Evolution of Strategic Planning for Water Sustainability in Coastal Cities of India –Contemporary Issues and Way Forward

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Abstract
Fresh water availability along coastal India is a critical issue pertaining to and affected by population explosion, rapid urbanisation and industrialisation. The coastal livelihood and infrastructure in India have subsequently grown post-independence without any substantial scientific planning for infrastructural developments such as public water distribution systems and wastewater drainage. Due to the predominant inconsistency in meeting the regular water consumption demands as against water availability, uncontrolled water distribution systems became critically responsible for harnessing our fresh water resources (surface water and groundwater). There is an ever-demanding need for strategic planning for Indian coastal cities with inclusive technological interventions to effectively utilise the available resources for achieving water sustainability. This paper reviews on the contemporary challenges and possible strategies for planning and implementing innovations in community water supply sector for coastal cities in India. Considering the pros and cons while strategic planning in the diverse geo-marine environment, we realise that ultimately the choice of water conservation mechanism must be unique for a given region, but consistent with the sustainable goals considering the overall well-being of the ultimate beneficiaries.

Key Words: Water Resources; Water Scarcity; Water Supply; Strategic Planning; Sustainable Development

1. Introduction

History remarks the start of human settlements and civilizations at the river banks and coastal areas. Nonetheless, more than two-third of current world population and lion-share of large cities are situated within a range of 80 km from the coasts and deltas. The promise of the national constitution to provide safe and secured drinking water and sanitation are most rarely attended with its due care in the dark side of the developments, where we see people are struggling for existence in the slums and coastal...
settlements [1-2]. There is no exaggeration to admit that water resources have already reached a stage of exhaustion, if not, at least, an era of severe scarcity. Over the years, population explosion, agricultural growth, sophisticated standards of living, rapid urbanisation and industrialisation have pushed up the demand for water. Plenty of reports are available to scare us about the upcoming severe water shortage where at least one-third of the population will ultimately fail to wet their lips [3-4]. Drinking water scarcity is considerably higher in the coastal regions of India compared to the interior parts, primarily due to salt water intrusion in marine aquifers (Fig. 1)[6-11]. Uneven coverage of water supply and unpredictability of water quality in the coastal cities lead fresh water scarcity to be a growing problem, putting challenges to the sustainability of existing water supply and sanitation systems. ‘The strategy for safe supply of water for all’ only can fulfil the vision of water as a human right.

Some of the viable options for overcoming the crisis of water shortage can be addressed by promoting development of inland and coastal reservoirs, optimization of surface water through interlinking of rivers, conjunctive water use planning, and reuse of wastewater [3-4]. In the present scenario, however, it is imperative to address some of these crucial factors about the vitality of contemporary lives and derive collative vision for sustainable water management, especially in the coastal cities of India. The primary objective of the present paper is to provide an overview on existing water management issues with factual identification of causes and effects. Further, the paper addresses the scope of innovative technologies to combat the water crisis, both on a larger, national scale, as well as on a very individual scale. The paper discusses major strategies to be followed while planning and designing for water supply scheme for water-scarce regions.

2. Coastal Water Management Issues

2.1. Climate Change and Coastal Water

Water deficiency varies seasonally and spatially across the states of India [5] (Table 2). The coastal India especially suffers the aftereffects of the extremities in climate change. Although the torrential rains
of monsoon annually discharges about 4400 TMC of water of water to the Arabian Sea, India is still not water-starving. However, the rainfall significantly varies from 20cm to over 800cm annually across the six major agro-climatic regions of the country. The coastal areas are observed to be witnessing an increasing intensity of storm surge during the events of torrential rainfall, causing severe disruption to the water supply infrastructure. Lack of proper storm water runoff could also damage the coastal water environment leading to high sediment loading in the surface water bodies. On another aspect of climate change, there is an apparent increase in temperature during the sea breeze time demanding more cooling water requirement. Similarly, the increase in seawater level and saltwater intrusion issues are practically making the coastal aquifers vulnerable to high salinity issues. This has creates a long term impact on the public water dependency in coastal regions especially where piped water distribution are not so adequately maintained. The dependency of energy-intensive water purification systems such as desalination plants and large-scale reverse osmosis units have not been conducive for what is being envisioned in the public utility maintenance policy on mere grounds of high economic and environmental impacts. Therefore it is inevitable to have an adaptive plan for coastal water management which is inclusive of climate change effects.

2.2 Water Quality Status in Coastal Cities of India

Being a complex system with multi-faceted interactions with various ecological elements, continuous monitoring of coastal environment provides good database for effective decision making. Technological interventions also have remarkably resulted in improved monitoring of water quality in coastal environment. Seasonal trends in water quality of Gulf of Kutch were effectively monitored by remote sensing techniques [6]. Groundwater quality in coastal aquifers is always in threat of salt water intrusion, marine effluent discharges and natural events like Tsunami. Studies from the coastal areas of Tuticorin city have reported abundance of major cationic (sodium, calcium, magnesium and potassium) and anionic (chloride, sulphate, phosphate, bicarbonate, carbonate and nitrate) groups making groundwater very hard and alkaline and unfit for domestic consumption [7]. Alternatively, mathematical simulations can predict and visualize the futuristic impacts of various anthropogenic activities on coastal water environment. In an interesting study, maximum damage to habitat due to potential sewage pumping failure was effectively simulated using MIKE 21 software for the city of Mumbai [8].

In a contemporary study, impact of sewage discharge of creek water quality in Thane was simulated using hydrodynamic models in order to check the compliance level with water quality standards [9]. Apart from this, anthropogenic activities such as discharge of cooling water from thermal power plants can also affect the water quality significantly. A case study from Kalpakam coastal area stated that backwater inflow could also influence the final impact of industrial effluents in the marine environment [10]. A long-term analysis of water quality and pollution levels in Chennai coastal areas (over a period of 35 years) revealed that increasing levels of toxic effluents in the rivers as well as decreasing levels of dispersion are due to ephemeral flow pattern [11]. Similarly, water quality analysis in coastal and estuarine areas near Gujarat coast were reported to have very high levels of bacterial contamination, making it unfit for domestic purpose without disinfection treatments [12].

2.3. Implications of saltwater intrusion

Since marine water has high mineral potential than fresh water, it can push below the ground water when ground water levels become low or the sea level rises. The biochemical changes due to saltwater intrusion cascade into ecological changes. The salinity stress can also lead to coastal forest loss. Salinity is an important ecological structuring agent in estuarine wetland plant communities [13]. In response to saltwater intrusion, downriver and more salt-tolerant tidal wetland plant species can shift upriver, with brackish plants replacing oligohaline plant communities (Schuyler et al. 1993) and oligohaline plants
replacing tidal freshwater plant communities (Perry and Hershner 1999). Kate Tully, et al (2019) has discussed the social implications and adaptive responses regarding saltwater intrusion in various aspects.

2.4. Implications of RO plants in coastal areas

Desalination is the most common method to obtain potable water in coastal areas. Though various methods are available for desalination, Reverse Osmosis (RO) is used widely for its ease of use. Setting up of these RO desalination plants in coastal areas have a number of consequences in ecological as well as physiochemical aspects. In general, impingement (IPM) and entrainment (ETM) processes include the removal of marine organisms during the intake system operation of desalination plants [14]. This has a great impact especially in the coral reefs. The physiochemical properties like temperature, Dissolved Oxygen (DO), presence of heavy metals etc also vary when compared to the ambient water.

2.5. Contemporary Issues in Water Management in Coastal Cities of India

Based on the previous reports by World Bank, UNICEF and various agencies under Government of India, we summarise the major issues identified as the driving causes of water scarcity in coastal India [15-18]. This is further evaluated to highlight the importance of selecting adequate factors and impacts in developing a planning framework.

| Issues                          | Variables                                      | Impacts                                      |
|---------------------------------|------------------------------------------------|----------------------------------------------|
| Pollution                       | Water quality parameters                       | Unfit for consumption                        |
|                                 | Land use change in catchment                   | Added cost of treatment                      |
|                                 | Rate of deforestation                          | Soil and groundwater contamination           |
|                                 | Rate of urbanisation                           | Added health and safety issues               |
|                                 | Rate of population explosion                   | Sewage mixing with water bodies              |
|                                 | Coverage and efficiency of drainage network    | Added toxicity to ecosystem                  |
| Inadequate/ inaccessible source | Rainfall pattern                               | Inadequate to meet the intended purpose      |
|                                 | Groundwater table                              | Health, education and well-being             |
|                                 | Coverage of water network                      | Social restriction to access water source    |
|                                 | Travelling distance to fetch water             |                                              |
|                                 | Accessibility to public water source           |                                              |
|                                 | Dependency on public water source              |                                              |
|                                 | Rate of deforestation                          |                                              |
|                                 | Rate of urbanisation                           |                                              |
|                                 | Rate of population explosion                   |                                              |
| Water overuse/wastage           | Pumping rate                                   | Shortage of water                            |
|                                 | Leaking rate                                   | Shift in consumptive use pattern             |
|                                 | Pressure drop                                  | Conflicts in water sharing                  |
|                                 | Change in per capita demand                    | Inefficient scheduling of distribution      |
| Climate change                  | Mean temperature change                        | Change in frequency of occurrence of droughts and floods |
|                                 | Mean sea level change                          | Flash floods                                 |
| Agriculture – over dependency on groundwater | Duty and delta                               | Crop productivity                            |
|                                 | Consumptive use                                | Economic loss                                |
|                                 | Irrigation water quality                       | Groundwater depletion                        |
|                                 | Irrigation efficiency                          | Agricultural water loss                      |
|                                 | Water holding capacity of soil                 | High energy for pumping                      |
|                                 | Groundwater fluctuations                       |                                              |
3. Sustainable Remedies in Action

3.1 Recent Indigenous and Isolated Developments

There is no lack of innovation in practicing sustainable water management in the common man’s life, where the solutions start from indigenously designed devices to industrial scale mechanisms. Although promoted through the media and accepted widely, one basic problem in comprehending such innovative attempts is that there not enough scientific documentation in most cases. Considering the scope of future expansions and market potentials, we identified a few such ideas and compared their techno-socio-economic viability.

- Capturing humidity
  As there is less access to fresh water in coastal areas, water can be extracted from the humid air. This process is employed by an Israeli company Water-Gen Ltd [19]. The vapour from the humid air is extracted to make consumable water and the device is found to be successful with minimal energy consumption.

- Combining with Carbon Capture
  Water crisis and global warming are the two major threats to the world today. It would be an impeccable option if both the issues can be approached with a common solution. Most of the industries are located on the coastal line giving rise to various water related problems and global warming issues. Water is being used as a coolant in almost all industries and also for cleaning purposes. This leads to wastage of enormous amount of water. Fortunately, we have an option to use carbon-di-oxide for cleaning in place of water. It is used in its solid form and is propelled with high pressure out of a nozzle enabling efficient dry cleaning. This method is applicable to clean intricate parts of automotive structures, machinery, aircrafts and complex medical equipment. Recycled carbon-di-oxide evolved from other industries is used here, thereby helps in regulating global warming [20]. This also is a viable solution for water crisis.

- Solar Desalination
  Desalination of marine water is one of the methodologies to avail potable water. The technique has been tried in India, but it proved to be inefficient due to increased energy consumption and uneconomical. Israelis have come up with an alternative approach with some modifications to the conventional methods. With this method, 90% of the energy consumption can be cut off with solar desalination process. Since 60% of their land area is desert, they are able to produce more fresh water more than it is required. They have been helping 150 countries with water crisis around the world [21].

- Fog Catcher
  This method is similar to that of extracting water from the humid air. In some places, especially on the hills in the Peruvian coast, there is occurrence of fog but lack of rain. The new invention, the fog catcher, captures the microdroplets present in the air and they get entrapped in the mesh. The water flows through PVC gutters and through organic filters into the tank. Around 200-400
litres of water are obtained by this method each day from each net. The obtained water is mainly used for intensive farming and studies are being done to make it drinkable soon [22].

- **Ultra-Shower**
  Usage of geyser has been one of the sophistications in modern era. On turning on the tap, it takes a few minutes for the water delivered to be at the required temperature. Until then, the cold water is wasted. To overcome this wastage, Ogodeton invented a shower system which is eco-friendly and it makes the water reach the required temperature within 30 seconds [23].
  Another innovation is made by Peter Cullin in Adelaide, Australia [24]. His device is named ‘The Cullector’ or the ultra-efficient shower. This device is installed with a reservoir that collects the water that is normally wasted during the heating up the shower and pumps it back into the geyser at the right temperature. This helps in reducing water wastage to a greater extent even if it is installed in houses on a small scale. Since people in coastal areas lack proper access to potable water, even small conservation alternatives for available water utility can result in an enormous desirable shift towards more water availability.

- **Dry Bathing**
  Dry bathing may seem out of question but it is veracious that a 17-year old boy has found all the ingredients required for a dry shower while travelling to Limpopo, South Africa [25]. His lotion has bioflavonoids, essential oils and chemicals that get rid of odor. The lotion can be applied directly on the skin and serves to be equivalent to that of a normal shower. The stagnant water that remains back after a wet shower is the cause of growth of pathogenic bacteria and spread of communicable diseases. This dry bathing technique helps to prevent the spread of those diseases in under-developed areas and also conserves water to a greater extent. This idea would be highly useful in coastal areas with the residences of fishermen tribe and slums. People there are known to have developed many diseases due to lack of proper sanitation due to less water availability. Hence, this dry bathing technique would serve the right purpose to overcome both water scarcity as well as sanitation.

- **Mitigation plans for ecological impacts of desalination plants**
  To mitigate the impingement and entrainment of larger plankton in intakes, a low through-screen velocity (lower than 0.15 m/s), small screen openings (less than 22 cm), and suitable fine screen mesh size (less than 9 mm) should be used to reduce the impact on plankton, fish eggs and larvae. One common mitigation strategy to reduce impacts is to use modern surface water intake designs or a subsurface intake. In particular, subsurface intakes can virtually eliminate IPM and ETM, as seawater is taken from beneath the sea floor [14].

### 3.2 Way Forward

The time to take more initiatives has arrived and there needs more looking back to move forward. On a government level, there are quite a few initiatives in India such as the interlinking of rivers and combining surface water reservoirs. However, there is always a danger in missing the synergistic concept while implementation, especially in issues like such as land acquisition, rehabilitation and ecological disasters. Another initiative for storing flood water in sea-based reservoirs is emerging as they can absorb flood water shocks while releasing outflow during low tides. The strategic plan called Sarovar Mala envisages the concept of linking sea-based and coastal reservoirs for the major South Indian Rivers [26]. Considering the vast drainage plain of the Ganges, a feasible solution should be to divert a part (about 30%) of the regular flood water and the melting snow water to the central Indian states using canal or pipe networks. This can not only reduce the antecedent damage to the coastal regions in the Bay of Bengal, but can also supplement safe and secured water supply to the Central Indian states which are prone to droughts due to the semi-arid to arid conditions.

In essence, there is a substantial need for an inclusive, adaptive and well-informed strategic planning to ensure water safety and security in the coastal regions of India. We need to realize that all needs and
impacts are not same; therefore, a priority-based planning approach is necessary to address the most needed issues properly.

Table 2: Mapping of priority requirements in coastal water management with corresponding strategic planning objectives

| S. No. | Priority Requirements                          | Planning Objectives                                                                 |
|--------|-----------------------------------------------|-------------------------------------------------------------------------------------|
| 1      | Freshwater protection                         | ✓ Identification of water stress vulnerability areas                                 |
|        |                                               | ✓ Implementation of pragmatic policy framework for environmental disposal             |
| 2      | Managing community supply and demand          | ✓ Estimation of realistic expectations                                               |
|        |                                               | ✓ Real-time monitoring and detection                                                 |
| 3      | Water for the environment                     | ✓ Revamping the interrelations within the ecosystem                                  |
|        |                                               | ✓ Implementation of monitoring system for safe discharge limit                        |
| 4      | Climate change adaptation                     | ✓ Assessment of risk-based adaptation for the infrastructure and assets               |
|        |                                               | ✓ Development of emergency action plan and rehabilitation plan                       |
| 5      | Technological interventions and innovations   | ✓ Design and development of materials and methods with interdisciplinary approach     |
|        |                                               | ✓ Improvement of real-time monitoring and assessment of environmental and social variables |
|        |                                               | ✓ Mapping and prediction of resources with extraction limits                          |

The above Table clearly demarcates the existing gaps and futuristic ways in addressing the coastal water management issues in general. However, this is not comprehensive and can accommodate many other diverse issues related to the socio-economic barriers and diversities existing in the coastal India. The organizational framework of an integrated coastal management system needs to ensure the capacity to meet the essential requirements of the coastal livelihood and infrastructure.

4. Conclusions

This paper provides an insight into the existing water scarcity problem in coastal areas of India and the possible causes, effects and viable solutions in brief. Contemporary scenario puts forward multitudes of challenges in water management in the coastal ecosystem. The study realises that a comprehensive strategic planning and adaptation of synergistic management are necessary for ensuring safe and secured water distribution irrespective of the geographical and demographical variations in the Indian coastal cities. A comparison between regional and individual attempts for innovative solutions proves that there is ample opportunity to integrate such indigenous and isolated developments to rise to a successful solution model. Finally, an approach for matching the water management priorities and corresponding planning objectives has been derived. This can serve as a useful contextual reference while comparing the strategic planning needs for similar water-stressed regions.

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