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GROWING WATER SCARCITY AND CLIMATE CHANGE IN PAKISTAN: AN ANALYSIS OF URBAN RESILIENCE AND WATER INFRASTRUCTURE OF KARACHI

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Abstract
This case study investigates the water scarcity of Karachi, which has been made worse by rapid growth and climate change. The Indus River Basin, Keenjhar Lake, and Hub Dam are the main sources of water for Karachi, which has a population of around 20 million. However, these sources are heavily burdened due to the city's growing population, old infrastructure, and erratic weather patterns. The study examines how climate change has exacerbated these issues by bringing about stronger monsoons, more frequent and severe droughts, and rising temperatures, all of which have an impact on the amount and quality of water. The environment, food security, public health, and economic stability are all impacted by this water disaster. The reduction in agricultural output, the rise in waterborne infections, and the rising cost of water disproportionately affect the city's most disadvantaged citizens. The Karachi Water and Sewerage Board (KWSB) has several challenges in managing the city's water supplies, from outdated infrastructure to financial constraints and inefficient management. In response, Karachi has implemented many policies aimed at reducing water scarcity and enhancing resilience. These include installing water meters, updating water pipelines, and looking into new freshwater sources. Additionally, the city is investing in state-of-the-art technologies such as sophisticated water management systems and desalination facilities. Community-based initiatives and international assistance have also been crucial in addressing the problem, despite ongoing shortcomings in policy implementation and infrastructure development. This study highlights the necessity of employing a comprehensive, multipronged approach to manage Karachi's water resources. The policy recommendations include enhanced public awareness, climate-resilient urban planning, public-private partnerships, advanced water loss control, and integrated water resources management (IWRM). Karachi's water problem might teach other cities facing similar problems a lot.
Keywords: *Climate Change, Water Scarcity, Water Infrastructure, Urban Resilience, Pakistan*

INTRODUCTION

One of the biggest and most complicated factors influencing the worldwide supply of natural resources, particularly water, is climate change. The effects of climate change exacerbate the social and economic issues that already plague Pakistan. The Pakistani city of Karachi has experienced serious water shortages. Its enormous population, industrialization, and geographic position all contribute to this situation by placing strain on the current water infrastructure (Celik, 2021; Khan, 2022; Tang & Azman, 2024).

Climate change poses a number of dangers globally, including heat waves, droughts, and other impacts of global warming brought on by greenhouse gas emissions and human activity. These changes are affecting the amount and quality of water, its accessibility for use, and the methods by which it is stored in Pakistan. In the case of Pakistan, these changes take the shape of local weather fluctuations as well as an increase in the frequency and severity of disasters. Climate change is a major issue for Pakistan as it has made water scarcity worse in some places. Since, agriculture is the primary industry in the nation, it is crucial for both agricultural purposes and people's everyday lives. However, incidents like floods and droughts have made the supply and demand for water unpredictable due to abrupt changes in the climate, temperatures, and rainfall patterns (Farooqi, 2005; Khan, 2020; Zenios, 2024).

Pakistan is particularly vulnerable to climate change because of its diverse geography and climate, including the Thar desert, the Indus plain, mountain ranges, and coastal regions. Climate change and population growth are putting tremendous strain on the Indus Basin, which provides the majority of the world's population with its primary water source. The northern hemisphere's glaciers, one of the main water supplies, are melting more quickly than they are being replenished. These problems need even more attention and assistance, notwithstanding the efforts to combat them. Implementing legislation, managing existing infrastructure, and creating better ways to deal with the effects of climate change on water supplies are examples of controlling methods. It is imperative that Pakistan include climate resilience and sustainable practices into its policies in order to conserve the ecosystem and supply water for future generations (Khan, 2016; Naeem & Hameed, 2019; Yan & Sirboonchitta, 2024).

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Karachi, which is situated on a coastal plain with a moderate climate that has scorching summers and mild winters, has seen significant temperature fluctuations in the past. Water resources are heavily reliant on a complex water supply system that incorporates both surface and groundwater sources due to the exceptionally low average total precipitation level, which is around 174.1 mm (Kumar, 2019). The city has seen fast urban and industrial expansion, which has placed a great deal of strain on the water supplies, making this natural water shortage even more pronounced.

Karachi's water management infrastructure has been modified to suit its requirements. The water supply and other resources are supplied by the Indus River System, Keenjhar Lake, and the locally built Hub Dam. Now, these networks are under a lot of strain because of rising demand and poor maintenance. According to statistics, the city's growing population has made water a significant problem, with supplies significantly falling short of demand (Tayyab, 2021).

IMPACTS OF CLIMATE CHANGE ON KARACHI

Water supply difficulties in Karachi have gotten worse due to more recent weather, particularly the severe monsoons in 2022. The amount and quality of water accessible to city dwellers are drastically altered as a result of such events. While extended periods of rainfall scarcity have led to water shortages during dry seasons, increased and heavier rainfall has increased the frequency of floods (Irfan, 2018).

The buildup of silt in reservoirs and the increased strain on drainage and sewage systems, which leads to pollution, are a couple of the direct repercussions on the water supply facilities. The rise in waterborne infections during floods and water shortages is another way that these changes affect public health. Additionally, there is disruption to the agricultural sector, which is heavily reliant on water supplies, endangering food security and the standard of living for those living in and around the urban area. Karachi residents also deal with a difficult water scenario since they are forced to utilize expensive and sometimes contaminated well water or water from private corporations due to a lack of adequate water sources. Improving resilience and adaptability to climatic changes in urban settings is crucial, especially in light of the growing challenges in infrastructure management and distribution brought on by climate change and the resulting escalation of extreme weather conditions (Qureshi, 2005). The examination of the aforementioned historical patterns, contemporary problems, and prospective outlooks provides a thorough understanding of how climate change is influencing Karachi and the city's attempts to alleviate water scarcity. This knowledge serves as the foundation for discussions on specific actions and policy suggestions aimed at safeguarding the city's water future.

WATER INFRASTRUCTURE OF KARACHI

The Indus River Basin, together with the nearby HUB Dam and Keenjhar Lake, is the primary source of water for Karachi. The Karachi Water and sewage Board (KWSB) is the primary agency in charge of providing water supply and sewage in Karachi. More than 20 million people are served by this system, which consists of many pipelines, treatment facilities, and pumping stations (Kumar P. F., 2022). Nevertheless, there are several problems with Karachi's water systems. The infrastructure is outdated and in continual need of repair. Numerous treatment facilities and pipelines are deteriorated and regularly broken. Lack of funding and bureaucratic constraints that make timely upgrades and repairs challenging exacerbate maintenance issues. The city's water delivery system is also a problem since it was not designed to handle the rapid population increase and infrastructural development over the last few decades. Therefore, the private sector's and government's engagement is important for Karachi's water supply. The government is also primarily involved in the provision of water supply and sewerage, with significant assistance from KWSB and the provincial governments. However, many inhabitants rely on private water tankers, which provide the majority of the city's water supply at a fee, as a result of the public management's inadequate water service. Despite appearing to be a short-term solution, the privatization of the water supply simply highlights the urgent need to reform the public sector (Khalil, 2023).

RESILIENCE AND ADAPTATION STRATEGIES FOR KARACHI'S WATER SCARCITY

The city has no choice but to implement the four essential measures mentioned above to make urban water sustainable in the future because of the limited supply of water, particularly in Karachi. Acute strategic steps have been necessary because to the city's numerous water concerns, which include rapidly growing metropolitan areas, supply and demand issues, and climate change.

The most significant strategy to address Karachi's water scarcity has been refurbishing old buildings. The city has taken significant measures to reduce NRW, including providing water meters and repairing infrastructure. These programs aim to accomplish both the organizational objective of improving water utilities' financial status in order to boost revenue and reduce leakage, as well as the technical goal of conserving water

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(Tabassum, 2020). Furthermore, in order to guarantee equitable water distribution across the city, Karachi implemented water rationing during periods of extreme water scarcity. Building small to medium-sized water dams on the city's outskirts is one way to explore new freshwater sources in conjunction with this approach. These dams are intended to regulate water availability annually and boost Karachi's storage capacity (Hussain, 2020).

Karachi is also looking for cutting-edge solutions that would help them become more resilient to the water crisis. Water Authorities can obtain timely information necessary to improve the amount and quality of water using smart water management systems that employ data collected from the physical environment. Furthermore, given the growing population and thus the increasing need for water, there is potential for the construction of desalination facilities as a long-term source of water supply. The amount of water accessible in the city would undoubtedly grow significantly if these facilities were able to purify seawater to drinking water standards. Additional improvisations include purifying wastewater for use in industry or agriculture. Based on this, it can be said that Karachi may reduce the strain on freshwater supplies and make the best use of the resources available in the freshwater supply by reusing water that contains aeration wastes (Zhang, 2020).

The research also highlighted the function of community-based initiatives, which are limited to addressing the smaller-scale aspects of Karachi's water crisis. Numerous NGOs and CBOs have played an equally important role in raising community awareness of the importance of water conservation, installing rainwater collection systems, and even running campaigns to install community water filtration facilities. These bottom-up projects aim to give the people a say in how to solve their water issue, which goes well beyond just distributing water to areas that are in dire need. International aid has played a major role in supporting these endeavors. Large-scale initiatives aimed at enhancing water supply and sanitation services have received funding from international institutions including the World Bank and Asian Development Bank. Features for building local capacity and governance may be included in these initiatives to guarantee that the advancements are long-lasting and locally driven. Additionally, collaborations with other nations have made it possible to exchange technology and expertise, learn from other global cities' experiences, and use innovative techniques and developments in Karachi's water management. When it comes to water shortage, the researchers and academics involved in these partnerships have been important in developing resilience tactics that will work both now and, in the future (Iftikhar, 2018).

ANALYSIS OF CASE STUDY

Karachi's water scarcity problem has sparked a number of fresh concepts aimed at improving the city's water sustainability. One of these is the Karachi Water and Sewerage Services Improvement Project (KWSSIP), which aims to improve service delivery and build benchmarks for water and sewage systems. The second is the S-III project, which aims to avoid the impact on marine life and water purification quality by teaching and supplying construction waste treatment and water purification of sewage before discharge to the Arabian Sea (Janjua, 2021).

SUCCESS STORIES AND AREAS NEEDING IMPROVEMENT

Campaigns to collect rainwater in several parts of Karachi are hoped to succeed. These initiatives have helped to alleviate some of the strains on the city's water supply system while raising public knowledge of water conservation strategies. Additionally, in certain regions, the installation of a reverse osmosis facility has successfully and efficiently supplied drinking water in areas where the sources were polluted. It is crucial to remember, nonetheless, that despite the accomplishment of these objectives, the city still faces many difficulties. The majority of the treatment facilities and water pipelines are outdated and require replacement and repair, which hasn't been done in a long time. Unauthorized connections and water theft are also frequent occurrences, which suggests that significant amounts of water are lost before it even reaches the customers. These areas require immediate governmental attention in order to prevent these difficulties from continuously undermining the accomplishments noted in these sectors (Syvrud, 2021).

COMPARISON WITH OTHER CITIES THAT HAVE SIMILAR PROBLEMS

Karachi's water management issues are not unique, and they are probably present in other cities as well. For instance, severe water scarcity issues in Cape Town, South Africa, have prompted the nation to implement stringent water consumption quotas and significant investments in water infrastructure. Improvements in the infrastructure and water management systems coincided with the water scarcity issue in São Paulo, Brazil, in 2015 (Millington, 2018). Karachi may learn more about public involvement strategies and the application of advanced technologies in the water industry from these cities. These cities' performance demonstrates the

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importance of effective governance and the ongoing need to enhance the water and sanitation systems that have been put in place.

CONCLUSION AND POLICY RECOMMENDATION

Climate change, the expansion of the megacity, and decaying infrastructure are some of the factors contributing to Karachi's complicated water shortage. The Karachi Water and Sewerage Services Improvement Project and, in particular, community rainwater collection are good examples. There is still need for improvement, nevertheless, particularly with regard to the water supply system's advanced level of development and the bolstering of legal and regulatory requirements for sustainable water management.

To summarize, the future of water security in Karachi depends on sustained investments in the form of SWM adoption and infrastructure expansion, as well as effective policy implementation through community engagement facilitation. It is further demonstrated that sustainable solutions are always possible if all levels of government and society are committed to providing and planning for water resource management systems. Karachi's experiences demonstrate the potential effects of long-term water scarcity on the global community and highlight the need for sound IWRM principles and climate change preparedness for cities worldwide.

It is clear that Karachi has serious issues with water management, which are made worse by the city's growth and the consequences of climate change. The process of solving problems is intricate and involves not just improving the resources at hand but also incorporating new concepts and individuals. The following improved policy suggestions are meant to help Karachi develop a more resilient and sustainable water management system (Hanan, 2024).

In order to minimize significant water losses in Karachi's supply network, comprehensive water loss management methods must be implemented. Find leaks quickly and correct them. This calls for the use of advanced acoustic sensors and automated pressure management systems. Non-revenue water may be significantly decreased by using district metered areas (DMAs) to better monitor and regulate water flow.

The implementation of an Integrated Water Resources Management plan is necessary in Karachi to ensure the sustainable use of water resources. This should include developing policies that promote equitable distribution and water conservation. Simplifying the integration of surface water, groundwater, and other water sources, such as desalinated water and treated wastewater, is necessary to strengthen the city's resilience to water scarcity.

Encourage public-private partnerships to be formed in order to supervise and manage water infrastructure projects. These collaborations might facilitate the modernization of water treatment plants and the extension of water distribution networks. The private sector's contribution of much-needed capital, innovation, and efficiency might help the public water sector.

Future urban planning and construction must incorporate climate-resilient infrastructure to effectively manage the consequences of climate change. This includes constructing rain gardens, green roofs, and permeable pavements to enhance groundwater recharge and mitigate the effects of urban heat, as well as elevating critical infrastructure in urban designs to lessen the risk of flooding.

Promote the establishment of neighbourhood-based water management initiatives to improve links between nearby communities. The distribution of water resources and the monitoring and maintenance of adjacent water sources can include local stakeholders through these initiatives. It is necessary to provide educational and training programs to boost local knowledge of sustainable water management practices.

Implement strict laws aimed at managing and conserving water to reform water governance. This should include stricter laws governing industrial discharges into waterways and mandating that homes and businesses adopt water-efficient technology. A legislative framework for water reuse and recycling is also required, especially in the industrial and agricultural sectors. Conduct extensive public education campaigns to educate people about the need of water conservation. These should emphasize the benefits of investing in water-efficient equipment and the promotion of water-saving practices in households and businesses.

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