J. Indian Water Resour. Soc.,
42, No. 3 & 4, Jul. & Oct. 2022

URBAN DESIGN STRATEGIES FOR WATER RESOURCE MANAGEMENT

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ABSTRACT

Most of the cities have evolved around water bodies. Rapid urbanization has resulted in laying stress on these resources. 'NITI Aayog' suggests that 60 million of the Indian population are water stressed and 21 Indian cities are vulnerable to 'Day Zero', where, the demand for potable water will outstrip supply by 2030 if steps are not taken. Unsustainable urban development is causing instability in the water cycle and impacting the resilience of these systems. Implementation of out-of-date urban planning models without considering the urban morphology and the fragile ecosystem are major threats to urban systems. The intent of this paper is to derive urban design strategies based on urban morphology for water resource management and explains possibilities of interventions in a chosen site. The paper becomes more relevant as our government is planning to build 100 smart cities across India for which sustainable water management is an important pillar.

Keywords:*Climate Change;Water;Water Resource Management; Urban Design Strategies;Urban Morphology; Urbanization*

INTRODUCTION

Water is an essential resource for our daily life and survival. Similarly, water resources are the drivers of modern settlements from villages to cities to megacities. Most of the cities have evolved around a water body. Overexploitation of natural resources is placing strain on our water supply as a result of rapid urbanization and increasing population in urban areas. This results in groundwater depletion, contamination, and other negative effects on the ecosystem. Rapidly rising urban water demands highlight the importance of making urban water systems more robust, especially in light of climate change.Climate change is contributing to more intense and frequent extreme weather events. Wildfires, floods, storms, extreme precipitation, drought, and extreme heat are among the most serious.Increasing disputes, scarcity, pollution, and depletion of natural resources necessitate a rethinking of traditional ideas that have become obsolete in the current situation. Day Zero is a term coined in Cape Town in South Africa and is defined as severe multi-year drought (Burls, N.J. 2019).

The management of water in and around urban areas does not originate at an industrial site alone, but rather from rooftops, lawns, driveways, parking lots, and roads(Hill, L.2009). Hence Urban Design plays a very important role in Climate Change Mitigation and Water Resource Management. One important aspect being Urban Morphology is defined as the study of urban form and also the effective use of morphological theories, concepts and methods in planning practice remains limited (Oliveira, V.2014). Looking at Water Resource Management from an Urban Design perspective, the major problems caused are destruction of built forms and degradation of environmental quality mainly on the canalization of streams, the high levels of pollution, and shortage of open green areas. Urban Design Initiatives/ Strategies are the steps taken to resolve all of these dynamic and complicated urban issues by offering clarification and guidance in order to find innovative solutions.

A recent report by Niti Aayog suggests that 60 million Indian populations are vulnerable to extreme water risks and 21 Indian cities are vulnerable to Day Zero. Out-of-date urban planning models and planning systems without considering the urban morphology and care for the fragile ecosystem are the threats to these situations. Water Resource Management is the process of planning, developing, distributing, and managing water resources in order to reduce harmful environmental impacts.

The purpose of the research is to formulate Urban Design Strategies to aid Water Resource Management. An in depth understanding on Urban Morphology, Climate Change and Urban Water system was done. The impact of unplanned urbanization on water system was analyzed and urban design parameters were identified in order to derive solutions for urban water management. Scope of the research is a holistic development plan for Urban Water Management through Urban Design Interventions and community participation so that we could save our cities from "Day Zero". The selection of primary study area for the research is limited to Palakkad District in Kerala,based on the researcher's familiarity with the place and looking at the water stress faced by different districts of Kerala. Since the strategies have evolved from the climatic and geomorphological conditions of the district, it might not be generic in nature. The study will be focused on Urban Morphology, Climate Change and Water Resource Management strategies in an urban area.

LITERATURE REVIEW

Urban Water

Human settlements started evolving around rivers. During pre-industrial times they moved closer to these water bodies for cultivation or industrialization because humans were

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Manuscript No. 1588
Received: 16 August 2022; Accepted: 17 November 2023

attracted to areas lying near aquifers or where there is easy accessibility to water. But later these areas became major destination for industries and people started shifting their settlements away from water centers to the outskirts. Over a period of time, technological development resulted in a decreased dependency on the direct proximity to water bodies. Advanced measures to transport water such as canals, pipelines, groundwater pumping had adverse effect on the natural ecosystem. This resulted in exploitation of groundwater mainly due to its availability, quality and convenience.Advanced transport systems such as rail, road and air, built infrastructures critically damaged open water ecosystems. Main pattern that has shaped water resources management over time are instrument of Colonization, the Hydraulic Paradigm, Integrated Water Resources Management (IWRM), Adaptive Management (AM) and Urban-Centric approaches to Water Management (Fath, B.D. 2020).

Urban Centric Approach: Water Sensitive Urban Design

Due to urbanization, occupants in a single lot increases, which in turn increases the water demand. This results in drawing more ground water which thus cause groundwater depletion. (Fig. 1).We need water for many uses, but we also need to make sure that there is good water infrastructure system to look after us from a public health perspective. Taking into account the available spaces left after built-up areas could be used for water conservation techniques in the case of developed areas. Water sensitive urban design (WSUD) is an approach to urban planning and design that integrates the management of the total water cycle into the land use and development process (Wong,T.H. 2011).

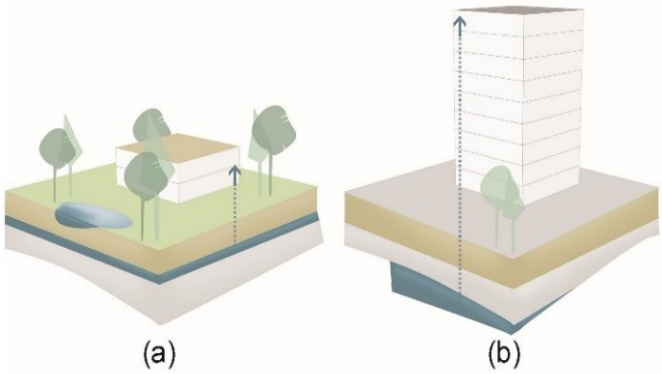

Fig. 1: Ground water during(a) Pre-Development and (b) Post Development (Author 2021)

We must connect urban morphology and water resource management to make the best use of water and mitigate Day Zero. It is a method of properly integrating the water cycle with the built environment. WSUD can be used at any size, from a single household to a whole country.

Water Stress resulting in Urban Drought

Baker explains Urban Drought as a hydrological phenomenon as well as a socioeconomic problem. Building resilience to Urban drought requires adaptive physical and social infrastructure(Baker,L.A. 2019). Natural and Engineered components including groundwater, surface water, urban aquifer, urban morphology and water infrastructure comes under this category. Whereas, Wilhite's theory on Urban Drought explains the consequence of natural reduction in the amount of precipitation received over an extended period of time(Wilhite, D.A. 1993). This usually takes a season or more in length, although other climatic factors (such as high temperatures, high winds, and low relative humidity) are often associated with it (Wilhite, D.A. 1993). Rapid expansion in urbanization and industrialization coupled with recent drought conditions has triggered unplanned groundwater development leading to severe stress on groundwater resources in many urban cities of India (Pandith, M. 2017).

Urban Morphology

Morphology of urban space is the field of scientific discourse on built space, depending on the presence of water, endeavors to explain the nature of the "form" of a city (Cakaric, J. 2010). Urban Morphology also refers to the study of urban form and the effective use of morphological theories, concepts and methods in planning practice remains limited (Oliveira, V. 2014).For studying these spatial aspects, a plan is prepared based on land use, urban systems and operative units. Certain patterns such as Historic areas where we could find most of the ancient urban fabric; Urban development areas; Areas with continuous building facades such as streets and blocks; Business Park; Green Areas; Industrial Areas and Transportation areas are categorized. Then problems such as the cause for destruction of these built forms and degradation of environmental quality such as canalization of streams, levels of pollution, shortage of green space were identified. From a morphological point of view, the originality of their design thinking derives from the design models which are the products of a 'systemic' typological understanding of traditional urban forms(Caliskan, O. 2011).

Urban Drought and Morphology

The practice of climate change adaptation varies across time, scale, and space, and therefore, its specific actions are grounded in the locality and are dependent upon the nature and the degree of vulnerability.By definition, urban morphology facilitates the study of the composite nature of urban form. Urban morphology, similar to "morpheme" in linguistics, includes the smallest meaningful and undividable units of a form-composition (Caliskan, O. 2011).

Dimensions

The four dimensions regarding the study on Urban morphology and drought vulnerability includes ecological,

physical, functional and spatial aspects. Integration of nature with settlement comes under ecological aspects whereas the physical aspects deal with streets, street networks, blocks and buildings. Similarly, land use and human activities are the functional aspects; the layout and heterogeneity of urban form comes under spatial planning. (Dhar,T.K. 2017)

Case Studies

Case studies were chosen on behalf of its climate and geomorphologic conditions. The design programs which they adopted are looked upon to build strategies and guidelines.

Jodhpur, India

Jodhpur City's morphology is related to water. The city is built on a sloping terrain and working on a water management mechanism. Jodhpur is a city in Rajasthan, India's northwest province, situated in the Thar Desert. During the nearly year-long dry season, Jodhpur's climate is hot and semiarid, with a brief rainy season. The region's integrated water architecture turned the sparse rainfall into a reliable source of water that communities could rely on all year. There is no permanent drainage in the region. Water from the top of the ridge is collected in the Fort's Talab (Tank). These large Tanks are connected to the lower area. Large and small streets meet at junctions, where there is a tree. These trees give a visual identity and a small recreational zone. Streets are built along these valleys. Hence, we can say that these streets are working as a drainage network. After several junctions, there comes a Tank. Apart from these, there are pipe connections starting from the upper Tank, which starts working when the lower region runs out of water. This case demonstrates certain theoretical components of development which cause changes in urban morphology, such as system and structure of street network, city shape within its landform, and relationship with the existing landscape.

Chennai, India

Chennai is a city in Tamil Nadu, India. The climate of Chennai is similar to the area of intervention. The strategies which they adopted are based on the physical and social aspects. They adopted the concept of Store and Release techniques, so that the restored water bodies could be used as a shared space for socializing. The ponds located in economically disadvantaged communities could be used to improve their resilience in extreme weather events (Cities100. 2019). These help to recharge groundwater and replenish the urban water system.

Arequipa, Peru

The city is characterized by predetermined grid iron shape. Their settlement patterns are built along these networks which lead its way to the rivers. The residential settlements get water through the canal system which makes it a livable green city. They have a well-connected underground drainage system. In Residential settlements, small patches of green junctions are provided for recreation and maintenance. Whereas in the case of Public or Commercial settlements, large Parks, Public squares and Recreational spaces are provided.

Design Programs Adopted

Design programs were adopted from 3 case studies on Jodhpur, Chennai and Arequipa. Jodhpur had extensive community participation, public open spaces and designed streets along valleys or drains. Chennai concentrated on restoring water bodies, inclusive designs such as shared space, considering human health, nature, neighborhood and resilience. On the other side Arequipa had public square, connected water system, settlement patterns which were built along these networks leading its way to the river.

MATERIALS AND METHODOLOGY/ STUDY AREA AND METHODS

The selection of primary study area for the research is limited to Palakkad District in Kerala, based on the researcher's familiarity with the place and looking at the water stress faced by different districts of Kerala. Since the strategies have evolved from the climatic and geomorphological conditions of the district, it might not be generic in nature. For the research, the entire Palakkad Municipality was chosen and different zones has been identified with the help of geomorphologic data.

Palakkad is located on the Western side of the Palghat Gap, which links the plains of Tamil Nadu and the Deccan in India. The Palakkad plains have a climate that is distinct from the rest of Kerala due to its geographic position. The hot dry winds from the East and South Western winds from Arabian sea which passes through the Palghat gap dries the clouds along which causes lack of rain in Palakkad District (Fig. ii). The annual rainfall pattern showed a trend of significant decline, as the years proceed. The decrement in rainfall may reflect the actual regional level climate changes compounded by various anthropogenic factors (Nikhil Raj, P.P.2012). Palakkad is already identified as a major global climate hotspot in the State Action Plan on Changing Climate, with mitigation action advised. This increase in temperature put pressure on the water bodies and water level in rivers and ponds decrease due to evaporation. In Kerala's water-rich state, Palakkad district has far more water bodies compared to other districts. Palakkad is located between the Kalpathy and Kannadi rivers to the north and south, respectively. Malampuzha canal in the East and other streams along with these rivers joins Bharathapuzha.

Fig. 2: Geomorphological Features and Location of Palakkad (Author 2021)

Based on the parameters obtained from the literature and case studies, the primary observation was based on urbanization, climate change, groundwater level, infrastructure, built form, and land degradation. From the land use map (Fig. iii), the existing condition were analyzed and different areas were chosen to conduct the primary study. These include the core area where the Fort is located; the commercial area between Shornur road and Market Road; and the residential area near Kalpathy river and Kannadi river.

HISTORY

The early settlements started during 100-1000 CE when people from North travelled to the port of Ponnani andMuziris through Palakkad.During 1000-1500 CE, Brahmins who settled near the Kalpathy river shifted to the higher plains and they constructed ponds to store water. Later, in 1941 AD, British built aqueducts on Kalpathy River to transport water. By this time, Palakkad became an important hub for trade. The city started spreading towards outskirts.From the 20st Century, intensive deforestation and extensive urban development resulted in a great influence on the annual rainfall variation of the region. (Nikhil Raj, P.P., 2010)

URBANIZATION

The rise of Urbanization at a faster pace led to the decrease in water bodies and open spaces.From this pattern of development, the future development is towards outer wings.About 5% of the open land is used as recreational spaces like playgrounds, parks, communal spaces.Communal and recreational space here is very less. There is also opportunity for interlinking water bodies such as canals and ponds.

WATER SYSTEM

Urbanization is causing a huge impact on water resources which leads to climate change and a drastic decrease in water bodies. Public ownership and inefficient capacity in planning leads to poor condition of water bodies and networks. These water networks which meet the rivers also gets polluted.

Fig. 3: Land Use Map; from left 1980, 2010, 2031 (Published Master Plans, Palakkad)

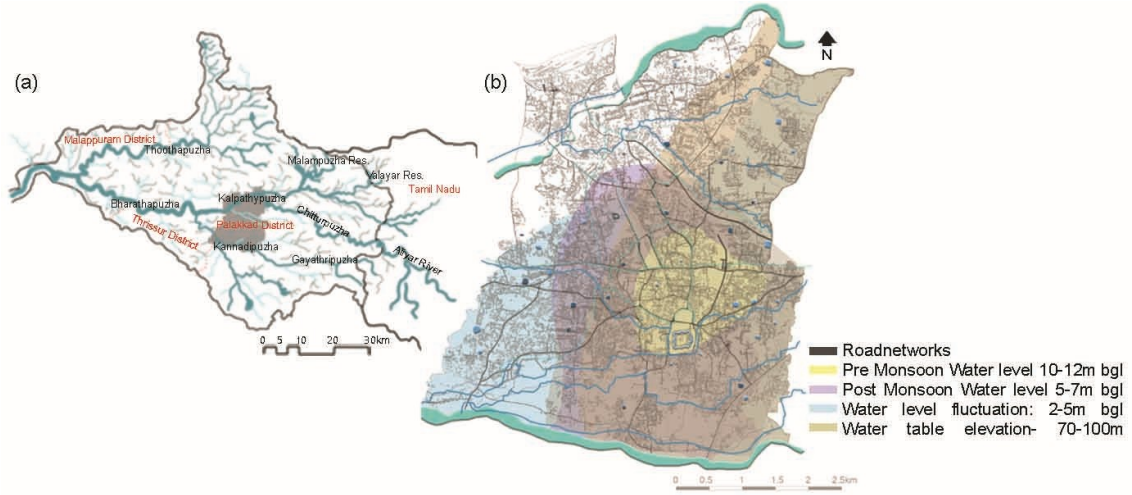

Fig. 4: Water Resource, (a) Surface Water, (b) Groundwater Table Levels (Author 2021)

Since the urban sprawl is towards the outer wing, any further development should incorporate urban design strategies to avoid their threat from depletion. Whereas, there are ponds which are privately owned doesn't have much impacts. Here, Communal and recreational space is very less. Hence, there is an opportunity for interlinking water bodies such as canals and ponds.

Fig. iv shows the surface water and ground water resource in Palakkad district. The Bharathapuzha is extensively dammed. There are 11 reservoirs along the course of the river, and two more are under construction.Kalpathy and Kannadi rivers to the north and south, Malampuzha canal in the East and other streams along with these rivers joins Bharathapuzha.

ANALYSIS

From the literature and case studies, Morphological parameterssuch as physical, social, spatial and ecological factors were identified for determining Water Stress Level. These parameters include Settlement pattern, Land use, Built use, Street networks, Public open space, Human activities, Layout and Heterogeneity of Urban form. From these factors, 3 Zones within the Municipality were identified as critical Zones.

Fig. 5: Water Resources, Settlements and Identified Zones in Palakkad Municipality (Author 2021)

Water body and drain between Shagunthala Junction and Kalpathy River

Zone 1 covers Shagunthala Junction- BOC Rd- Chunnambuthura Road- Vadakkanthara Road- Shanguvaram Thodu- Sundaram Colony- Kalpathy River. Fig vi. (a) depicts the sectionshighlighting the residential areas near Kalpathy river and (b) shows the photographs of the existing condition. Hence, the Samples chosen are of residential category with adjacent water bodies (Canals to River). The sections show the encroachment and unsustainable water use by these areas' residential clusters which are placing strain on the rivers and canal system that link them.

ZONE 2

Water body between Shornur Road and Market Road

Zone 2 covers ACM Aboobacker Road- Vithunni Junction- Pattani Street- Melamuri Road- Single Street -Meparamba Junction.

Fig. vii (a) depicts the sections between Shornur Road and Market Road and river and (b) shows the photographs of the existing condition, which is one of Palakkad Municipality's most commercialized areas.This location was chosen because the region's commercial activities, such as markets and mixed land use are putting strain on water resources and infrastructure. Different combinations such as highly

Fig. 6: Zone 1(Author 2021)

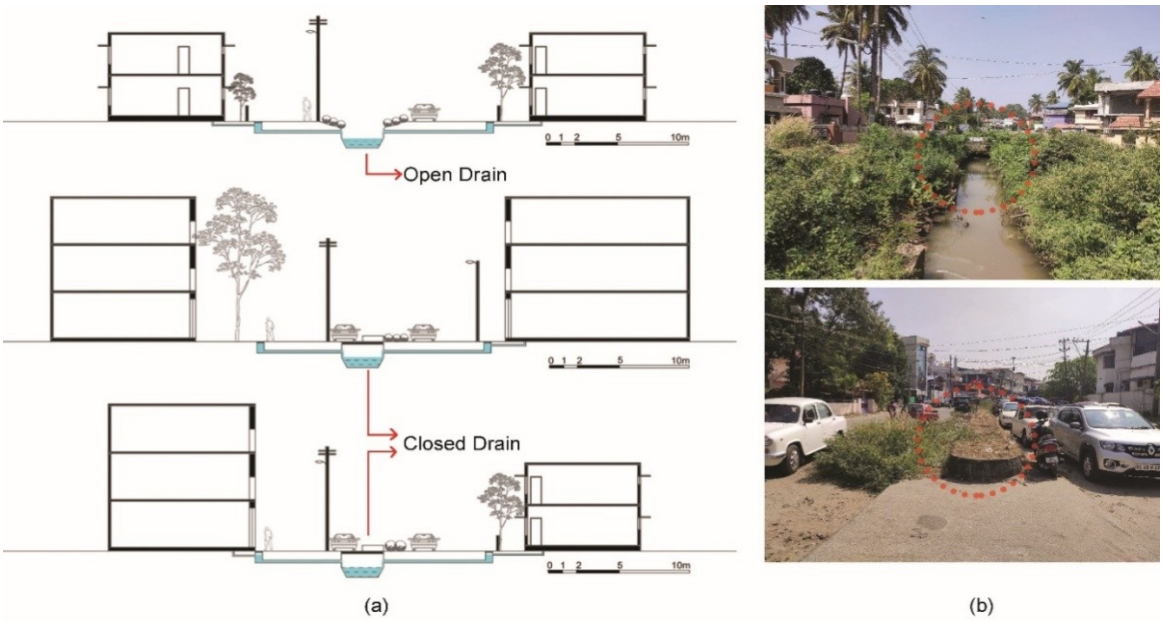

Fig. 7: Zone 2(Author 2021)

commercialized, mixed use and residential areas were chosen and analyzed. The wastes from highly commercialized areas are accumulated here and closed drains are not maintained. These are caused due to the lack of planning from an Urban Design perspective on Water Resources Management.

ZONE 3

Water body around the Fort

Fig. viii (a) shows the section through the outer ring of the core/ historic area around the Palakkad Fort and (b) shows the photographs of the waste dumping and pollution. This Zone was chosen due to its land use and different patterns such as Historic, Public and Commercial activities. The sections show closed and semi open drainswhich were under stress due to urbanization, climate change and land degradation due to mismanagement of water resources.

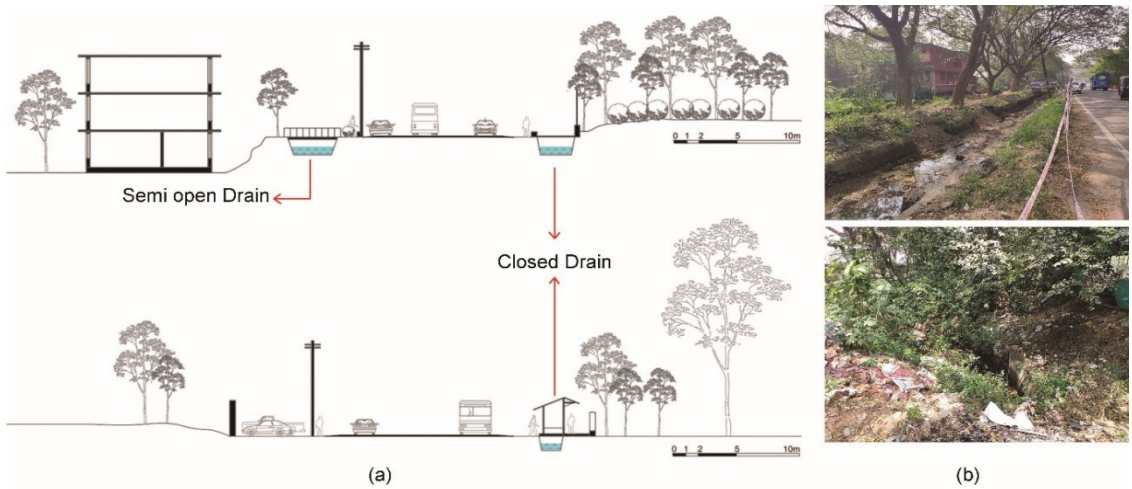

Fig. 8: Zone 3, Fort Area (Author 2021)

INFERENCE AND DISCUSSION

Fig. ix shows the conceptual model based on the aspects and parameters arrived from literature and case studies suitable for the primary site.

a) **Heterogeneity** separates different components of urban form into different parts and reduce the level of risk within the space. It also helps to recharge ground water.

b) **Well-connected and hierarchical networks** of urban infrastructure (surface water, groundwater and urban aquifers) increase the scopes for future development.

c) **Harmony and consistency with Nature** and urban forms promote ecological resilience.

d) **Modularity** of an urban system facilitates to control and group different parts of urban form providing strong relationship with nature.

STRATEGIES

1. Design Interventions: Strengthen socio-cultural activities - Maintenance of public infrastructure and amenities near Fort area and Stadium Bus Stand and converting the existing open as shared space for socializing and water conservation.
2. The Settlements near Kalpathy River are mostly residential with fine or uneven texture.The unbuilt areas thus have a scope for suitable interventions such as a well-connected and hierarchy with rivers,public parks or riverfront developments etc. Public facilities could be improved so that it could provide spatial, physical, social and ecological benefits. Guidelines could be adopted in case of river edge constructions.
3. Commercial Settlement in the core area, where the market is located have continuous built form. Scattered settlements and Coarse grain are seen in newer buildings outside the major commercial areas. Sudden change affects the water demand. Hence, the different tissues identified based on Residential, Commercial, Public, Transportation and open spaces are to be treated with dimensions such as Heterogeneity, Well-connected and hierarchical networks, Harmony, Consistency with Nature and Modularity.

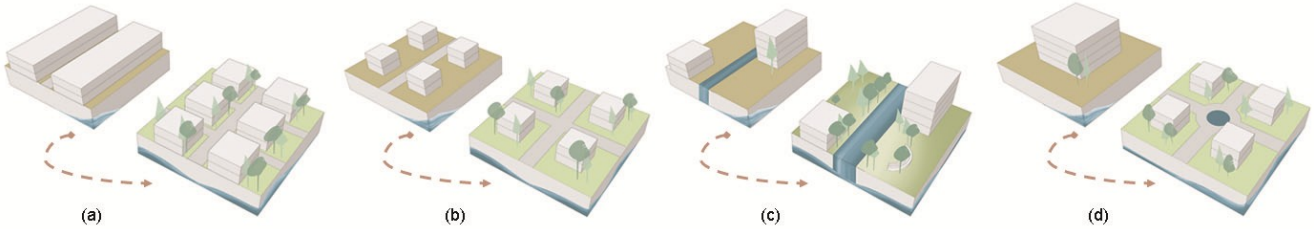

Fig. 9: Concepts (Author 2021)

4. Climate-proofing rainfall-based systems near commercial edges with continuous building facade for the Market area to prevent storm water runoff.
5. Historic Zone (Palakkad Fort) is properly maintained.Waste disposal is the major issue identified here.Administrative level interventions such as fine, tax and public awareness could solve the issue.
6. The empty spaces near Fort, Market, Residential areas near KSRTC Bus stand and along the stretch of Bharathapuzha Canal when converted to a public/ shared space, will generate public participation and ownership. Hence, illegal dumping of waste and pollution rate will be reduced.
7. Expanding the role of intermediate rain fed-irrigated systems and connecting the watershed to Malampuzha Canal for the new transport network could be added near Stadium Bus stand area.

RECOMMENTATIONS

1. For areas with water scarcity, the emphasis must be on increasing the resilience of production systems to deal with drought and extreme heat, and reducing their vulnerability.
2. Proper infiltration systems are required at every scale from household to neighborhood to city level.
3. River and Canal Edge can be treated with respect to the built form. Raingardens, infiltration trenches and swales can be installed with respect to the context.
4. Proper waste management and wastewater treatment is required before letting them out to the rivers.
5. Policy level: Awareness on Day Zero and water related topics at all levels of educational curriculum.

CONCLUSIONS

Urbanization has a huge impact on our water resources which are getting depleted due to unplanned developments. The management of water within urban areas are a result of morphological factors. Applying Urban design strategies at all levels play an important role in every city planning and helps in mitigating the impacts caused by climate change. Urban Morphology is the study of Urban form and its applications remains limited. The built form and surrounding morphology would benefit from rehabilitating existing infrastructure and providing a consistent water supply development, water management, and defenseplan. Incorporating these aspects and parameters for managing Water Resources helps to reduce the risk and vulnerability of degradation, pollution and other structural damages. Maintenance of public facilities and infrastructures as well as introducing Day Zero and water-related topics at all levels of educational curriculum, will have a positive effect on Water Resources.

The strategies and recommendations adopted could be taken to a next level of designing since it is becoming more relevant as our government is planning to build 100 smart cities across India, for which sustainable Water Resource Management is an important pillar.

ACKNOWLEDGEMENTS

Dr. Bejene S Kothari (Head of the Department), Prof. Saritha G Parambath and Ar. Alok Dinesh from Department of Architecture,College of Engineering Trivandrum, Kerala, India.

Dr. Manoj Kumar Kini (Principal, Kerala State Institute of Design, India)

Ar. Biley Menon (Principal Eco Planner & Urban Designer, Idea Design, Kochi, India)

Jidhesh K. P (Assistant Manager-Production, CEAT Tyres, Chennai)

Sandeep B Menon (Landscape Architect, Core Faculty @ KRVIA | Mumbai & Research Associate @ BReUCom Research Project of the European Union Erasmus+ Program)

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