosystem materially. Simultaneously, their rapidly declining water resources will be burdened by unprocessed industrial waste. The World Bank has predicted that achieving a growth rate of 8% or above for India will be possible only with a robust water management system. These emerging issues, like those existing throughout the world, present a complicated suite of problems that will require technological advances, limits on usage, and collective wisdom, and compassion to create sustainable solutions. For instance, the control over carbon emissions by developed countries is probably not the reason for the globe's survival, but the lack of development in less-developed countries is, according to the Intergovernmental Panel on Climate Change (IPCC). Sustainable economic and technological development for all is needed, although acquiring a quality of life comparable to the United States for the rest of the world would require significant advances in treating, purifying, and manging water. Water challenges are highly interdisciplinary, and solutions therefore must cut across boundaries of disciplines. Water in diverse forms is related to climate, food, health, and many other aspects of life, including its origin. The need for urgent, concerted action from all fronts is clear from just one observation: ca. 83% of freshwater species have declined globally in the last 50 years!

Our challenges: Of the global precipitation of 505,000 billion cubic meters (BCM), India gets its < 4000 BCM for a geographical area of 328.7 million hectares, with an average rainfall of 1085 mm, 85th in a list of 186 countries with Egypt at 51 mm at the bottom and Columbia at 3240 mm at the top (as on 2014). Water footprint, estimated by considering production and consumption of goods and services, works out to 2842, 1071 and 1089 m^3 per capita per year (PCPY), respectively for USA, China and India, the global average being 1385 PCPY. Therefore, with a water availability of around 1100 m^3 PCPY, India has no water to lose and no water to dirty during its activities. Besides, the country experiences extremes such as ambient temperatures in the range of -40 to +50 ^oC and rainfall between 210 to 11800 mm, making every possible water technology necessary. These technologies have to address all the sectors - agricultural, industrial and domestic - major domains of water use, and for every region of the country.

Our agriculture is becoming increasingly unsustainable. In several regions, intense farming run on ground water has made the land dry and this depletion calls for urgent reversal of our policies and widespread rainwater harvesting, to ensure food security. Poorly-crafted agricultural policies have flooded our fields with poison. For example, arsenic has been found in South Indian paddy fields where it is geologically impossible, and has ultimately reached our dinner table, making the population vulnerable. While this occurs, our rivers have run out of water and all of them have been polluted and each one of them has lost significant biodiversity.

Every segment of our industry – mining, clothing, leather, pharma, tourism, and many others need to implement sustainable practices. Climate change is increasingly manifested in the country with receding glaciers, changing monsoons, unprecedented droughts, and frequent typhoons, and each one impacts water, either causing excess or scarcity.

Although a drive to provide 70 litres per capita per day (lpcd) for the whole nation in the rural areas and 40 lpcd in the cities is being pursued, availability of this water at acceptable quality is an issue. This quantity accounts for drinking,

cooking, cleaning and livestock needs. It is estimated that over 20% of India's diseases are connected to water, 1 in 5 children die below 5 years of age by water-related causes, poor sanitation or inadequate hygiene. We have some of the worst water contamination issues: Over 130 million people are affected due to fluoride and about 100 million due to arsenic. Several pockets of uranium, mercury, chromium, perchlorate, nitrate, etc., poisoning exist across the country. There are issues of antibiotics, emerging contaminants, pesticides, etc., as well. Environmental issues are too many, such as frothing and coloured rivers. In water crises, the most affected are poor, who earn less than Rs. 100 a day. Our religious practices often contaminate water bodies and everyone, regardless of faith, and the ecosystem suffer.

For a typical city dweller, about 130 litres of water per day is used for bathing, washing and flushing. With about 40% of the population living in cities, we could in principle run about 73 billion litres per day through our sewers and about 90% of it could be recycled. Currently, we recycle just about 30% of the 19 billion litres of sewage from our cities.

Looking towards 2047: While all the needs of water availability, recycling, irrigation, inequality, environmental sustainability, conservation, etc., need to be addressed, mostly with known solutions but with better management practices, enforcement and water literacy, more emphasis is needed on affordable, reliable and sustainable technologies. Large scale deployment of each one of those solutions, to meet our own internal aspirations, and sustainable development goals, are sure to result in completely new opportunities for the global community. In that process, it is expected that India could provide new examples for the world to emulate.

Where to look for new opportunities: Nearly 40% of the global population resides within 100 km distance of an ocean or a sea, rendering desalination a crucial solution to water scarcity. Presently, there are 19,744 desalination plants operating across 150 countries supplying 100 million m^3 of water per day to 300 million people globally. However, desalination is still energy-intensive and hazardous to the environment. It consumes 0.4% of the global electricity, that is, 75 TWh per year. Three major challenges for desalination technologies are (1) high specific energy consumption (SEC), (2) CO_2 emissions from burning of fossil fuels, and (3) negative impacts on marine ecosystems due to the discharge of concentrated brine back into the sea. Desalination technologies are either pressure-driven, temperature-driven, or chemical-driven processes and all these need innovations. In the foreseeable future, seawater desalination could be driven by solar hydrogen, at 0.9 paise per litre. In this case, water is both the source and the product!

The earth's troposphere contains approximately 1.42×10^{19} liters of water in the form of water vapor, and the world population today is about 7.6 billion. Therefore, there is nearly 1.8 billion litres of water available per person in the atmosphere. Atmospheric water harvesting, thus, has vast potential, even if only a miniscule fraction of this resource is used. Note that the oceans of the planet were once dry and were filled by rain. Water harvesting using renewable power could make deserts bloom.

Globally, the water sector is too broad to estimate its net worth. Yet, the value of water infrastructure for a connected global population of 9 billion people by 2050 is estimated to be about US$60 trillion. Compare this with India's total wealth, estimated as US$13.5 trillion. Including water-related services such as sensors and associated analytics and subsequent predictions, water related service industry is expected to grow to comparable numbers. Increasing awareness of the need for essential minerals in water and the dangers of harmful ones will necessitate optimal mineral content to be delivered through drinking water. Next-generation technologies that can retain certain minerals or reject others completely would make it possible for water purifiers to select purification technologies according to need. Big data analytics would thus help create personal health advisories. The availability of such data across a population would be of use to communities and governments to understand and plan for the health of their people. Water purifiers may become intelligent devices in the foreseeable future. Future solutions will need to be implementable both locally and nationally. The decentralization of water technologies is essential for any country, but especially for emerging economies. Many nations have adequate resources to empower local governments with region-specific solutions. The decentralization and implementation of technologies will also trigger the generation and employment of local manpower, which would help strengthen the economy, if carried out nationwide. It is vital for new technologies to be environmentally friendly with no net carbon emissions.

How will all these drive innovations of tomorrow? Look at two scenarios, among the many possibilities. (1) *Make desalination Net Zero.* Global CO_2 emissions due to desalination were nearly 76 million tons (MT) in 2015, and global methanol requirements that year were approximately 75 MT. Can an efficient catalytic system make CO_2-to-methanol conversion possible with renewable energy so that India contributes to Net Zero as far as desalination is concerned (and subsequently in other sectors)? (2) *Implement water audit on every product.* We need to count the water cost

from food to toiletries. For example, cradle-to-grave life cycle assessments of the process of washing 5 kg of laundry (requiring medium hardness water at 40 C and consuming 120 g of liquid detergent, 49 L of water, and 0.53 kWh of electricity per washing cycle) reveals a primary energy footprint of 6.57 MJ equivalent and a carbon footprint of 0.54 kg CO_2 equivalent. This understanding may change the consumer's choice of detergents, packaging materials, chemicals, building materials, clothing, etc., and consequently lead to new products which are less harmful to the environment, while being affordable. This thought would extend to create new agriculture, clothing, infrastructure, transportation, etc. We may move to more efficient irrigation, 'water smart' foodstuff, which will also be animal friendly. Water for all sustainably calls for radically new innovations.

It is clear that water is big in every scale – Gaps, opportunities, wealth and ultimately professional satisfaction.