



Climate Change and Accumulating Water Scarcity in Pakistan: A Case Study of Karachi's Water Infrastructure and Resilience

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Abstract

This case study examines Karachi's water shortage, aggravated by climate change and fast development. With a population of nearly 20 million, Karachi is primarily dependent on the Indus River Basin, Keenjhar Lake, and Hub Dam for its water supplies. However, because of the city's expanding population, outdated infrastructure, and unpredictable weather patterns, these sources are under a great deal of strain. The research looks at how these problems have become worse due to climate change, which has caused powerful monsoons, more frequent and severe droughts, and increasing temperatures that have all affected the quantity and quality of water. This water catastrophe has an influence on public health, food security, economic stability, and the environment. The most vulnerable residents of the city are heavily burdened by the rise in waterborne illnesses, the fall in agricultural production, and the increase in water costs. The management of the city's water resources is fraught with difficulties for the Karachi Water and Sewerage Board (KWSB), ranging from antiquated infrastructure to budgetary limitations and ineffective administration. Karachi has responded by putting in place a number of measures to lessen water shortages and improve resilience. These include investigating new freshwater sources, installing water meters, and renovating water pipes. The city is also spending money on cutting-edge technology like desalination facilities and intelligent water management systems. In order to handle the issue, community-based efforts and foreign help have also been essential, although there are still gaps in the construction of infrastructure and the application of policies. This research emphasizes the need to manage water resources in Karachi using a thorough, multifaceted strategy. Advanced water loss control, integrated water resources management (IWRM), public-private partnerships, urban development that is climate resilient, and increased public awareness are some of the policy proposals. Other cities dealing with comparable issues may learn a lot from Karachi's water dilemma.

Keywords: Climate Change, Water Scarcity, Karachi, Water Infrastructure, Urban Resilience, Water Management, Public-Private Partnerships, Sustainable Development, Smart Water Management

1. Introduction

Climate change is one of the greatest and most complex phenomena which affect the availability of natural resources, specifically water, on a global scale. As for Pakistan, which already has many social and economic problems, the outcomes of climate change make the situation worse. Karachi is a metropolis in Pakistan that has had severe water crises. This scenario is exacerbated by its large population, industrialization and geographical location, which exerts pressure on the existing water systems (Khan H. F., 2022).

Worldwide, climate change, such as droughts, heat waves, and other global warming effects caused by human activities and greenhouse emissions, are various threats. In the case of Pakistan, such changes are in the form of variations in the weather of the country and a higher frequency and intensity of calamities, which are influencing the quantity and quality of water, its availability for usage and the ways it is stored in the country.

1.1. Climate Change and Growing Water Scarcity in Pakistan

A serious concern for Pakistan as a country is climate change as it has worsened water scarcity in different areas. It is important for agricultural purposes and for the daily use of people since the country is a mainly agricultural one. However, due to sudden changes in climate, temperatures, and rainfall patterns, water supply and demand have become unpredictable due to events like floods and droughts (Farooqi, 2005).

Pakistan is a country most exposed to climate change due to its geographic and climatic diversities like the Thar desert, Indus plain, mountain ranges and coastal region. The Indus Basin as the main water source for most of the population is under immense pressure from climate change factors and a growing population. One of the major water resources, namely glaciers in the northern hemisphere, are melting at a faster pace than a replenishment rate.

Despite the attempts to counter these issues, they require even more attention and support. Controlling measures include the implementation of policies, management and development of better means of handling our infrastructure and climate change on water resources. It is high time for Pakistan to involve sustainable measures and climate resilience into the country's policies, so that they could provide water for future generations and preserve the environment (Khan M. A., 2016).

2. Background and Context

The climate of Karachi has largely fluctuated in the past, and it is located on a coastal plain with a temperate climate, having a hot summer and mild winter. The average total precipitation level is significantly low, which is

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notably low, at around 174.1 mm, making water resources extensively dependent on a compounded water supply system that involves both surface and groundwater sources (Kumar L. &.-P., 2019). This natural scarcity of water is even more exaggerated by the fact that the city has undergone rapid urban and industrial development that has put a lot of pressure on the water resources.

The infrastructure for water management in Karachi has been adapted to meet its needs. The Indus River System provides the water supply and additional resources, as does the locally constructed Hub Dam and Keenjhar Lake. However, these systems are now under severe pressure due to increasing demand and inadequate maintenance. Statistical records further show that water has been a major issue in the city due to the growth of its population, which has seen supply greatly lag behind demand (Tayyab, 2021).

2.1. Impacts of Climate Change on Karachi

More recent climatic conditions, especially the intense monsoons in 2022, have made water supply situations worse in Karachi. Such occurrences lead to dramatic changes in the availability of water and the quality of water that is available to inhabitants of the city. More and heavier rainfall has contributed to frequent floods, while long periods of rainfall shortage have contributed to water shortage during dry seasons (Irfan, 2018).

Some of the direct effects on the water supply facilities are the accumulation of silt in the reservoirs and additional load to the drainage and sewage systems, which results in contamination. These changes influence public health in another way, as waterborne illnesses increase during flood occurrence and water rationing. Further, the agricultural sector, which is largely dependent on water supply, is disturbed in a way that poses a threat to food security and the livelihood of the people in and around the metropolitan.

Residents of Karachi also face a problematic water situation, as unavailable water sources subsequently lead to the use of costly and frequently polluted well water or water from private companies, which are unfeasible. With the existing problems in the management and distribution of infrastructure consistently increasing, climate change and consequent intensification of extreme weather conditions only add to the importance of improving both resilience and adaptability to climatic changes in urban settings (Qureshi, 2005).

The analysis of the historical trends, current issues, and future perspectives described above offers a detailed insight into how climate change is transforming Karachi and the city's efforts to address water scarcity. This informed understanding represents the premise from which concrete measures and policy recommendations for the protection of the city's water future are discussed.

2.2. Karachi's Water Infrastructure

The water supply of Karachi mainly relies on the Indus River Basin in addition to the local HUB Dam and Keenjhar Lake. The main organization responsible for providing water supply and sewerage in Karachi is the Karachi Water and Sewerage Board (KWSB). This system involves many pipes, treatment plants, and several pumping stations, and it has been created for more than 20 million inhabitants (Kumar P. F., 2022).

However, the water networks in Karachi have a number of issues. The infrastructure is old and requires constant rehabilitation. Many of the pipes and treatment facilities are worn out and frequently breached. Problems with maintenance are aggravated by the lack of funds and the realities of bureaucracy that make timely updates and repairs difficult. Another drawback of the city is that the water supply system is inadequate, as it was not planned for the booming population growth and expansion of infrastructures over the past few decades.

Thus, the involvement of the government and the private sector is significant to Karachi's water supply. The government, with the major input from KWSB and the provincial governments, is also chiefly involved in the provision of water supply and sewerage. However, due to poor management in the provision of water by public management, many residents depend on private water tankers, which supply most of the water in the city but at a cost. This privatization of water supply, while being an apparently satisfactory solution for the short term, only serves to emphasize the real need for overhauling the public sector (Khalil, 2023).

2.3. Resilience and Adaptation Strategies for Karachi's Water Scarcity

Due to the poor availability of water, especially in Karachi, the city has no option other than applying the above-stated four key strategies for making urban water sustainable in the city in the future. Due to the multiple water challenges in the city, ranging from supply and demand issues, climate change, and rapid growth in the urban center, acute strategic measures have been required.

2.3.1. Current Strategies to Combat Water Scarcity and Improve Resilience

The most considerable approach that was used to tackle water shortage within Karachi has been the improvement of existing structures. There are progressive steps implemented in the city for the diminution of NRW, and some of them are the rehabilitation of pipelines and the provision of water meters. These initiatives are intended to achieve not only the technical goal of water savings but also the organizational goal of enhancing the financial situation of water utilities to increase income and decrease leakage (Tabassum, 2020).

In addition, Karachi has adopted water rationing in severe water shortages to ensure the fair distribution of water in different areas of the city. This strategy is accompanied by the exploration of new sources of freshwater, such as the construction of small to medium-sized water dams on the outskirts of the city. These dams are planned to increase the Karachi storage potential and control water availability on a yearly basis (Hussain, 2020).

2.3.2. Innovative Approaches and Technologies Being Implemented

Karachi is also seeking emerging technologies necessary for enhancing resilience to the water situation. Smart water management systems that use data acquired from the physical environment enable Water Authorities to have timely information needed to enhance water quality and quantity. Moreover, there are prospects of building desalinating plants as the long-term source of water supply since the population and, thus, demand for water continues to expand. These plants could purify sea water to drinking water standards, which would certainly substantially increase the water available in the city.

Other improvisations involve the reuse of wastewater by treating it for industrial and or agricultural uses. On this basis, one can conclude that, through the reuse of water containing aeration wastes, Karachi can mitigate the pressure on freshwater sources and optimize the use of the available resources in the supply of fresh water (Zhang, 2020).

2.3.3. Role of Community Initiatives and International Aid

The literature also revealed the role of community-based interventions, which are only for coping with micro-dimensions of water crises in Karachi. Many NGOs and CBOs have equally been instrumental in sensitizing communities to the need to conserve water, putting up rainwater harvesting structures, and even conducting campaigns to put up community water filtration plants. Such bottom-up initiatives do much more than simply distribute water in regions that desperately need it; they are about giving the people a voice in how to address their water crisis.

These initiatives have been supported by international aid to a large extent. International organizations such as the World Bank and Asian Development Bank have supported big projects that are intended to improve water supply and sanitation services. These projects may incorporate features for the development of local capacity and governance that ensure that the improvements are sustainable and locally instigated.

Further, partnerships with other countries have allowed for the sharing of knowledge and technology, acquiring the experience of other international cities, and drawing on new methods and advancements in water management in Karachi. The professors and researchers in these collaborations have played an important role in creating resilience strategies that can be effective now and in the future with regard to water scarcity (Iftikhar, 2018).

3. Case Study Analysis

The issue of water shortages in Karachi has given rise to several new ideas that are intended to increase the water sustainability of the city. One of them is the Karachi Water and Sewerage Services Improvement Project (KWSSIP), aimed at the development of water supply references as well as sewage systems and the improvement of service delivery. The other is the S-III project, which involves training and providing construction waste treatment and water purification of sewage before discharge to the Arabian Sea to help prevent the impact on marine life and water purification quality (Janjua, 2021).

3.1. Success Stories and Areas Needing Improvement

There is hope that rainwater harvesting campaigns in different areas of Karachi will be successful. Through these projects, some of the burdens from the water supply system in the city have been eased while creating awareness among the people on the ways and means of conserving water. Furthermore, the incorporation of a reverse osmosis plant in some districts has effectively and efficiently provided drinking water where the sources used were contaminated.

However, it is important to note that the city continues to struggle with numerous challenges even after the achievement of these goals. Most of the water pipes and treatment facilities are old and need replacement and rehabilitation, which has not been practised for many years. Furthermore, cases of water theft and unauthorized connections are common, implying huge losses of water before it even gets to the consumers. To avoid these challenges from being a constant thorn in the achievements registered in these sectors, these areas need policy attention now (Syvrud, 2021).

3.2. Comparison with Other Cities that have Similar Problems

The water management problems in Karachi are not exceptional and are likely to be seen in other cities as well. For example, Cape Town, South Africa, also faces critical water shortage problems that have led to the country's coming up with strict water usage rationing and hefty investment in water infrastructure. In the same year, 2015, São Paulo, Brazil, had a water shortage problem, which was accompanied by improvements in the infrastructure and water management systems (Millington, 2018).

From these cities, Karachi can learn more about public engagement approaches and the use of sophisticated technology in the water sector. The performance of these cities shows lessons on efficient governance and the constant need to further improve the systems put in place that deal with water and sanitation.

4. Policy Recommendations

It is well evident that Karachi faces major problems in water management, compounded by the problem of urbanization and the effects of climate change. Solving them is a complex process that does not only imply enhancing the available resources but also implementing new ideas and involving people. The following enhanced

policy recommendations aim to establish a more sustainable and resilient water management system for Karachi (Hanan, 2024):

4.1. Advanced Water Loss Management

Adopting thorough water loss control solutions is crucial to reducing major water losses in Karachi's supply network. Quickly locate and fix leaks. This involves using automated pressure management systems and cutting-edge acoustic sensors. District metered areas (DMAs) may also be used to monitor and control water flow more successfully, which will greatly reduce non-revenue water.

4.2. Integrated Water Resources Management (IWRM)

To guarantee the sustainable use of water resources, Karachi should implement an Integrated Water Resources Management strategy. Creating regulations that support fair distribution and water conservation should be part of this. To increase the city's resistance to water shortage, the integration of surface water, groundwater, and alternative water sources, including desalinated water and treated wastewater, has to be simplified.

4.3. Public-Private Collaborations for Water Infrastructure

Promote the establishment of public-private partnerships to oversee and finance initiatives related to water infrastructure. These partnerships may make it easier to expand water distribution networks and update water treatment facilities. The public water industry may benefit from the infusion of much-needed funds, creativity, and efficiency from the private sector.

4.4. Climate-Resilient Urban Planning

In order to successfully manage the implications of climate change, climate-resilient infrastructure must be included in future urban planning and construction. To improve groundwater recharge and lessen the impacts of urban heat, this involves building rain gardens, green roofs, and permeable pavements. Critical infrastructure should be elevated in urban designs to reduce the danger of flooding (Khan H. A., 2022).

4.5. Community-Based Water Management Initiatives

Encourage the creation of community-based water management systems to strengthen the bonds between neighboring communities. Through these programs, local stakeholders may be included in the allocation of water resources as well as the monitoring and upkeep of nearby water sources. Programs for teaching and training must be offered in order to increase local expertise in sustainable water management techniques.

4.6. Legislative Reforms for Water Conservation

Reform water governance with stringent regulations focused on water conservation and management. Stricter regulations on industrial discharges into water bodies and rules requiring the use of water-efficient equipment in households and businesses should be part of this. It is also necessary to provide a legislative framework for the reuse and recycling of water, particularly in the agricultural and industrial sectors.

4.7. Enhanced Public Awareness Campaigns

Run wide-ranging public awareness initiatives to inform people of the value of conserving water. These need to center on encouraging water-saving behaviors in businesses and homes as well as the advantages of funding water-efficient technology.

5. Conclusion

The roots of water scarcity in Karachi are complex and deepened by climate change, the growth of the mega-city, and deteriorating facilities. Positive examples include the Karachi Water and Sewerage Services Improvement Project and, specifically, rainwater harvesting by the community. However, there is still room for improvement – this concerns the advanced scale of development of the water supply system, as well as the strengthening of regulatory and legal obligations on sustainable water management.

To sum up, the future of Karachi's water security lies in the continued investments in the form of infrastructural development and the adoption of SWM, along with efficient policy implementation through facilitating community participation. Karachi's experiences are proof of the impacts long-term water scarcity could pose to the worldwide community and inspire the need for the principles of sound IWRM and climate change preparedness for cities around the globe, further proving that sustainable solutions can always be made if there are a commitment from all the layers of government and the society in providing and planning for water resource management systems.

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