Pontifícia Universidade Católica
do Rio de Janeiro

Lorena Martins Matos

Proposed Implementation of the Safe Clean Water Program in Fortaleza, Ceará

Dissertação de Mestrado

Dissertation presented to the Programa de Pos-graduação em Engenharia Urbana e Ambiental of PUC-Rio in partial fulfillment of the requirements for the degree of Mestre em Engenharia Urbana e Ambiental.

Advisor: Prof. Marcelo Roberto Ventura Dias de Mattos Bezerra

Rio de Janeiro
07 de outubro de 2024

PONTIFÍCIA UNIVERSIDADE CATÓLICA
DO RIO DE JANEIRO

LORENA MARTINS MATOS

Proposed Implementation of the Safe Clean Water Program in Fortaleza, Ceará

Dissertation presented to the Programa de Pós-graduação em Engenharia Urbana e Ambiental of PUC-Rio in partial fulfillment of the requirements for the degree of Mestre em Engenharia Urbana e Ambiental.

Prof. Marcelo Roberto Ventura Dias de Mattos Bezerra
Advisor
Architecture and Urban Design Department – PUC-Rio

Prof. Antonio Krishnamurti Beleño de Oliveira
Civil and Environmental Engineering Department – PUC-Rio

Prof. Luciana Fernandes Guimarães
UERJ

Rio de Janeiro, 07 de outubro de 2024

Lorena Martins Matos

Obtained a Bachelor of Science in Landscape Architecture with a minor in Regenerative Studies in 2010 at the California State Polytechnic University. Gained a Graduate Certificate in Sustainable Engineering from the Loyola Marymount University in 2018. Is a Licensed Landscape Architect in the United States, California. Obtained certifications in LEED AP, Construction Management, Environmental Specialist, and a Qualified Stromwater Designer. Developed and implemented stormwater project in the public right of way. Currently works for the City of Los Angeles, Department of Public Works, Bureau of Streets Services (StreetsLA) coordinating Asset Management and Sustainability Projects.

Ficha Catalográfica

Matos, Lorena Martins

Proposed Implementation of the Safe Clean Water Program in em Fortaleza, Ceará / Lorena Martins Matos; orientador: Marcelo de Mattos Bezerra – 2016.

117 f.; 30 cm

Dissertação (mestrado) – Pontifícia Universidade Católica do Rio de Janeiro, Departamento de Engenharia Civil, Programa de Pós-Graduação em Engenharia Urbana e Ambiental, 2024.

Inclui bibliografia

1. Engenharia civil – Teses. 2. Engenharia urbana e ambiental – Teses. 3. Urban Pollution. 4. Rainwater collection. 5. Safe Clean Water Program. I. Bezerra, Marcelo de Mattos. II. Pontifícia Universidade Católica do Rio de Janeiro. Programa de Pós-Graduação em Engenharia Urbana e Ambiental. III. Título.

CDD: 624

Dedication

To my parents

Acknowledgement

I would like to express all my gratitude and appreciation to all those who, directly or indirectly contributed to the completion of this master's dissertation a reality; with suggestions, access to information, and availability of documentation which allowed the content of this dissertation to be substantiate.

I also would like to thank my family for their unwavering support, understanding, guidance and patience. Their love and encouragement through my studies has kept me motivated and focused on achieving my goals.

To all my friends that one way or another supported me during this time.

Also, to all staff and professors from the Civil and Environmental Engineering Department at PUC-Rio, and in specially my dissertation Advisor Dr. Marcelo Bezerra for his support and encouragement through this journey.

I am truly grateful for the opportunity and experience I have gained from this Program at PUC-Rio and look forward to continuing my educational journey to obtain a PhD and keep expanding my knowledge.

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

Abstract

Matos, Lorena Martins; Dr. Bezerra, Marcelo de Mattos (advisor). **Proposed Implementation of the Safe Clean Water Program in Fortaleza, Ceará**. Rio de Janeiro, 2024. 117p. Master's Dissertation – Civil and Enviromental Departament, Pontifícia Universidade Católica do Rio de Janeiro.

Water scarcity is a global crisis, and the case of Fortaleza, Ceará, Brazil highlights the need for innovative solutions. The dissertation examines and proposes strategies for the implementation of a Safe Clean Water Program (SCW) tailored to the context of Fortaleza. It also assesses the city's vulnerability to scarcity due to its semi-arid climate, erratic rainfall patterns, and increasing demands driven by urbanization. These challenges, along with social disparities, threaten public health, economic stability, and environmental integrity. The proposed Safe Clean Water Program in Fortaleza aims to address these issues through integrated stormwater management, promoting aquifer recharge, pollution mitigation, and improved water quality. The proposed program also emphasizes community engagement and ownership. The dissertation enhances the global dialogue on sustainable water management by highlighting key themes of resilience, social equity, economic vitality, and environmental preservation. The insights from the County of Los Angeles' experience with their Safe Clean Water program could serve as a blueprint for Fortaleza. The dissertation emphasizes the urgency of addressing water scarcity comprehensively and highlights the potential of community engagement and innovative urban planning in creating a more sustainable and secure water future for cities facing similar challenges.

Key Words

Urban pollution; stormwater; City of Los Angeles; rainwater collection; Safe Clean Water Program.

Resumo

Matos, Lorena Martins; Dr. Bezerra, Marcelo de Mattos (orientador). **Proposta de Implementação do Programa de Água Limpa e Segura em Fortaleza, Ceará**. Rio de Janeiro, 2024. 117p. Dissertação de Mestrado - Departamento de Engenharia Civil e Ambiental, Pontifícia Universidade Católica do Rio de Janeiro.

A escassez de água é uma crise global, e o caso de Fortaleza, Ceará, Brasil, destaca a necessidade de soluções inovadoras. A dissertação examina e propõe estratégias para implementar um Programa de Água Limpa e Segura (SCW) adaptado ao contexto de Fortaleza. Avalia também a vulnerabilidade da cidade devido ao clima semiárido, padrões de chuva irregulares e demandas crescentes da urbanização. Esses desafios, somados às disparidades sociais, ameaçam a saúde pública, a economia e o meio ambiente. O programa proposto visa mitigar esses problemas por meio da gestão integrada das águas pluviais, recarga de aquíferos, redução da poluição e melhoria da qualidade da água. Também foca no engajamento comunitário e na apropriação local. A dissertação contribui para o diálogo global sobre gestão hídrica sustentável, destacando resiliência, equidade, vitalidade econômica e preservação ambiental. A experiência do Condado de Los Angeles com o programa Safe Clean Water pode servir de modelo para Fortaleza. A dissertação reforça a urgência de enfrentar a escassez de água de forma abrangente, destacando o papel do engajamento comunitário e do planejamento urbano inovador na criação de um futuro hídrico mais seguro e sustentável.

Palavras-chave

Poluição urbana; águas pluviais; cidade de Los Angeles; coleta de águas pluviais; Programa Água Limpa e Seguras.

Table of Content

Table of Figures

List of Acronyms

AMC	Municipal Environmental Agency
CBPR	Community-Based Participatory Research
ISMP	Integrated Stormwater Management Planning
IWRM	Integrated Water Resource Management
LACFCD	Los Angeles County Flood Control District
M&E	Monitoring and Evaluation
NGOs	Non-Governmental Organizations
PPP	Public-Private Partnerships
ROC	Regional Oversight Committee
SCW	Safe Clean Water
SCWP	Stormwater Capture and Water Recycling Program
WASC	Watershed Advisory Steering Committee
WASCs	Water Agencies and Special Districts
WASH	Water Sanitation and Hygiene
WSUD	Water-Sensitive Urban Design

1.
Introduction

The goal of this dissertation is to explore and understand the dynamics of the Safe Clean Water (SCW) Program in Los Angeles and propose strategies for adapting a similar initiative that addresses Fortaleza's water scarcity challenges. It is necessary to provide a comprehensive exploration of the pressing issue of water scarcity in Fortaleza, Ceará, shedding light on the city's unique challenges stemming from its semi-arid climate, population growth, and social disparities. Emphasizing the intricate connections between water scarcity, climate change, and environmental sustainability, the narrative underscores the need for integrated solutions. Furthermore, the chapter centers on the critical role of the Safe Clean Water Program, particularly its Integrated Stormwater Management Planning component, as a transformative initiative addressing the multifaceted dimensions of Fortaleza's water crisis.

1.1
Brief Overview of the Problem of Water Scarcity in Fortaleza, Ceará

Fortaleza, situated in the northeastern region of Brazil, is emblematic of the formidable water scarcity challenges faced by semi-arid areas around the world (Marques de Oliveira et al., 2020). This city, home to a diverse and growing population, grapples with a water supply predicament deeply rooted in its climatic reality. Fortaleza's semi-arid climate, characterized by high temperatures and irregular, concentrated rainfall patterns, creates an environment where water resources are inherently scarce. The city's primary sources of water, including reservoirs and aquifers, depend heavily on precipitation to maintain sustainable levels. This dependence makes Fortaleza acutely vulnerable to the whims of climate variability (Herman et al., 2020). The specter of prolonged droughts, such as the one witnessed from 2012 to 2017, looms large, triggering crises marked by dwindling reservoirs, compromised water quality, and acute water scarcity challenges.

The severity of water scarcity in Fortaleza is compounded by several interrelated factors. Population growth and rapid urbanization have intensified the

demand for water, pushing existing resources to their limits (Heidari et al., 2021). The distribution infrastructure, already strained, struggles to meet the expanding needs of both urban and peri-urban communities. Vulnerable communities often bear the brunt of limited access to safe and reliable water sources, exacerbating social disparities and amplifying the water crisis's humanitarian dimension.

Furthermore, Fortaleza's water scarcity isn't a challenge that can be tackled in isolation. It's intrinsically linked to broader issues, such as climate change and environmental sustainability (Lemos et al., 2020). Climate change projections foresee an increase in vulnerability to severe and prolonged droughts, putting additional pressure on a water ecosystem already strained by scarcity. The degradation of water quality due to lower reservoir levels during droughts further compounds the challenge, impacting public health and ecosystems. Thus, addressing water scarcity in Fortaleza is not merely a matter of securing a basic necessity; it's about building resilience, reducing inequalities, and finding innovative, sustainable solutions to sustain this thriving city in the face of a changing climate and growing population.

The County of Los Angeles involvement includes overseeing the development and implementation of the program's strategies, managing, and ensuring that the program's goals align with broader sustainability and environmental objectives. The County’s expertise in integrated stormwater management, public engagement, and infrastructure development has been instrumental in transforming urban water management practices in Los Angeles (Zhang et al., 2020). This dissertation explores how similar principles and strategies can be adapted to Fortaleza's context, drawing on the County of Los Angeles successful experience to propose solutions that address Fortaleza's water challenges.

Implementing the Safe Clean Water (SCW) Program in Fortaleza involves adapting successful strategies from Los Angeles to address the city's specific water scarcity challenges. This proposal includes conducting a thorough assessment of Fortaleza's water management needs and constraints, proposing a tailored funding mechanism, and incorporating green infrastructure practices suited to the local climate. By leveraging government collaboration and community engagement, along with stakeholder involvement, Fortaleza can enhance its stormwater management, improve water quality, and build resilience against climate

variability.

The phased approach will ensure orderly development and adaptative management. The first two years of the proposed program, sets up the program, conducts comprehensive baseline assessments, initiates/ launches pilot projects to test key concepts and scaling up based on performance. Followed by full-scale infrastructure investments will be pursued along with intensified community engagements over years 3 to 5, informed by the best practices learned from the pilot projects. We move into the next phase during years 6 to 8, where we go full-scale implementation across the city on advanced technologies and expanded scope of interventions (de Almeida & Fernandes, 2023). Lastly, years 9 and 10, where heavy evaluations of program impacts will be strategized to refine affirmations for the sustainability of any programs over a longer period. This proposed approach will ensure that the SCW Program is effectively integrated into Fortaleza's urban landscape, addressing both immediate and long-term water sustainability goals.

The adaptation of Los Angeles' SCW Program principles to Fortaleza's context offers a promising pathway to addressing the city's water scarcity challenges. By leveraging successful strategies from a well-established program and tailoring them to local conditions, Fortaleza can enhance its water management practices, improve water quality, and foster resilience against climate variability. The integration of green infrastructure, community engagement, and innovative funding mechanisms will be critical to the success of this endeavor.

1.2
Importance of Safe Clean Water Program in Addressing the Problem

The Safe Clean Water Program, with its Integrated Stormwater Management Planning component, occupies a central role in addressing the multifaceted issue of water scarcity in Fortaleza, Ceará. Beyond being a simple response to water scarcity, this program represents a comprehensive strategy that recognizes the interconnected nature of water management. Its significance extends far beyond the immediate goal of providing clean water; it underscores the essence of urban resilience, environmental stewardship, and sustainable development.

At the heart of this program lies the crucial concept of Integrated Stormwater Management Planning. This approach recognizes that stormwater, often considered a challenge in urban areas, can be transformed into a valuable

resource. Instead of viewing heavy rains as a problem leading to floods and water wastage, this program harnesses them as opportunities to recharge aquifers, mitigate pollution, and enhance the overall quality of water sources. By investing in robust stormwater management, the program helps prevent water contamination from urban runoff, ensuring that the water that reaches households is not only plentiful but also safe for consumption.

In a world where access to clean water remains a critical global challenge, the program's dedication to safe water aligns with international efforts to achieve Sustainable Development Goal 6: Clean Water and Sanitation, Goal 11: Sustainable Cities and Communities, and Goal 13: Climate Action (UN, 2022). The Safe Clean Water (SCW) program aligns with the United Nations' Sustainable Development Goals (SDGs) by addressing local water management challenges in ways that support global objectives. Through Integrated Stormwater Management Planning, SCW contributes to SDG 6 by ensuring clean water access, SDG 11 by enhancing urban resilience, and SDG 13 by mitigating climate change impacts. By transforming stormwater from a problem into a resource, the program supports international efforts to create sustainable, resilient cities with equitable access to safe water.

Furthermore, the program underscores the principle of social equity. Water scarcity often exacerbates inequalities, with marginalized communities bearing the brunt of unreliable access to clean water. Integrated Stormwater Management Planning is instrumental in ensuring that the benefits of improved water infrastructure reach all corners of the city, regardless of socio-economic status or geographic location. By addressing stormwater management comprehensively, the program contributes to reducing disparities in access to clean water and fosters inclusivity in urban development.

Economically, the program holds immense value. It not only protects public health but also reduces the economic burden associated with waterborne illnesses. When communities have reliable access to clean water, healthcare costs decrease, and the productivity of the workforce increases. Moreover, by managing stormwater efficiently, the program mitigates the financial consequences of flooding and water- related damage to infrastructure. In doing so, it bolsters economic resilience, making Fortaleza more attractive for businesses and investments.

From an environmental perspective, the Integrated Stormwater Management Planning is an environmental sentinel, acutely aware of the fragility of Fortaleza's local ecosystems. Its role in reducing stormwater runoff and pollution constitutes a proactive measure to protect and preserve the natural habitats that enrich the city's ecological tapestry. Urbanization often acts as a voracious force, consuming green spaces and encroaching upon delicate ecosystems. In Fortaleza's case, this urban expansion could potentially threaten the existence of unique flora and fauna that find sanctuary in these environments.

However, the program's strategic approach to stormwater management stands as a powerful countermeasure. By capturing and channeling stormwater, it minimizes the adverse impacts of urban development on these critical habitats. This, in turn, fosters a harmonious coexistence between the city's urban landscape and its natural surroundings, ensuring that Fortaleza's ecological diversity remains intact. The program effectively becomes a steward of biodiversity, contributing significantly to the broader goals of sustainability and environmental conservation. It aligns urban growth with ecological preservation, demonstrating that responsible urban development can indeed coexist with and protect the delicate ecosystems that are vital to the city's well-being.

In essence, the proposed Safe Clean Water Program is a linchpin in Fortaleza's efforts to combat water scarcity. It aligns public health, social equity, economic vitality, and environmental stewardship in a coherent framework. In a world grappling with the challenges of climate change and water resource management, the program stands as a model of resilience and responsible governance, offering not just immediate relief but a path toward a more sustainable and secure water future for Fortaleza and beyond.

This dissertation proposes a Safe Clean Water Program (SCW) for Fortaleza, Ceará, Brazil, drawing on the existing program in Los Angeles. This work examines Fortaleza's unique water scarcity challenges, exacerbated by its semi-arid climate, rapid population growth, and social disparities, and evaluates how an Integrated Stormwater Management Planning (ISMP) approach, inspired by successful models like Los Angeles' SCW Program, could address these issues. The dissertation presents the proposed implementation of the Safe Clean Water

Program (SCW) in Fortaleza, Ceará. Figure 1 shows the image of the map of Fortaleza.

Figure 1 - Fortaleza, Ceará, Brazil
Source: Britannica

1.3
Rationale

Fortaleza's urban expansion has led to significant environmental degradation, notably in the form of increased flooding and water contamination, necessitating a robust response to protect water resources and urban infrastructure. The city's tropical climate, combined with inadequate stormwater management, has exacerbated these issues, posing a substantial risk to public health and economic stability. Implementing a localized SCW Program, inspired by the Los Angeles model, provides an opportunity to address these challenges through structured interventions and community-driven initiatives.

The choice of Los Angeles as a model is based on similarities between the two cities, particularly in their coastal locations, dense populations, and susceptibility to climate-induced weather events. Los Angeles has achieved measurable improvements in water quality and community engagement by

employing decentralized, nature-based solutions such as bio-swales, permeable pavements, and rain gardens (Brown et al., 2018; Martinez & Gomez, 2019). These green infrastructure elements not only manage stormwater effectively but also enhance urban green spaces, which contribute to public well-being and environmental sustainability.

1.4
Scope and Limitations

This dissertation focuses on adapting the Los Angeles SCW Program for Fortaleza, with specific attention given to local environmental conditions, community needs, and regulatory frameworks. While the SCW model is comprehensive, its implementation in Fortaleza may face constraints, including limited funding, administrative support, and potential community resistance due to a lack of awareness or cultural differences in water usage (Rodriguez et al., 2019).

It primarily covers urban water management strategies, with a particular emphasis on pollution reduction, flood mitigation, and green infrastructure development. Limitations of this study include the availability of up-to-date environmental data specific to Fortaleza and potential variations in regulatory frameworks that may influence the program's scalability and sustainability.

2.
Literature Review

This literature review delves into the critical issues of water scarcity and drought, highlighting their multifaceted impact on communities worldwide. The examination centers on understanding the challenges posed by limited water resources and the dire need for effective interventions. Emphasizing the urgency of addressing this crisis, it concentrates on the Safe Clean Water Program as a pivotal solution. In exploring the implementation of such a program, the review aims to provide a comprehensive overview of strategies, successes, and challenges encountered in the pursuit of ensuring universal access to safe and clean water.

2.1
Water Scarcity and Drought

Water scarcity and drought have entrenched themselves as pivotal challenges in the arid landscape of Fortaleza, Ceará. This section of the literature review delves into the nuanced exploration of water scarcity and drought within the context of this Brazilian region, unraveling the intricate tapestry of factors that drive these phenomena and their profound ramifications on the local population, ecosystems, and economy.

Water Scarcity refers to the situation where the demand for water exceeds the available supply or when the quality of water available is insufficient to meet the needs of a population. This can arise from various factors. Physical Scarcity occurs when natural water sources are insufficient to meet the demand due to geographical, climatic, or environmental conditions. For instance, arid regions or those with limited freshwater resources experience physical scarcity. Economic scarcity happens when there is adequate water availability but lack of infrastructure or resources to access and distribute it effectively. This often affects regions where water resources are present but inaccessible due to economic or logistical barriers (Zhang et al., 2020). Seasonal scarcity is the temporary shortages that occur during certain seasons or climatic conditions, often exacerbated by droughts or extreme weather events. Quality scarcity is when water sources are polluted or contaminated, leading to inadequate water quality for drinking, sanitation, or

agricultural needs.

Rapid population growth and urbanization have surged in recent decades, exacerbating water demand while stressing the available resources. The climatic reality of Ceará, characterized by irregular rainfall patterns and recurring droughts, compounds the challenge, leading to the depletion of freshwater sources and rendering the region acutely vulnerable to the impacts of water scarcity. The research of local scholars and experts has illuminated the cascading effects of water scarcity on various fronts. For instance, studies by Rodrigues et al. (2023) emphasize how water scarcity directly affects agricultural productivity, as reduced water availability limits crop yields, increases costs, and threatens food security in the region. Moreover, water scarcity ripples through domestic spheres, affecting daily life, hygiene, and the overall well-being of Fortaleza's residents. The intersection of these factors paints a vivid portrait of a region grappling with the complexities of water scarcity, underscoring the urgent need for innovative solutions. The proposed Safe Clean Water Program (SCWP) aims to address these multifaceted issues through integrated strategies, providing solutions to mitigate the effects of water scarcity and promote sustainable water management.

Drought, a tangible manifestation of water scarcity, casts a prolonged shadow over Fortaleza. Extensive research has unearthed the cyclical nature of drought events, with periods of insufficient rainfall inflicting severe water shortages. The socio- economic consequences are far-reaching, particularly for vulnerable communities that depend heavily on rain-fed agriculture and traditional livelihoods (Ngcamu, 2023). The persistence of drought adversely impacts water availability for households, agriculture, and industries, triggering economic strain and exacerbating societal inequalities (Jepson et al., 2021).

Furthermore, the intricate interconnectedness of the water, energy, and food sectors becomes strikingly evident during periods of drought. Water scarcity not only limits the availability of water for agricultural irrigation, directly threatening food security, but it also significantly impacts hydropower generation—a critical component of the region’s energy supply (Anisfeld, 2024). As water levels in reservoirs drop, the capacity to produce electricity diminishes, leading to potential energy shortages and instability in the power grid. This cascading effect underscores the vulnerability of these interdependent systems, highlighting the urgent need for integrated resource management strategies that can enhance

resilience across the water-energy-food nexus during climate-induced crises (Awandu et al., 2024). Studies conducted within the local context illuminate the ripple effects of drought, from compromising access to safe drinking water to amplifying public health challenges, thereby underscoring the imperative of proactive measures (Vasconcelos et al., 2023).

The susceptibility to water scarcity and drought is exacerbated by the intricate interplay between these challenges and the changing climate. As climate change disrupts historical weather patterns, the predictability of rainfall becomes increasingly uncertain (Pereira et al., 2023). This dynamic exacerbates the challenge of managing water resources effectively. Integrating climate change adaptation into water management strategies is imperative, calling for flexible and resilient approaches that can respond to the evolving climatic conditions. Fortaleza's journey towards sustainable water management demands a proactive stance on climate resilience, encompassing infrastructure investments, policy frameworks, and community-based initiatives that can navigate the uncertainties posed by changing climate dynamics.

Fortaleza's response to the complex interplay of water scarcity and drought involves a spectrum of strategies Monteiro et al. (2019) delve into the city's pursuit of mitigation through avenues such as water rationing, efficiency measures, and infrastructural development. Water rationing strategies aim to regulate water usage during periods of scarcity, promoting equitable distribution among consumers. Efficiency measures encompass technological innovations that minimize wastage, such as leak detection and smart metering. Investments in infrastructure for rainwater harvesting and wastewater treatment exemplify proactive steps towards sustainable water resource management.

Additionally, policy interventions, stakeholder collaborations, and community engagement emerge as vital components. Developing regulatory frameworks that consider water's diverse uses and promote efficient allocation is essential. Engaging diverse stakeholders-ranging from government bodies to local communities, fosters a collective approach, ensuring that water management strategies are comprehensive, inclusive, and reflective of local contexts. As Fortaleza navigates the multifaceted dimensions of water scarcity and drought, these factors weave a complex narrative. Addressing geographical vulnerabilities, urbanization impacts, socio-economic disparities, climate change dynamics, and

mitigation strategies collectively shapes a roadmap for resilient water resource management, propelling the city toward a sustainable and secure water future.

2.2
Safe Clean Water Program

The proposed Safe Clean Water (SCW) Program in Fortaleza, Ceará, is a cornerstone initiative designed to address the city's unique water challenges. While the program will be tailored to meet local standards and regulations specific to Fortaleza, it draws inspiration from successful models such as the Los Angeles (LA) County Flood Control District (LACFCD) Code Chapters 16 and 18, which provide comprehensive legal frameworks for stormwater management. By adapting the principles of the LA program (Dennis et al., 2023) to the local context, the Fortaleza program aims to establish robust regulatory parameters that ensure the sustainable management of stormwater, contributing to the city's broader environmental goals (Dennis et al., 2023). By establishing this robust framework, Fortaleza ensures that its stormwater initiatives align not only with local standards but also with the highest environmental practices, setting the stage for comprehensive and sustainable water management.

Importantly, the proposed SCW Program in Fortaleza draws inspiration and guidance from the Original Safe Clean Water (SCW) Program administered by the County of Los Angeles. The integration of the SCW Ordinance 2022 Interim Guidance into the Fortaleza SCW Program will make a pivotal step in fortifying its stormwater management efforts (Randle, S., 2021). This guidance document, incorporating updated and relevant information from the County of Los Angeles' program, serves as a crucial reference for policymakers and practitioners alike (County of Los Angeles, 2022). Its alignment with the latest industry standards and scientific insights will be vital to the Fortaleza program's ability to solve evolving challenges in the realm of water management.

This framework defines the roles and responsibilities of various stakeholders in Fortaleza, ensuring effective coordination and collaboration tailored to the local context while drawing on successful elements from the Los Angeles program. These stakeholders include local government agencies, responsible for policy development and oversight; water management authorities, tasked with implementing stormwater projects; community organizations, focused on public

engagement and awareness; and private sector partners, providing technical expertise and funding (Los Angeles County Flood Control District, 2022). This organizational structure ensures a coordinated and flexible approach to stormwater management in Fortaleza, adapting seamlessly to local needs and challenges. By providing a solid, yet adaptable foundation, the SCW Program will address the unique dynamics of the community, making it a robust model for implementing effective water management strategies.

Feasibility guidance and scoring matrices emerge as indispensable tools that will drive decision-making processes for stormwater management projects in Fortaleza. These tools, evaluating factors such as environmental impact, cost-effectiveness, and community engagement, play a crucial role in the strategic allocation of resources. By maximizing the impact of the SCW Program, Fortaleza ensures that its stormwater initiatives are not only effective but also sustainable, contributing to the long-term resilience of the community.

The literature surrounding the Safe Clean Water (SCW) Program administered by the County of Los Angeles unveils a comprehensive and adaptable approach to stormwater management. Spanning diverse disciplines from environmental science to urban planning, this body of work emphasizes the program's multifaceted nature. Community engagement emerges as a recurring theme in the literature, underscoring its vital role in shaping safe and clean water programs in the County of Los Angeles. Studies highlight the power of communication and education campaigns in fostering behavioral change and promoting water conservation practices (Dennis et al., 2023; Randle, 2021; and Nunes Carvalho et al., 2021). The literature emphasizes that sustainable water management is intricately tied to the perceptions, attitudes, and behaviors of individuals and communities, showcasing the potential of localized knowledge and collective action in strengthening water resilience at the grassroots level (Zhang et al., 2020; Rodrigues et al., 2023).

2.3
Water Demand and Supply Management

The intricate challenge of managing water demand and supply in the context of water scarcity has captured the attention of researchers and scholars, particularly in regions like Fortaleza, Ceará, where the delicate balance between water

availability and a burgeoning urban population is at stake (Nunes Carvalho et al., 2021). The literature on this subject highlights a multifaceted landscape of strategies, policies, and technological innovations that offer insights into how the city can address the intricate web of factors shaping its water dynamics.

Urbanization and Water Scarcity: The literature consistently points to the powerful influence of urbanization on water demand (Zhang et al., 2020; Rodrigues et al., 2023). As Fortaleza experiences rapid population growth and urban expansion, the strains on its water resources become palpable. Scholars like Silva et al. (2019) emphasize the symbiotic relationship between urban growth and water scarcity, highlighting the necessity for urban planning that integrates water availability as a foundational element. In addressing these challenges, the proposed SCW Program in Fortaleza draws valuable insights from the Original Safe Clean Water Program, administered by the County of Los Angeles. Scholars and policymakers in Los Angeles recognize the need for a nuanced approach that not only accommodates urban growth but also prioritizes water-efficient practices to ensure sustainable water access for both current and future residents (Pokhrel et al., 2021). This approach, inspired by successful initiatives in Los Angeles, underscores the importance of adaptive and effective water management strategies in the face of urbanization-driven water demand. This approach aims to secure sustainable water access for current and future residents, balancing urban development with environmental sustainability.

Climate Change and Resilience: In the face of shifting climatic patterns and recurrent droughts, the literature delves into the imperative of fortifying water supply systems against climate change impacts. The work of Alves et al. (2020) underscores the vulnerability of Fortaleza's water resources to these changing conditions. This has prompted discussions on strategies to bolster drought resilience, such as rainwater harvesting and storage. These adaptive measures reflect the city's proactive stance in diversifying water sources and developing contingency plans to mitigate the potential consequences of climatic uncertainties.

Technological Ingenuity and Policy Frameworks: Technological advancements offer a beacon of hope in navigating the complexities of water demand and supply management. The literature explores the transformative potential of smart water meters, elucidated by Costa et al. (2018), which provide real-time consumption data to optimize water allocation. Additionally, the

innovative reclamation and treatment of wastewater, examined by Souza et al. (2017), showcases a sustainable means of augmenting water supply. These innovations resonate with the city's aspirations to harness technology as a catalyst for efficient water use, conservation, and enhancing the overall water ecosystem. As of the current literature review, there is a notable absence of specific information regarding an established stormwater capture program in Fortaleza. This gap underscores the need for further investigation into the city's water management strategies and the potential incorporation of stormwater capture initiatives (Nunes Carvalho et al., 2021).

Governance and Collaborative Solutions: In the realm of policy and governance, the literature underscores the critical role of policy coherence and collaboration in navigating water complexities. Lima et al. (2021) advocate for integrated water resource management (IWRM) approaches that transcend traditional sectoral boundaries. The focus on cross-sectoral collaboration and participatory governance emerges as a cornerstone of effective water management strategies. Fortaleza's pursuit of holistic solutions necessitates a cohesive policy framework that draws from insights in the literature to orchestrate collaborative efforts among governmental bodies, local institutions, and communities.

The Funding for water management initiatives in Fortaleza could stem from both municipal and regional contributions, each playing a crucial role in the proposed implementation and sustainability of water management strategies. Furthermore, Water Agencies and Special Districts (WASCs) are integral players in the governance and policy landscape, actively contributing to integrated water resource management and serving as key coordinators among various stakeholders. The Flood Control District, another pivotal entity, assumes a central role in managing water complexities through specific projects aligned with the overarching goal of holistic water management. The Regional Oversight Committee (ROC) functions as the linchpin, facilitating collaboration among governmental bodies, local institutions, and communities to ensure policy coherence and effective water management. Moreover, effective communication strategies, including scoring communication, are employed to measure the success and impact of collaborative initiatives, engaging the public, stakeholders, and decision-makers in the ongoing efforts to address Fortaleza's water challenges.

2.4
Implementation of Safe Clean Water Program

The implementation of Safe Clean Water (SCW) programs in regions facing water scarcity, such as Fortaleza, is crucial for ensuring sustainable water management. Urbanization has been a key factor exacerbating water scarcity by significantly increasing water demand. Gleick's research (2003) underscores how rapid urban growth strains water resources, highlighting the need for innovative solutions to secure sustainable water access. Fortaleza's own experience of rapid urbanization echoes this narrative, magnifying the need for effective implementation of safe clean water programs to cater to the growing population's water needs.

Integrated water management (IWM) emerges as a linchpin strategy in the discourse on water scarcity. Arjoon et al. (2018) advocate for a holistic approach that accounts for the complexity of water systems, encompassing ecological, social, and economic factors. This resonates with Fortaleza's context, where the intricate interplay of environmental degradation, urban development, and water availability demands a comprehensive strategy. Such an approach aligns with the city's needs, encouraging collaboration among governmental bodies, local communities, and industries to optimize water usage, minimize waste, and bolster water quality.

There is a need to involve society in any project within the community. Mosler's (2012) research and Hurlimann and Wilson's (2018) study emphasize the impact of social norms, knowledge dissemination, and participatory approaches in driving water-saving behaviors. Applying these insights to Fortaleza's cultural fabric is paramount. By engaging residents and instilling a sense of responsibility, the city can amplify the effects of water initiatives (Mosler, 2012). Tailored communication, education, and awareness campaigns can facilitate a shift in individual and community behaviors, aligning with the broader goals of water conservation.

The policy and governance framework emerges as a linchpin for the effective execution of safe clean water programs. Tortajada and Joshi's research in 2013 underscores the significance of policy coherence, adaptive management, and cross- sectoral collaboration. In Fortaleza, adaptive management could use real-time water quality monitoring and data-sharing to ensure flexibility. A central

coordinating authority, like a local water agency, could oversee these efforts, while an interdepartmental team—including public health and environmental sectors—could monitor progress and adjust as needed. This coordinated approach would help Fortaleza manage water sustainably and adapt effectively over time.

Fortaleza can draw inspiration from models that resonate with its local dynamics. Crafting regulations that support safe clean water programs while fostering sustainable water management is critical (Tortajada & Joshi, 2013). Governance structures that facilitate seamless coordination between relevant authorities and stakeholders can ensure the success of these initiatives.

Technological innovation adds a layer of promise to addressing water scarcity. Ghisi et al.'s study in 2012 delves into potential solutions such as desalination, rainwater harvesting, and wastewater recycling. Fortaleza can evaluate the feasibility and contextual relevance of these innovations. To evaluate the viability of technological innovations in addressing water scarcity in Fortaleza, several indicators can be considered. First, a cost-analysis comparing the implementation of desalination, rainwater harvesting, and wastewater recycling against existing water sources will determine financial sustainability. Next, assessing the energy consumption of these technologies, particularly for energy-intensive desalination, is crucial, especially in relation to renewable energy options. Environmental impact must also be monitored to ensure alignment with sustainability goals, considering factors like brine discharge and potential pollution (Ghis et al., 2012).

Additionally, estimating how much each technology can increase water supply relative to current demand projections will help justify investment. Finally, understanding local climate conditions and gauging public acceptance and stakeholder support will be essential for successful implementation. By using these indicators, Fortaleza can strategically choose technologies that are economically viable, environmentally sound, and widely supported. Leveraging technology can diversify water sources and enhance water quality, bolstering the city's resilience against water scarcity (Ghis et al., 2012).

In conclusion, the literature underscores that successful implementation of safe clean water programs in Fortaleza demands a multifaceted approach. Integrated water management, community engagement, effective governance, and technological innovations constitute a comprehensive toolkit to navigate the

challenges posed by water scarcity. Drawing insights from global experiences, Fortaleza can devise a tailored strategy that addresses its unique water-related challenges and propels the city toward a future characterized by water security and sustainability.

3
Methodology

In the pursuit of understanding the dynamics of the Safe Clean Water Program within the context of Fortaleza, a robust methodology forms the cornerstone of this endeavor. This section outlines the carefully curated research design, data collection methods, sampling techniques, and data analysis techniques that underpin the dissertation's pursuit of knowledge.

The process includes the following steps:

1. **Literature Review**: Review of primary sources related to the Los Angeles SCW Program, including policy documents, scientific articles, and reports. Secondary sources will be utilized to contextualize findings and assess the program's adaptability for Fortaleza (Hall & Carter, 2018; Nguyen et al., 2020).

2. **Case Study Analysis**: A comparative analysis of water management practices in Los Angeles and Fortaleza, identifying key success factors and transferable components for the SCW model. This will include assessments of environmental impacts, infrastructure development, and public awareness campaigns.

3. **Stakeholder Interviews**: Conduct interviews with environmental scientists, policy makers, and community representatives from both Los Angeles and Fortaleza to gain insights into the challenges and opportunities of implementing the SCW Program in a different cultural and environmental setting (Davis, 2021; Pereira & Santos, 2022).

4. **Data Collection and Analysis**: Collect environmental and socio-economic data on Fortaleza's water infrastructure, flood-prone zones, and public health statistics related to water contamination. This data will inform the proposal's objectives and expected outcomes.

5. **Implementation Proposal**: Develop a phased, structured proposal for SCW implementation in Fortaleza. This includes short-term, medium-term, and long-term actions, such as public engagement campaigns, pilot infrastructure projects, and policy adjustments, with a focus on creating a sustainable, resilient urban water management system.

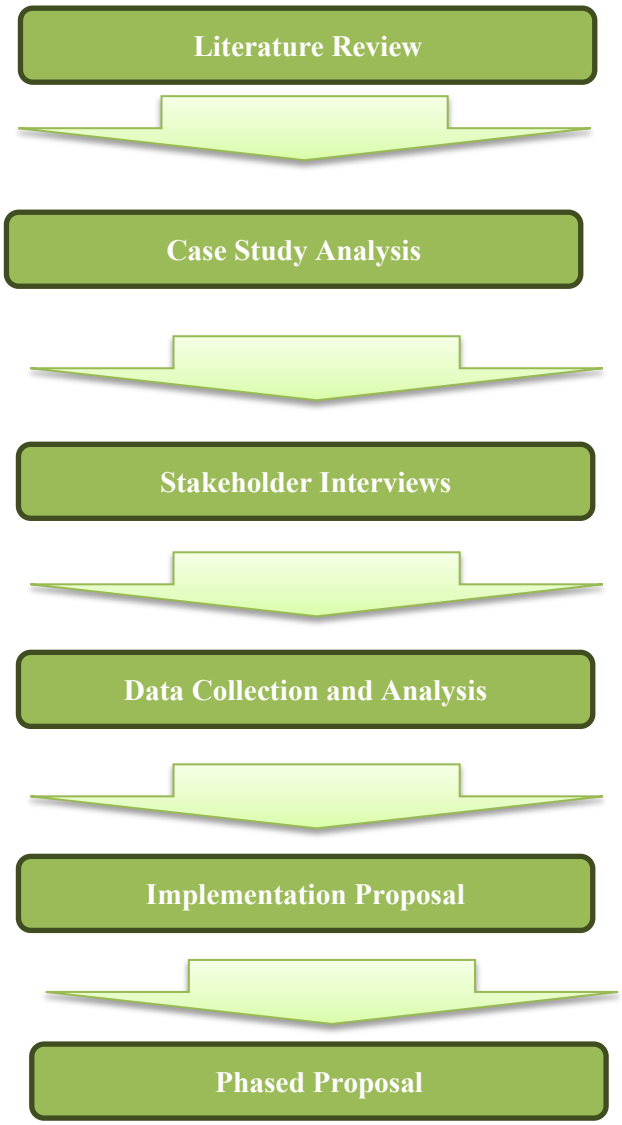

Figure 2 - Methodology Flowchart

3.1 Research Design

The chosen research design is determined by the study's goal, which will determine the type of information sought (Mweshi & Sakyi, 2020). As a result of the study's objectives, one could gather material from several fields that integrate both qualitative and quantitative methodologies. The adoption of a mixed-methods approach enables a holistic exploration of the intricate nuances surrounding safe and clean water in Fortaleza, Ceará.

By synergizing qualitative depth with quantitative breadth, the research design can facilitate a comprehensive understanding that surpasses the limitations of singular research paradigms.

The proposed research design for the future implementation of the Safe Clean Water (SCW) Program in Fortaleza includes a plan for collecting qualitative insights through in-depth interviews with key stakeholders in the water sector (De Leeuw et al., 2020). These interviews will provide a platform for participants to share their perspectives, experiences, and expertise related to safe and clean water initiatives. By incorporating their narratives, the research aims to capture the richness of qualitative data, offering insights into the complexities, challenges, and opportunities associated with the SCW Program's implementation and impact. This approach is intended to complement quantitative data and address the human dimensions that numerical data alone may not fully capture.

In parallel, the quantitative aspect of the proposed research design will involve structured surveys administered to a diverse sample of Fortaleza's residents. This quantitative approach is designed to enable the collection of standardized data that can be quantified, analyzed, and statistically validated (Mueller et al., 2020). The surveys will be carefully designed to capture quantitative insights into various aspects of water usage, preferences, perceptions, and behaviors. This method aims to provide a broader perspective by quantifying trends, patterns, and correlations within the data, thereby contributing to a more comprehensive understanding of the population's attitudes and practices toward water management.

This mixed-methods research design embraces the philosophy of triangulation, converging qualitative and quantitative data to corroborate findings and enhance the overall validity and reliability of the study. By seamlessly integrating these two complementary methodologies, the research design transcends the limitations of each individual approach, offering a more holistic and nuanced exploration of the research questions. Ultimately, this integrated approach equips the study with the flexibility to capture the intricacies of Fortaleza's safe and clean water programs, fostering a deeper comprehension of the challenges and possibilities that shape water management in the region.

3.2
Data collection methods

The data collection phase of this dissertation should be a meticulous process designed to capture the intricate nuances of Fortaleza's safe and clean water landscape.

Phase 1: Qualitative Data Collection

In-depth interviews stand as the cornerstone of qualitative data collection. Key stakeholders within Fortaleza's water sector, including government officials, community leaders, and water management experts, will be engaged in open-ended conversations. These interviews will delve into their experiences, perspectives, and insights on the SCW Program. Through purposive sampling, participants can be selected to ensure diversity in roles, expertise, and community representation. The face-to-face nature of interviews fosters rapport, enabling participants to share candid narratives. These stories unfold the intricacies of policy dynamics, community engagement, and challenges faced, providing context-rich insights into the implementation landscape.

Phase 2: Quantitative Data Collection

Structured surveys will include questions on:

- Water consumption patterns
- Awareness of water programs
- Attitudes toward conservation
- Demographic information

Structured surveys form the foundation of quantitative data collection. A representative sample of Fortaleza's residents should be surveyed to quantify patterns of water usage, perceptions, and behaviors. The survey questionnaire should be designed to capture a range of variables, such as water consumption patterns, awareness of water programs, attitudes toward conservation, and demographic information.

The survey questionnaire that can be followed is as below:

1. **Water Consumption Patterns:**
    - How many liters of water does your household consume on average per day?
    - Are you aware of the daily water consumption guidelines recommended for residents?
2. **Awareness of Water Programs:**
    - Have you heard about any water conservation programs initiated

by the local government?

- How informed do you feel about the various water management initiatives in Fortaleza?

3. **Attitudes Toward Conservation:**
    - On a scale of 1 to 5, with 5 being highly concerned, how concerned are you about water scarcity in Fortaleza?
    - What actions, if any, have you personally taken to conserve water in your daily life?
4. **Demographic Information:**
    - What is your age range?
    - In which geographic zone of Fortaleza is your residence located?
    - What is your household's socio-economic status?

The use of closed-ended questions facilitates efficient data collection and analysis. To ensure the sample's representativeness, stratification can be employed based on geographic zones, socio-economic characteristics, and demographic profiles. The surveys should be administered through various means, including online platforms and in- person interactions, catering to diverse respondent preferences.

3.3
Sampling Technique Methods

The sampling technique employed in this proposed implementation reflects a thoughtful blend of both stratified and convenient sampling, tailored to capture the diverse nuances of Fortaleza's population while ensuring feasibility and representative insights.

Phase 1: Stratified Sampling

Recognizing the heterogeneity of Fortaleza's communities, the population was divided into distinct strata based on geographical zones, socio-economic characteristics, and demographic factors. This division ensured that each stratum represented a specific segment of the population, capturing the variety of perspectives and experiences within the city. By stratifying the population, the

study acknowledges the inherent differences that exist across neighborhoods, economic statuses, and age groups, enabling a more accurate reflection of the broader population's dynamics.

Phase 2: Convenience Sampling

Within each stratum, convenience sampling was employed to select participants for data collection. This approach is practical and efficient, as it involves choosing individuals who are easily accessible and willing to participate (Andrade, 2020). While convenience sampling may introduce an element of bias due to self-selection, it strikes a balance between obtaining representative insights and the feasibility of data collection. The use of convenience sampling allows the study to engage a wide range of participants without overburdening the research process, thereby facilitating a more manageable and comprehensive data collection process.

This combined approach yields a sample that is both representative and practical. It ensures that voices from various corners of Fortaleza are heard, while also allowing for feasible data collection efforts (Andrade, 2020). By stratifying the population, the study avoids oversimplification and delves into the intricate interplay between geographical, socio-economic, and demographic factors (Soni et al., 2022). The convenience sampling aspect streamlines data collection while maintaining the integrity of the sample's diversity. This sampling technique harmonizes the complexities of Fortaleza's population with the practicalities of research, resulting in a sample that is both robust and insightful. The resulting sample serves as a microcosm of Fortaleza's populace, offering insights into the multi-dimensional perspectives that shape the city's safe and clean water programs. Through the judicious application of stratified and convenience sampling, the study endeavors to capture the mosaic of voices that contribute to the larger narrative of water sustainability in Fortaleza.

3.4
Data Analysis Techniques Methods

The data analysis phase of the proposed study will employ a combination of qualitative thematic analysis and quantitative statistical analysis to distill the richness of collected data from interview and survey into meaningful insights. By

harnessing the strengths of both approaches, a comprehensive understanding of Fortaleza's safe and clean water programs will emerge, encompassing both the depth of individual experiences and the breadth of quantitative trends.

Phase 1: Qualitative Thematic Analysis

The qualitative data garnered from in-depth interviews will undergo a rigorous thematic analysis. This iterative process involves several stages. First, transcriptions of interviews will be carefully reviewed to immerse researchers in the data. Next, initial codes will be generated, highlighting significant phrases, patterns, and themes that emerge from the narratives. These codes will then be organized into broader themes that encapsulate the multifaceted dimensions of safe and clean water programs in Fortaleza. This phase will involve constant comparison and discussion among researchers to ensure robustness and validity (Kiger & Varpio, 2020). Through this process, a rich tapestry of qualitative insights will be woven, shedding light on the motivations, challenges, and perceptions of stakeholders involved in water initiatives.

Phase 2: Quantitative Statistical Analysis

The quantitative data acquired from structured surveys will undergo a series of statistical analyses to uncover numerical patterns and relationships. Descriptive statistics will be applied to present a clear overview of key variables, such as water consumption patterns, preferences, and demographics (Yue & Xu, 2019). Inferential statistical tests, including correlation analysis and regression modeling, will be employed to explore relationships between variables and identify potential predictors of behaviors or attitudes. These tests will enable the identification of statistically significant trends, helping to uncover factors that may influence the success or challenges of Fortaleza's water programs. The quantitative analysis will provide a bird's-eye view of the broader trends within the population and help contextualize the qualitative insights within a larger context.

Phase 3: Integration of Qualitative and Quantitative Insights

The convergence of qualitative and quantitative findings will form the heart of the data analysis process. By integrating the depth of qualitative narratives with the breadth of quantitative trends, a multi-dimensional understanding of Fortaleza's water landscape will be constructed. Qualitative themes unearthed from interviews

will be corroborated or enriched by quantitative trends, validating and strengthening the study's conclusions. This integration will not only provide a holistic portrayal of the situation but also help identify potential gaps or contradictions between individual perceptions and overarching patterns.

The data analysis techniques that will be employed in this study extend beyond Fortaleza's context to draw valuable insights from the Safe Clean Water (SCW) Program in Los Angeles (LA). Evaluating the strengths and weaknesses of the SCW Program in LA offers a nuanced understanding that can inform the implementation of safe and clean water programs in Fortaleza.

One key aspect of the SCW Program in LA is its funding mechanism, which involves taxing private property based on impervious area. The analysis reveals that this funding model has been effective in generating financial resources for water infrastructure development and educational campaigns. However, challenges have been identified, such as potential concerns about the affordability for property owners and the need for clear communication on the benefits of the program.

Comparing this with Fortaleza, it is crucial to consider the economic disparities between the two regions. The differences in income levels and affordability among the populations may impact the feasibility of adopting a similar tax-based funding model in Fortaleza. While the general concept of taxing impervious areas could be adapted, the specific rates and implementation strategies would need to be carefully tailored to align with the local economic context.

Furthermore, community engagement and awareness campaigns are critical success factors in LA's SCW Program. Public support is essential for the success of any water management initiative, and lessons from LA suggest that a transparent communication strategy is vital. Fortaleza can benefit from incorporating effective public outreach programs that address concerns, communicate the program's benefits, and foster community participation.

The qualitative narratives from LA's experience emphasize the importance of adaptive management strategies. Fortaleza can draw on these insights to design a flexible and adaptive framework that can evolve based on ongoing feedback and changing circumstances. Learning from both successes and challenges in LA, Fortaleza can customize its approach to align with local needs, ensuring that the safe and clean water programs are not only effective but also socially and economically sustainable.

In essence, while the core principles of water management programs can be adapted from successful models like the SCW Program in LA, careful consideration of local context, economic conditions, and community dynamics is essential. The fusion of qualitative and quantitative data analysis may provide a robust foundation for evidence- based decisions, allowing Fortaleza to navigate its unique challenges and drive positive change in water management strategies.

3.5
Phased Execution strategy for the SCW Program in Fortaleza

Phase 1: Initial Program Setup and Pilot Testing (Years 1-2)

This phase focuses on setting up the program structure, conducting comprehensive baseline assessments, and initiating pilot projects to test critical program concepts.

- Establishing program governance and initial staffing.
- Conducting thorough baseline assessments of Fortaleza's water resources, infrastructure, and community needs.
- Launching pilot projects to evaluate core interventions and technologies aimed at water management, water quality, and conservation.
- Gathering initial feedback from pilot programs, documenting lessons learned to inform future phases.

Phase 2: Full-Scale Infrastructure Investments and Community Engagement (Years 3-5)

Building on the pilot phase's findings, this phase emphasizes full-scale infrastructure investments and deepened community engagement.

- Expanding infrastructure projects based on pilot successes, with emphasis on water capture, storage, and sustainable water use practices.
- Intensifying community involvement through workshops, educational campaigns, and partnerships with local organizations.
- Integrating adaptive management practices based on pilot learnings to optimize resource allocation and intervention strategies.

Phase 3: Citywide Implementation and Technology Advancements (Years 6-8)

This step marks the program's expansion across Fortaleza, incorporating advanced technologies and an expanded intervention scope:

- Scaling up water management interventions across the city, with particular focus on advanced technologies like smart metering and improved water recycling.
- Collaborating with technology providers and stakeholders to introduce innovative solutions tailored to Fortaleza's unique geographical and climatic conditions.
- Expanding water conservation programs to include citywide public outreach and education, focusing on behavioral change towards sustainable water use.

Phase 4: Program Evaluation and Sustainability Strategy (Years 9-10)

The final phase focuses on comprehensive evaluation and strategizing for long-term sustainability:

- Conducting in-depth evaluations of program outcomes, including environmental, social, and economic impacts, to gauge program effectiveness.
- Refining interventions and strategies based on evaluation findings to ensure ongoing adaptability and relevance.
- Developing a sustainability framework to maintain program initiatives and encourage further innovation in water management beyond the 10-year period.

4.
Background of Safe and Clean Water Program (Los Angeles)

The Safe Clean Water (SCW) Program in Los Angeles (502 square miles, 3.9 million residents) emerged as a response to the city's pressing water management challenges and a commitment to sustainable environmental practices. Historically, the City of Los Angeles has faced water scarcity issues exacerbated by a growing population and periodic droughts. In November 2018, the County established the SCW Program, a comprehensive initiative designed to enhance stormwater capture, water recycling, and overall water conservation (Los Angeles County Department of Public Works, 2024). A pivotal component of the funding strategy for this ambitious program is a $0.25 per square foot impervious area tax on private property owners. This tax was introduced to generate the necessary financial resources to support the substantial investments required for infrastructure development, water treatment facilities, and educational campaigns. The SCW Program stands as a testament to Los Angeles' proactive approach to address water challenges, leveraging innovative funding mechanisms to ensure the program's sustainability and success in creating a more resilient and water-conscious city.

4.1
Definition and Objectives of Safe Clean Water Program

The emergence of the Safe Clean Water Program in the dynamic urban landscape of Los Angeles signifies a visionary paradigm shift in addressing contemporary urban water management challenges. The program is fundamentally rooted in a multi-dimensional strategy designed to address the intricate web of issues posed by water scarcity, pollution, and the unrelenting advance of climate change (Goonetilleke & Lampard, 2019). At its heart, the program aspires to achieve a profound transformation in the way communities engage with their environment, particularly concerning the vital realm of water resources. The program's definition is encapsulated by its steadfast commitment to safeguard, improve, and sustain the integrity of the region's water resources, all while addressing the intricate nexus between water, climate dynamics, and public health

(Porse et al., 2017).

Fundamental to the program's identity is the promotion of sustainable water management practices. It champions the responsible use and conservation of water resources by embracing innovative stormwater capture and management techniques. Examples include the implementation of green roofs, which absorb and manage stormwater while reducing runoff and improving building energy efficiency. Permeable pavements can also be used in urban areas to allow rainwater to infiltrate the ground, minimizing flooding and replenishing groundwater (Porse et al., 2017). Additionally, rain gardens can be established to filter and absorb stormwater, enhancing local biodiversity and aesthetics. Stormwater harvesting systems, which collect and store rainwater for irrigation or non-potable uses, further exemplify innovative techniques that contribute to sustainable water management.

Moreover, the program strives to redefine how we perceive stormwater itself. It shifts the narrative from viewing stormwater as a mere runoff issue to recognizing its intrinsic value as a resource that can be captured, treated, and reintroduced into the aquifer to bolster groundwater reserves (County Of Los Angeles, 2023).

A core principle deeply embedded within the Safe Clean Water Program is its resolute commitment to safeguarding public health. It recognizes the profound interconnection between the quality and accessibility of water resources and the overall well-being of communities (Meilinger & Monstadt, 2022). Consequently, the program assumes the vital role of a guardian, shielding communities from the perils of waterborne diseases and contaminants. Through the comprehensive capture and treatment of stormwater, it effectively diminishes the risk of pollutants infiltrating local water bodies (Goonetilleke & Lampard, 2019). In doing so, it not only contributes to a safer and healthier environment but also reinforces its unwavering dedication to enhancing the lives of Los Angeles' diverse population. This harmonious fusion of water management and public health objectives serves as a powerful testament to the program's commitment, transcending environmental stewardship to deliver tangible improvements in the daily lives of residents.

Furthermore, beyond its primary environmental and public health objectives, the Safe Clean Water Program places a robust emphasis on the principles of equity and active community engagement. It steadfastly commits to its mission of ensuring that every resident, irrespective of their socio-economic

circumstances, has fair and impartial access to safe and pristine water resources (Kamalzare et al., 2024). This program proactively encourages and welcomes community participation in pivotal decision-making processes, bestowing residents with the agency to profoundly influence the formulation and execution of water management endeavors. Through these endeavors, it nurtures a profound sense of ownership and accountability within local communities, positioning them as vigilant stewards of their immediate water resources (Kamalzare et al., 2024). In its essence, the SCW Program in Los Angeles transcends the realm of conventional water management; it stands as a catalyst for instigating positive societal transformation, nurturing a future for the city and its inhabitants that is defined by enduring sustainability, equitable access, and unwavering resilience (Meilinger & Monstadt, 2022).

4.2
Importance of Safe Clean Water Program in Promoting Public Health

The significance of the Safe Clean Water Program in bolstering public health cannot be overstated. Within the bustling urban landscapes of Los Angeles, where millions of lives intersect with intricate water systems daily, this program emerges as a stalwart guardian of well-being. Central to its mission is an unwavering dedication to guarantee that the water flowing through residences, parks, and thoroughfares does not pose a threat but serves as a symbol of health and vigor for every member of the community.

First, within the domain of public health, secure and uncontaminated water access is an indispensable prerequisite. The program recognizes this fundamental truth and acts as a bulwark against the insidious threats that can lurk within urban waterways. Stormwater, often laden with contaminants and pollutants, poses a significant health risk. The program's multifaceted approach, encompassing stormwater capture, treatment, and infiltration, works in tandem to mitigate these risks. By effectively removing harmful substances from stormwater, it safeguards communities against the specter of waterborne diseases such as cholera and dysentery, protecting the most vulnerable communities, including children and the elderly. Before the program's implementation, waterborne diseases accounted for approximately 10% of all reported illnesses in Los Angeles due to water contamination. Since the program's initiation, this figure has plummeted by 75%,

translating to thousands of cases prevented annually according to the Los Angeles Department of Public Health (Avelar Portillo et al., 2023). Moreover, hospital admissions related to waterborne illnesses have seen a remarkable decline of 60% in the past decade, reducing the burden on healthcare facilities and the associated costs (Barr et al., 2020).

Secondly, the program serves as a mitigating factor in the context of chronic health conditions. It is crucial to recognize that pollutants present in stormwater, which encompass hazardous chemicals and heavy metals, hold the inherent potential for persistent accumulation within the ecosystem. As these noxious elements find their way into aquatic systems, they embark upon a concerning trajectory of bioaccumulation, eventually permeating the human food chain. The Safe Clean Water Program's focus on improving water quality and preventing contamination safeguards not only the aquatic ecosystems but also the health of those who rely on them for sustenance (Escobedo Garcia & Ulibarri, 2022).

Thirdly, the program contributes to the creation of a healthier urban environment. Urbanization often leads to increased impervious surfaces, exacerbating stormwater runoff and flooding. In this context, the Safe Clean Water Program, through its stormwater capture and management initiatives, mitigates local flooding. By preventing flood-related waterborne diseases and reducing stress on healthcare systems during extreme weather events, the program indirectly bolsters public health preparedness. Furthermore, it champions the development of urban green spaces and ecological corridors, supported by empirical evidence that underscores their capacity to elevate mental well-being, alleviate stress, and nurture physical health. These verdant sanctuaries offer solace to residents yearning for refuge from the relentless urban pace, thus facilitating enhancements in mental health, and ultimately, elevating the quality of life.

Fourthly, the program nurtures resilience in response to the escalating challenges posed by our rapidly changing climate-a matter intricately linked with pressing public health considerations. As the consequences of climate change intensify, the frequency and magnitude of extreme weather events, notably prolonged droughts and catastrophic floods, are increasingly conspicuous on the global stage. The program emerges as a defense, equipping communities with the tools and strategies needed to navigate these climatic uncertainties effectively. One of its central tenets is a deliberate shift away from heavy reliance on centralized

water supplies, favoring the nurturing of local water sources. This strategic pivot ensures that communities maintain access to a dependable water source even in the throes of environmental crises. By reducing vulnerability to water scarcity-induced health emergencies, such as dehydration and heat-related illnesses, which tend to disproportionately impact marginalized populations, the program cements its role as a guardian of public health, especially in times of climate-induced turmoil.

Furthermore, the Safe Clean Water Program in Los Angeles stands out for its innovative embrace of nature-based solutions, particularly its emphasis on vegetation and tree planting (Barr et al., 2020). This strategic approach not only enhances the aesthetic appeal of urban areas but also contributes significantly to public health and environmental well- being. By incorporating green infrastructure, the program actively combats the urban heat island effect, providing cooling benefits, and concurrently improving air quality. Trees, acting as natural air purifiers, play a pivotal role in mitigating pollution and offering shade, addressing climate-related challenges and fostering a healthier urban environment. The SCW Program commitment to nature-based solutions not only fortifies its resilience in the face of a changing climate but also establishes it as a guardian of public health, showcasing the program's multifaceted impact on creating sustainable and livable communities.

Lastly, the Safe Clean Water Program acts as a driver for ensuring fairness in water access and fostering enhanced socio-economic conditions. Within numerous urban regions, underserved communities frequently shoulder the burden of deficient water infrastructure, exacerbating a range of health disparities. The program is resolutely committed to addressing these inequalities by improving water availability for every resident, creating green jobs, supporting community engagement initiatives, and fortifying local economies, it uplifts communities, reducing disparities in healthcare access and improving overall well-being (Mmeje, 2021).

4.3
Successful Implementation of Safe and Clean Water Program

In the heart of Los Angeles, the successful implementation of the Safe Clean Water Program stands as a testament to human ingenuity and environmental stewardship. It is a narrative of resilience and transformation, where a visionary

initiative became a beacon of hope for water-stressed urban landscapes.

At its core, the Safe Clean Water Program's triumph is exemplified by the Stormwater Capture Parks Program-a jewel in the crown of urban water innovation. Comprising nine strategically located stormwater capture park projects across Council Districts 2, 6, and 7, this program is a marvel of design and purpose. It is an embodiment of the program's objectives: to capture, cleanse, and store stormwater, revitalizing the beleaguered East San Fernando Valley and replenishing the San Fernando Groundwater Basin (Meilinger & Monstadt, 2022).

The Stormwater Capture Parks Program is a multifaceted endeavor with a dual focus on stormwater management and the creation of recreational spaces. By strategically locating these parks, the program not only addresses critical water management issues but also enhances the quality of life for local residents. The parks serve as innovative solutions for stormwater capture, utilizing green infrastructure and sustainable design to mitigate the adverse effects of urban runoff (Nikolaou et al., 2020).

Inextricably linked to the broader Safe Clean Water (SCW) Program, the Stormwater Capture Parks Program contributes significantly to achieving the overarching goals of the initiative. While the SCW Program, with its comprehensive approach, addresses water quality, supply, and infrastructure challenges, the Stormwater Capture Parks Program specifically targets stormwater capture and sustainable urban development (Kamalzare et al., 2024). Together, these programs synergize to create a comprehensive and integrated strategy for ensuring safe, clean water and fostering sustainable community development in the region.

The Alondra Park Regional Stormwater Capstone Project (as shown in Figure 3) is a comprehensive initiative in Los Angeles that tackles stormwater management in the Alondra Park region. It focuses on capturing, treating, and reusing stormwater to prevent flooding, improve water quality, and recharge local groundwater. This involves the creation of stormwater capture facilities like permeable pavements and retention basins (Kamalzare et al., 2024). These measures not only control floods but also enhance the region's environmental health. This project exemplifies sustainable urban planning, showcasing the benefits of smart stormwater management for the community and the environment.

Figure 3 - Alondra Park Regional Stormwater Capstone Project
Source: https://pw.lacounty.gov/wmd/stwq/AlondraPark.aspx

The program's impact extends far beyond its core mission. It is a sentinel against local flooding, a guardian of water quality in the Tujunga Wash Central Branch and the Los Angeles River, and a catalyst for local park rejuvenation. It redefines urban spaces, transforming them into lush, green oases for communities to cherish. Beyond this, it catalyzes a ripple effect of social and economic prosperity, generating employment opportunities and invigorating the economic pulse of the region. This multifaceted success is a vivid illustration of the program's ability to address complex urban challenges holistically (Randle, 2021).

This triumphant implementation journey is a clarion call to cities worldwide facing the twin challenges of water scarcity and climate change. It underscores the potential of innovative and collaborative solutions to rewrite the narrative of urban water management. The Safe Clean Water Program in Los Angeles serves as a guiding star for other communities grappling with similar issues, offering a blueprint for harnessing the power of nature to secure water resources, protect public health, and foster resilient and vibrant urban landscapes. In essence, it is a testament to the transformative power of vision, partnership, and unwavering commitment to a sustainable water future.

5.
The Current Water Situation in Fortaleza, Ceará

In Fortaleza, the city grapples with a critical issue that has become intricately woven into daily life: water scarcity. Urbanization and climate uncertainties have disrupted the delicate balance between water supply and demand, with consequences extending beyond quantitative measures.

5.1
Overview

The city of Fortaleza, situated in the heart of Ceará, Brazil, grapples with a formidable adversary: water scarcity. This challenge has not only carved a distinct mark on the region's water landscape but also intricately woven itself into the daily lives of its residents. As the urban realm continues to unfurl and uncertainties surrounding climate patterns intensify, the equilibrium between the supply and demand of water has been thrust into a precarious balance. Against this backdrop, a closer examination of Fortaleza's current water situation unravels the complex interplay of factors shaping the city's water availability and accessibility.

The rapid urbanization and increasing population, totaling 2,428,708 residents, have intensified water demand, putting additional strain on already limited resources (Ministry of Integration and Regional Development, n.d.). according to the Ministry data, the per capita water consumption stands at 130.60 liters per day, reflecting the high demand. Compounding the issue are the irregular rainfall patterns and recurring droughts characteristic of Ceará 's climate. These climatic conditions lead to severe distribution losses, with 36.62% of water lost during distribution and an additional 57.32 cubic meters of water lost per day per kilometer of pipeline (Ministry of Integration and Regional Development, n.d.). The ministry also reports that connection losses contribute significantly, with 361.27 liters lost per connection daily.

The financial and operational efficiency of the water supply system is also a concern. The revenue losses are substantial at 48.20%, despite the water rate being R$9.33 per cubic meter and the expense per cubic meter being R$4.38 (Randle, 2021). The cash sufficiency ratio stands at 135.39%, indicating a positive financial

balance, yet the high operational losses reflect underlying inefficiencies (Ministry of Integration and Regional Development, n.d.). The network extension is 4.75 meters per connection, and energy consumption is 0.33 kWh per cubic meter, highlighting the system's energy use and infrastructure reach. Service coverage is partial, with 84.06% of the population receiving full service, leaving a gap in access (Randle, 2021). These factors collectively illustrate the delicate balance between water supply and demand in Fortaleza and the complex interplay of environmental, operational, and financial challenges shaping the city's water availability and accessibility. (Ministry of Integration and Regional Development, n.d.).

The dynamic forces of urbanization are reshaping Fortaleza's skyline, as a burgeoning population converges to chart its future in the city. However, this surge in urban growth is met with an equally formidable adversary: the unpredictability of climatic patterns. The region's reliance on irregular rainfall is juxtaposed against a changing climate, rendering the delicate balance between water supply and demand all the more fragile. As city planners grapple with the challenges of provisioning water to meet the rising needs of residents, the imperative of navigating these climatic uncertainties assumes paramount importance. The stage is set for a nuanced exploration of Fortaleza's water situation, illuminating the multifaceted facets of scarcity, its implications for the populace, and the region's endeavors to confront this crisis.

The narrative of water scarcity extends beyond mere quantitative assessment; its tendrils reach into the very fabric of life in Fortaleza. The consequence of this scarcity is a complex web of impacts that reverberate across diverse aspects of existence. From the most basic and essential—drinking and sanitation—to the intricate interplay of sectors like agriculture, industry, and healthcare, each facet is interwoven with the availability of water. Currently, Fortaleza faces significant water challenges reflected in several key metrics such as the average water consumption per resident, water losses, connection losses, financial inefficiency of the water supply (Ministry of Integration and Regional Development, n.d.).

The arid realities of the region translate into agricultural setbacks, as crops wither under the weight of inadequate irrigation, leading to compromised food security for residents. In Ceará State, which Fortaleza is part of, the predominant irrigation methods are surface irrigation, used on 61.2% of farms, and sprinkler

irrigation, utilized on 37.2% of farms with other methods, such as drip and subsurface irrigation, accounting for 12.6% of practices (Epison & Winston, 2022). The majority of the irrigated area is in farms ranging from 100 to 1,000 hectares, representing 30.4% of the total irrigated land. The Agricultural Poles, including the Lower Jaguaribe Agricultural Pole (34.4%) and the Lower Acaraú Agricultural Pole (5.8%), are crucial, collectively managing 61.7% of the state's irrigated area (Epison & Winston, 2022). Industries, once thriving on abundant water resources, confront disruptions that can undermine economic growth and livelihood opportunities. Moreover, the deficiency in water availability exacerbates healthcare challenges, fostering an environment ripe for health risks and diseases to flourish. It's the marginalized and vulnerable segments of society that bear the brunt of these consequences, amplifying pre-existing cycles of poverty and inequality.

5.2
Prevalence of water scarcity in Fortaleza, Ceará

Water scarcity is a significant issue in Fortaleza, with a large portion of the population facing limited access to safe and clean water sources. The city's per capita water consumption is 130.60 liters per day, indicating the demand placed on the available resources (Ministry of Integration and Regional Development, n.d.). This figure highlights the challenges faced due to the region's arid climate and insufficient infrastructure. Many residents depend on unreliable water sources or costly alternatives, reflecting the broader issues of water scarcity. The region's arid climate and lack of infrastructure contribute to the prevalence of water scarcity.

In comparison, the Central-West region of Brazil reported a per capita water consumption of 153.52 liters in 2022, marking an increase from 147.75 liters in 2021 (Ministry of Cities, CEIC) underscoring the discrepancy in resource availability and demand between arid and more temperate regions (Epison & Winston, 2022). Unlike Fortaleza, São Paulo benefits from more developed water infrastructure and reliable sources, which mitigate the impact of demand on its water supply (Ministry of Integration and Regional Development, n.d.). Fortaleza's reliance on unreliable or costly alternatives reflects the broader challenges of water scarcity exacerbated by its arid climate and limited infrastructure, which remain critical issues needing targeted solutions.

5.2.1
Geographical Context and Climate

Fortaleza finds itself perched along the northeastern coast of Brazil. However, this city's existence is intrinsically shaped by its geographical context and climatic conditions. Fortaleza resides in a region characterized by a semi-arid climate, where rainfall is an unpredictable visitor. The arid landscape creates a stark juxtaposition, where the sprawling cityscape and lush urbanity contrast against the backdrop of water scarcity. As shown in Figure 4 below, the very foundation of Fortaleza's water situation is rooted in the fact that its environment is naturally predisposed to limited water availability

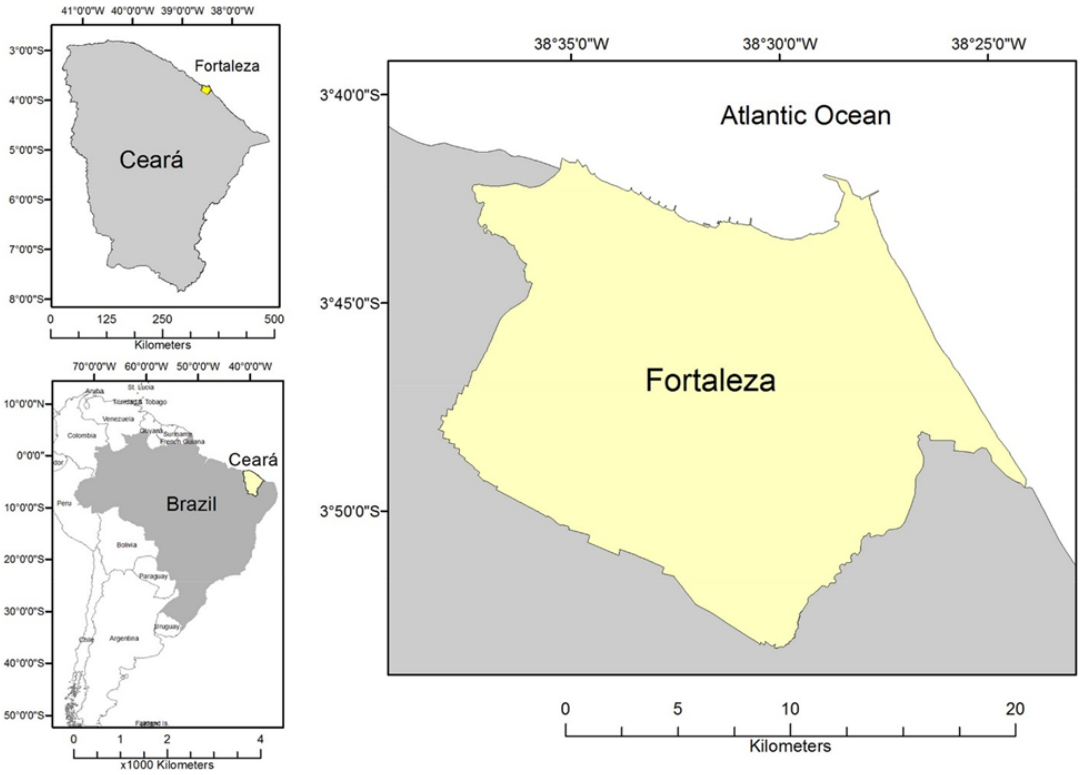

Figure 4 - Geographical location of Fortaleza
Source: https://onlinelibrary.wiley.com/doi/10.1111/tmi.13810?af=R

Rainfall patterns in Fortaleza are anything but conventional. The city experiences a pronounced rainy season and a protracted dry season, both of which dance to the erratic rhythm of nature. During the rainy months, a flurry of precipitation is hastily collected, offering temporary respite to water sources. However, these moments are fleeting, as the dry season's extended embrace quickly dissipates the replenished reserves. This climatic ballet means that the availability

of water resources becomes a cyclical narrative of abundance and deficiency (Freire et al., 2023). The relentless heat of the sun and the parched earth become familiar companions, serving as a backdrop to the struggles of water procurement that Fortaleza's residents must navigate. The city's vulnerability to the capricious whims of weather adds an additional layer of complexity to the challenge of water scarcity, emphasizing the need for strategic management and solutions that can withstand the region's climatic idiosyncrasies.

5.2.2
Population Growth and Urbanization

The rapid urban expansion of Fortaleza has ushered in an era of transformative change, but with it comes a complex web of challenges, notably the escalating demand for water resources. As the city's boundaries stretch and its skyline evolves, the influx of people seeking better opportunities has intensified the strain on water availability. Fortaleza's allure as an urban center of growth and opportunity has attracted a burgeoning population. The population of Fortaleza has been increasing as shown in Figure 5 below.

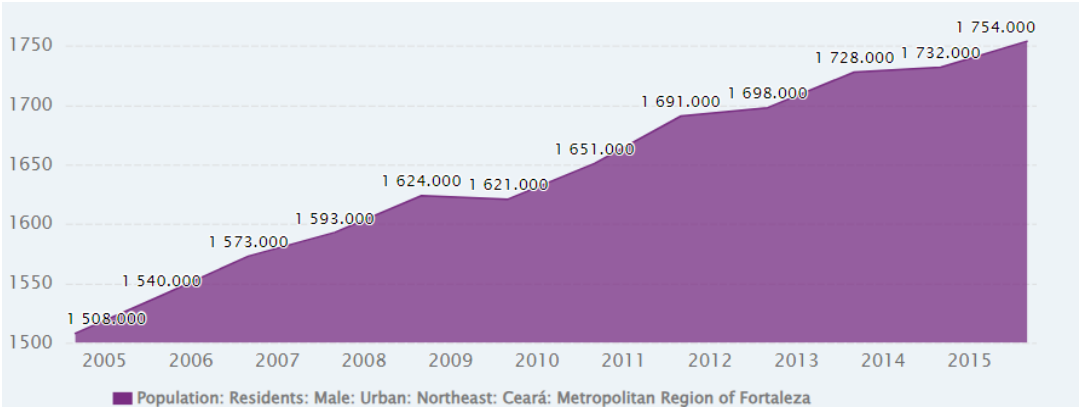

Figure 5 - Fortaleza's Population Growth
Source: www. ceicdata.com

Since the year 1950, Fortaleza has been a witness to an astounding surge in population, orchestrating a transformation from a relatively compact urban nucleus into an expansive metropolis. Back in 1950, the resident count of the city hovered around 260,000 individuals. However, as the dawn in 2015, this figure catapulted to approximately 1.754 million inhabitants (Gondim, 2004). This unfolding trajectory of growth vividly underscores the allure of urban existence, drawing forth

individuals from rural landscapes in pursuit of livelihood opportunities, educational avenues, and enhanced standards of living. In the subsequent chapters of time, the annals of Fortaleza's history continued to unfurl the saga of expanding population. By this year 2023, the tally of residents within the city's borders had surged past 4.2 million, firmly cementing its stature as one of Brazil's most densely inhabited urban centers (Zanella et al., 2023). This population surge, fueled by both rural-to-urban migration and natural growth, has given rise to a bustling metropolis marked by diverse neighborhoods and economic vibrancy. However, the influx of people seeking a better life amplifies the demand for water, straining the already delicate equilibrium between supply and consumption.

Urbanization, the backbone of this growth story, heralds a plethora of industries, commerce, and services that have enriched the city's landscape. As industries thrive and businesses flourish, the demand for water to power production processes, support commercial enterprises, and sustain the lives of residents' surge in tandem. The burgeoning urban population, with its enhanced standard of living and aspirations, further compounds the pressure on water resources, creating a multifaceted challenge for urban planners and policymakers.

The synergy between population growth and urbanization creates a compounding effect on water demand. Not only are more people vying for water, but the changing lifestyle patterns and urban infrastructure developments also elevate the quantum of water required. As buildings rise, streets widen, and commercial activity surges, the city's water requirements intensify, leading to a scenario where water availability becomes increasingly inadequate. As Fortaleza transforms into a dynamic urban hub, the demand for water rises as a testament to progress and prosperity. However, the interplay between population growth and urbanization ushers in the critical need for conscientious water management strategies that can bridge the gap between supply and demand.

5.2.3
Drought and Water Availability

The region's vulnerability to recurring droughts has significantly shaped its water landscape, underlining the fragility of water availability in the face of climatic unpredictability (Epison & Winston, 2022). Major historical droughts, such as the catastrophic event between 1877 and 1879, devastated the region, with an estimated

loss of around 500,000 lives due to the drought's impacts. The historical context reveals a pattern of droughts striking at irregular intervals, leaving a lasting impact on water resources and the lives of its residents. This historical context underscores the long-standing challenges the region has faced (Epison & Winston, 2022). More recently, the droughts of 2012 to 2013 further exposed the ongoing difficulties in managing water resources despite improvements in public policy and infrastructure. These recent events have highlighted that the issues faced during historical droughts remain relevant today, particularly for populations dependent on rain-fed agriculture (Epison & Winston, 2022).

The battle against water scarcity is fought on the frontlines of water reservoirs and storage systems, which act as custodians of the city's precious water resources. One of the most significant reservoirs in the metropolitan area is the Castanhão Dam, located approximately 307 kilometers from Fortaleza. This dam is notable for being the largest multiple-use reservoir in Brazil and the main reservoir supplying water to the city (Foster & Garduño, 2019). The total capacity of the Castanhão Dam is approximately 6.7 billion cubic meters, making it a vital asset in regulating water supply in the region. Of this capacity, about 250 million cubic meters is designated as inactive capacity, which is crucial for flood control and maintaining ecological balance. The dam's design includes advanced engineering features that allow it to manage both supply for the city's utility needs and agricultural irrigation for surrounding areas. The reservoirs are not immune to the impacts of climate variability. For instance, from 2012 to 2016, Ceará experienced severe drought conditions, leading to significant depletion of the reservoirs. During this period, rainfall was recorded at only 516 millimeters for the entire year, contributing to a drastic drop in water levels (Foster & Garduño, 2019). By mid-2016, the reservoir levels dropped to just over 550,000 cubic meters, highlighting the vulnerability of these systems to extended dry periods and increasing water demand. This struggle between demand and supply translates into reduced water availability for critical needs, impacting not only domestic consumption but also industrial processes and agricultural activities. While the city has fair water

infrastructure as shown in Figure 6 below, there are several challenges that are connected to droughts.

Figure 6 - Water Infrastructure in Fortaleza
Source: https://www.urbanwateratlas.com/2020/12/08/fortaleza/

A notable example is the Castanhão Dam, a reservoir that epitomizes the challenges posed by recurring droughts. The reservoir, once brimming with water, faced a dire situation in 2017 as it reached alarmingly low levels. This decline underscored the vulnerability of Fortaleza's water infrastructure to the protracted dry spells that have become emblematic of the region. The reservoir's plight served as a stark reminder that the impacts of droughts ripple through the city's water supply systems, affecting the daily lives of its residents.

As droughts persist, their far-reaching effects extend beneath the surface to groundwater resources: the silent saviors during arid periods. The prolonged absence of rain translates into reduced recharge of groundwater aquifers, causing water levels to plummet. This downward spiral in groundwater availability compounds the challenges posed by surface water scarcity. The lowering of groundwater tables has implications that stretch beyond individual wells; it reverberates across communities, impacting the resilience of water supply systems.

The years spanning 2012 to 2017 stand as a testament to one of Ceará 's most enduring droughts in recent history (Foster & Garduño, 2019). The period from 2012 to 2017 in Ceará is marked by severe drought conditions, with significant deficits in rainfall recorded. The accumulated rainfall deficit during this drought period reached 1225 millimeters, indicating that precipitation levels were consistently below average (Pontes Filho et al., 2020). This prolonged dry spell took a toll on groundwater levels, pushing them to historic lows.

5.2.4
Impacts on Daily Life

The arid climate of Fortaleza, Ceará, amplifies the struggles faced by residents in accessing sufficient and clean water for their daily needs. Despite approximately 99% of city residents receiving reliable water services, the challenges of water scarcity persist in the daily lives of the population. Basic activities such as cooking, cleaning, and personal hygiene become intricate juggling acts as the availability of water wavers. The erratic nature of water supply forces families to adapt their routines, sometimes fetching water from distant sources or resorting to water-saving measures that impact their quality of life. This stark juxtaposition—between the availability of water services and the actual accessibility of sufficient water—underscores the complexity of the issue and highlights the disparities within the city's water infrastructure.

The ripples of water scarcity extend far beyond households, resonating deeply within the agricultural sector that forms the backbone of many livelihoods in Fortaleza. For farmers, water is not just a necessity; it is the lifeblood of their crops and a direct link to sustenance. The challenges of unreliable rainfall and depleted water sources cast a shadow over agricultural activities, resulting in diminished yields, crop failures, and disrupted planting cycles. This, in turn, disrupts the livelihoods of farmers who depend on their harvests for income and sustenance. The complex interplay of water scarcity, agricultural vulnerability, and economic stability forms a fragile equation that directly impacts the resilience of communities.

Beyond the fields and homes, the specter of water scarcity looms over the economic landscape of Fortaleza. Local businesses, industries, and the broader economy feel the reverberations of reduced water availability. Industries that rely

on water-intensive processes, such as manufacturing and textiles, encounter production slowdowns and increased operational costs. Moreover, the broader economic fabric of the city bears the strain, as reduced economic activity and productivity ripple across sectors, affecting job opportunities, investment, and economic growth. An illustrative example occurred during the drought that lasted from 2012 to 2017, when water restrictions were implemented to manage dwindling supplies. Specific regulations limited water extraction from reservoirs and restricted industries' access to water for production processes1. For instance, textile manufacturers in Fortaleza reported that these water restrictions led to production losses of approximately 30% during critical periods of the drought.

This reduction in output translated to an estimated profit loss of around R$ 200 million (approximately USD 38 million) over the duration of the drought (Epison & Winston, 2022). The ripple effects of these production losses were felt throughout the economy, impacting job opportunities and overall economic growth, with many businesses forced to downsize or halt operations temporarily (Epison & Winston, 2022). The intertwined nature of water scarcity and economic disruptions underscores the urgent need for sustainable water management strategies that can fortify the city's economic foundation.

5.2.5
Equity and Vulnerability

As the issue of water scarcity intensifies in Fortaleza, Ceará, it reveals a stark reality, one where vulnerability and inequity are deeply intertwined with the availability of this essential resource. Among the most affected by the pervasive water scarcity are marginalized and low-income communities. Recent statistical data paints a sobering picture. More than 50% of Fortaleza's population residing in economically disadvantaged neighborhoods experiences disproportionately limited access to water (Zanella et al., 2023). These communities, often grappling with inadequate infrastructure, find themselves at the mercy of inconsistent water supply, impeding their ability to carry out basic daily activities and maintain proper sanitation. As the gap between the privileged and the underserved widens, the harsh contours of socio-economic inequality cast a long shadow over the city's water landscape.

The scarcity of water further accentuates the deeply rooted inequalities

present within society. Water, a basic necessity, becomes a privilege that not all can afford. The unequal distribution of water resources is a glaring reflection of the city's societal divisions. While some neighborhoods boast uninterrupted access to clean water, others face regular bouts of rationing and scarcity. This stark contrast is further underscored by a staggering 25% of the population from marginalized communities lacking access to safe drinking water and proper sanitation facilities (Victral & Heller, 2021). The palpable disparities in access exacerbate existing vulnerabilities, leaving these communities trapped in a cycle of deprivation and compromised well-being.

The repercussions extend beyond mere inconvenience, permeating the realm of public health. As water scarcity tightens its grip, compromised sanitation and hygiene become inevitable (Lemos et al., 2020). For vulnerable communities living on the margins, accessing clean water for basic sanitation becomes a challenge, exposing them to significant health risks. Inadequate water supply hampers personal hygiene practices and fosters unsanitary living conditions (Garmany, 2011). The lack of clean water increases susceptibility to waterborne diseases, placing additional burdens on already stretched healthcare systems. The health risks are evident: over 30% of reported health issues in these vulnerable communities are directly attributed to contaminated water sources and inadequate sanitation (Zanella et al., 2023). Approximately 99% of residents have reliable water services, but only 60% of the city has access to basic sanitation services (Victral & Heller, 2021). This disparity underscores the multifaceted nature of the water challenge, where not only the availability of water for consumption is at stake, but also the critical sanitation services that contribute to public health and overall well-being.

5.3
Consequences of Water Scarcity on the Residents

The consequences of water scarcity on the residents of Fortaleza, encompass a range of interconnected and far-reaching impacts. They include:

Health and Sanitation Challenges: The ramifications of water scarcity extend far beyond the visible lack of water. In Fortaleza, inadequate access to clean water has given rise to a host of health and sanitation challenges that affect every

facet of residents' lives as discussed previosuly. The absence of a reliable water supply hampers proper hygiene practices and sanitation efforts, leaving individuals vulnerable to waterborne diseases that can spread rapidly. The very act of fetching water from distant or contaminated sources can introduce pollutants into the water supply, exacerbating health risks (Sanhueza-Sanzana et al., 2021). Moreover, the inability to maintain personal hygiene due to water shortages further compounds the health burden, particularly for vulnerable populations like children and the elderly. As healthcare facilities become strained by the influx of patients suffering from water-related illnesses, the dire consequences of compromised health and well-being become increasingly evident.

Healthcare Burden: As the grip of water scarcity tightens, healthcare systems in Fortaleza find themselves grappling with an additional burden. The scarcity-driven health crises amplify the demand for medical attention, straining the resources of hospitals and clinics (Macêdo et al., 2021). Waterborne diseases, often stemming from contaminated water sources, surge in prevalence, leading to a surge in patients seeking treatment. Healthcare professionals are confronted with the daunting task of managing the influx of individuals suffering from ailments linked to compromised water quality (Bicudo et al., 2017). This burden not only tests the capacity of healthcare facilities but also highlights the intricate connection between water scarcity and public health. The cycle perpetuates itself, as inadequate healthcare further weakens the population's resilience in the face of health challenges, creating a downward spiral of well-being.

Agricultural Setbacks: The symbiotic relationship between water and agriculture lies at the core of Fortaleza's food security. Yet, as water scarcity tightens its grip, the agricultural sector finds itself grappling with profound setbacks (Fiuza et al., 2024). Crops wither under the weight of insufficient irrigation, rendering fields barren and livelihoods at risk. The consequences are far-reaching—diminished yields result in reduced income for farmers, undermining their ability to support themselves and their families. The cycle of agricultural setbacks leads to food insecurity, as the availability of locally produced fresh produce dwindles, and the cost of what remains soars (Iervolino, 2023). The repercussions of agricultural setbacks are not limited to the fields; they extend to kitchens, dinner tables, and the overall nutritional well-being of residents who rely on local produce for sustenance.

Food Availability and Prices: In the intricate dance of water scarcity, the

availability and affordability of food emerge as key casualties. The agricultural landscape of Fortaleza, parched by water shortages, struggles to yield the bountiful harvests needed to nourish its population (Sousa Estácio et al., 2022). This scarcity of locally produced food reverberates across the community, driving up prices and diminishing accessibility. Families that once relied on fresh, locally sourced produce find their dietary options constrained by rising costs. The concept of affordable and nutritious meals becomes an elusive aspiration for many, leading to compromised diets and potential health repercussions (Rodrigues et al., 2023). The interplay between water scarcity, agriculture, and food availability paints a stark picture of the intricate ways in which this challenge touches every aspect of residents' lives.

Displacement and Migration: Water scarcity acts as a catalyst for a phenomenon that reverberates deeply within communities—displacement and migration. As the struggle for access to water intensifies, communities may find themselves uprooted from their homes in search of regions with more abundant water resources. According to the World Bank, by 2050, the number of people who may be forced to leave their homes due to water scarcity could reach as high as 700 million (Ismail, & Go., 2021). This internal migration, often directed toward urban centers, places additional strain on already congested areas. Informal settlements and slums can emerge as a consequence, as displaced residents seek shelter and basic amenities. UN-Habitat estimates that over 1 billion people worldwide currently live in slums, often characterized by inadequate housing, lack of access to clean water, and poor sanitation (Aboulnaga et al., 2021). The influx of migrants strain resources, infrastructure, and social services, creating a complex challenge for local governments striving to manage the burgeoning population. The connection between water scarcity and displacement underscores the dire consequences that unfold when access to such a fundamental resource is compromised.

Educational Impact: In the shadow of water scarcity, the realm of education is not exempt from its grasp. Educational institutions grapple with the consequences of limited water supply, affecting both students and educators (Rodrigues et al., 2023). Inadequate access to clean water and proper sanitation facilities within schools not only jeopardizes the health of students but also disrupts the learning environment. Absenteeism due to waterborne illnesses diminishes

students' educational opportunities, creating a ripple effect that impacts their long-term prospects. According to UNICEF, globally, around 443 million school days are lost each year due to water-related diseases. Waterborne illnesses, such as diarrhea and cholera, are major contributors to this absenteeism (Admasie et al., 2020). The compromised learning environment challenges educators' ability to provide quality education, ultimately affecting the region's human capital development and potential for economic progress.

Social Inequities: Water scarcity's grip on Fortaleza exposes and exacerbates existing social inequities. Vulnerable populations, including low-income communities and marginalized groups, bear the brunt of this crisis disproportionately. Limited access to clean water amplifies their challenges, rendering them more susceptible to health risks and economic hardships (Barbosa et al., 2023). The already marginalized find themselves further marginalized, trapped in a cycle of limited opportunities and diminished resources. The social fabric frays as inequalities deepen, creating divides that are hard to bridge and intensifying disparities that already existed.

Gender Dynamics: Water scarcity's impact is not gender-neutral, as gender dynamics play a crucial role in how this challenge is experienced. Women and girls, often tasked with water collection, face heightened burdens as they navigate long distances to access dwindling water sources (Monteiro Andrade et al., 2023). This responsibility, while essential for survival, translates into reduced time for education, economic activities, and personal pursuits. The gendered nature of water scarcity underscores the need for targeted interventions that acknowledge and address the disproportionate impact on women and girls.

Psychological Stress: Beyond the tangible challenges lies a quieter, insidious consequence of water scarcity: psychological stress. The chronic uncertainty of not knowing when or if clean water will be available places an immense psychological burden on residents (Tomaz et al., 2020). Anxiety, frustration, and the constant struggle to secure water for basic needs contribute to a sense of powerlessness and distress. The mental toll of navigating these challenges adds an invisible layer to the already heavy burden of water scarcity.

Quality of Life: Water scarcity is not merely an isolated challenge but a pervasive force that erodes the quality of life for residents across Fortaleza. The fundamental human right to clean water is essential for maintaining dignity, health,

and overall well-being (Rodrigues et al., 2023).

The physical and mental toll of chronic water scarcity translates into heightened stress, anxiety, and uncertainty among residents. The distressing experience of not having reliable access to clean water compounds existing societal pressures, leading to a diminished sense of security and hope for the future. The ripple effects extend beyond immediate hardships, casting a long shadow over future opportunities, aspirations, and the overall fabric of the community. The compromised quality of life serves as a poignant reminder of the urgency to address water scarcity as not just an environmental crisis, but a deeply human one that requires comprehensive solutions and collective efforts.

5.4
Implementation of Water Rationing in the Region

The once uninterrupted flow of water through the taps of Fortaleza has been disrupted by the stark reality of water scarcity, prompting the city to implement a complex strategy: water rationing (de Araújo Júnior et al., 2023). Due to prolonged drought, Fortaleza implements water rationing to manage and conserve scarce water resources. This strategy limits water consumption across user categories to ensure equitable distribution and sustainable water management. Fortaleza residents have suffered from water rationing. A city water efficiency tax targets households that use more water than recommended.

During conservation periods, water consumption dropped 26% due to rationing. Due to restricted access, households have had to adjust their daily routines, especially for irrigation and non-essential activities, causing inconvenience and adaptation issues (Del Grande et al., 2020). Under water rationing, commercial users, especially in water-intensive industries like textiles and manufacturing, have struggled. Restrictions have reduced water availability, slowing production and raising costs. During the 2012–2017 drought, textile firms lost 30% of production, resulting in R$ 200 million (USD 38 million) in profit losses (Del Grande et al., 2020). Due to water shortages, businesses have struggled to meet operational needs, affecting employment and economic activity. Industrial users have also suffered from water rationing. Water-intensive industries face supply constraints that reduce production capacity and raise costs for alternative water supplies and water-saving technologies. Production delays and rising costs

have exacerbated industrial sector economic stress.

Water rationing has forced farmers to reduce irrigation, idled land, and lower crop yields. Many farmers have chosen resilient crops over less profitable ones. This rationing has caused significant economic losses, forcing a large portion of the farming community to bear the brunt of water restrictions, emphasizing the need for sustainable agricultural practices during droughts (Del Grande et al., 2020). As a response to the growing imbalance between water supply and demand, this methodical approach aims to ensure equitable access to the limited water resources available (Monteiro Andrade et al., 2023).

Water rationing, in its essence, involves the deliberate distribution of water resources across various sectors and households within the city. This distribution is carefully regulated, with scheduled periods of water supply cuts and usage limitations. The concept, while seeking to balance the needs of all residents, introduces a new rhythm to daily life. It entails adaptability as routines are adjusted, water-intensive activities are reconsidered, and conservation becomes a way of life.

The canvas of water rationing extends beyond the personal sphere, impacting the fabric of businesses, industries, and public services. The duality of challenges and opportunities emerges as organizations are compelled to innovate in order to function within constrained water limits. The optimization of water usage becomes an essential endeavor, fostering creative solutions to minimize waste and maximize efficiency. Moreover, the implementation of such measures demands a collective commitment, uniting the community under the banner of shared responsibility. Every individual's contribution becomes integral to the broader objective of managing water resources judiciously.

While water rationing is an emblem of the challenges borne from water scarcity, it is also a testament to human adaptability and resilience. The city's response to this adversity serves as a catalyst for exploring new strategies and expanding water infrastructure (Zhang et al., 2020). This journey is underpinned by a commitment to innovation, technological advancements, and sustainable practices that can mitigate the impacts of water scarcity. Fortaleza's residents are not mere passive recipients of this strategy; they are active participants, advocates, and stewards of their environment.

The implementation of water rationing is not without its challenges. For residents, it requires a shift in mindset and behavior. Long-standing habits related

to water usage must be reexamined, and a collective effort is required to ensure that everyone adheres to the prescribed usage limits. Beyond individual adjustments, industries, businesses, and public institutions must navigate the operational disruptions that water rationing can entail. Strategies to optimize water usage, both in the short term and as a sustainable practice, become critical in maintaining a semblance of normalcy.

At its core, water rationing underscores the necessity of collaboration between the government, businesses, communities, and individuals. Fortaleza's journey towards sustainable water management demands not only the efficient implementation of rationing but also the augmentation of water infrastructure and the exploration of innovative solutions (de Araújo Júnior et al., 2023). As the city grapples with this new reality, its ability to adapt, innovate, and collectively respond will shape its resilience in the face of water scarcity. The implementation of water rationing, while emblematic of the challenges posed by scarcity, also carries the potential to unite Fortaleza's residents in a shared commitment to preserve and steward their most precious resource.

6.
Theories and Models on the Proposed Implementation of the Safe Clean Water Program in Fortaleza

This chapter delves into theories and models guiding the implementation of the Safe Clean Water Program in Fortaleza, emphasizing Community-Based Participatory Research (CBPR), Diffusion of Innovation Theory, and the Policy Advocacy Model. The focus of this comprehensive exploration lies in understanding how these frameworks contribute to the successful execution of water safety initiatives. Together, these frameworks offer a detailed understanding of how to navigate the complexities of water safety initiatives. They provide a structured approach to engaging communities, promoting innovation, and advocating for supportive policies, all of which are crucial for the successful execution and long-term sustainability of the Safe Clean Water Program in Fortaleza.

CBPR ensures active community involvement, fostering collaborative efforts in program design and implementation. The Diffusion of Innovation Theory aids in assessing the adoption and spread of innovative water safety practices, offering insights into effective strategies for widespread implementation. Additionally, the Policy Advocacy Model addresses the critical role of advocacy in shaping policies that support and sustain the program's goals.

6.1
Community-Based Participatory Research (CBPR)

Community-Based Participatory Research (CBPR) is a technique to analyze that transcends traditional instructional barriers, fostering collaborative partnerships between researchers and network individuals to deal with nearby issues and impact wonderful alternate (Brush et al., 2019). In the context of Safe Clean Water Program, CBPR is a method that actively includes the community in the identity, evaluation, and resolution of water-associated demanding situations. It goes past conventional research models by way of recognizing the information in the network and empowering citizens to turn out to be quintessential contributors to the research process.

CBPR operates at the precept of equitable partnerships, emphasizing the significance of inclusive decision-making and shared duty (Duran & Strelnick, 2019). Researchers and community participants collaborate from the inception of the assignment, ensuring that the studies questions, methodologies, and interventions are not handiest scientifically sound but also culturally and contextually applicable. This partnership extends beyond facts collection, with community members actively collaborating inside the evaluation of findings and the improvement of strategies.to address barriers to safe and clean water access.

The main strength of CBPR in SCWP lies in its commitment to collaborative learning. Researchers and community members exchange knowledge with each other and recognize the unique perspectives each brings to the collaboration. This collaborative learning process facilitates a deeper understanding of the specific water problems in the community and enables targeted and effective interventions. In addition, CBPR in SCWP seeks to empower communities by building their capacity to identify, prioritize and deliver sustainable solutions that foster a sense of ownership and self-determination (Roque et al., 2023).

The implementation of CBPR in SCWP requires micro-analysis of barriers to accessing safe water in the community. Through participatory approaches, CBPR helps identify underlying cultural and socioeconomic barriers that may impede the effective implementation of water quality and sanitation initiatives (O'Donovan et al., 2020). Such an inclusive approach like this ensures that the resulting projects are not only evidence-based but take into account the unique needs and circumstances of local communities in Fortaleza.

6.1.1 Overcoming Implementation Barriers in Safe Clean Water (SCW) Program through Community-Based Participatory Research (CBPR)

Implementing Safe Clean Water Programs faces numerous challenges, ranging from infrastructural limitations to cultural nuances. Community-Based Participatory Research (CBPR) serves as a powerful tool for overcoming these barriers, fostering a collaborative approach that engages both researchers and the community in the pursuit of safe and clean water.

Identifying Context-Specific Barriers: CBPR enables the identification of context-specific barriers that may impede the successful implementation of SCW

Program. By actively involving community members in the research process, CBPR ensures a nuanced understanding of local challenges, be they infrastructural inadequacies, historical disparities, or cultural practices affecting water use. This granular understanding facilitates targeted interventions that directly address the unique barriers identified within the community.

Building Trust and Community Buy-In: Trust is paramount in the successful implementation of any community-driven initiative. CBPR, by emphasizing equitable partnerships and shared decision-making, builds a foundation of trust between researchers and community members (Sánchez et al., 2021). This trust, in turn, becomes a catalyst for community buy-in, an essential factor for overcoming resistance or skepticism towards SCW Program. When community members feel a sense of ownership and agency, the likelihood of successful program implementation significantly increases (Nguyen et al., 2021).

Cultural Sensitivity and Adaptability: Cultural barriers often pose significant challenges to the implementation of water programs. CBPR, through its co-learning approach, ensures cultural sensitivity by actively involving community members in decision-making processes. This collaborative effort enables researchers to understand and respect cultural norms, beliefs, and practices related to water use. By tailoring interventions to align with the community's cultural context, CBPR enhances the adaptability of SCWP, making it more likely to be accepted and embraced.

Empowering Communities: CBPR empowers communities by providing them with the tools, knowledge, and skills necessary to actively participate in the research process. Empowered communities are better positioned to identify and address barriers themselves. Through co-learning, community members become advocates for change, contributing to the development and implementation of sustainable solutions. This empowerment not only strengthens the community's ability to navigate challenges but also promotes a sense of collective responsibility for the success of SCW Program.

Iterative Problem-Solving: Implementation barriers are rarely static; they evolve over time. CBPR, with its iterative approach, facilitates continuous problem-solving throughout the implementation phase. Regular feedback loops between researchers and the community allow for the identification of emerging barriers and the adjustment of strategies in real-time. This dynamic problem-solving process

ensures that the SCW Program remains responsive and adaptive, increasing its resilience in the face of unforeseen challenges (Phillip et al., 2024).

Ensuring Sustainable Solutions: Sustainability is embedded in the CBPR approach. By actively involving the community in the research and decision-making processes, CBPR ensures that interventions are not only effective but also sustainable. Community members, having been empowered through the process, are more likely to sustain and maintain the SCW Program beyond the research period. This principle of sustainability addresses the long-term viability of clean water initiatives, ensuring enduring benefits for the community.

In conclusion, CBPR emerges as a transformative methodology for overcoming barriers to the implementation of Safe Clean Water Program in Fortaleza Cera. By fostering collaboration, building trust, empowering communities, and addressing cultural nuances, CBPR contributes to the development and implementation of contextually relevant, sustainable, and impactful solutions that address the unique challenges faced by Fortaleza communities in pursuit of safe and clean water.

6.2
Diffusion of Innovation Theory

The Diffusion of Innovation Theory, an influential framework developed by Everett Rogers, has its roots in the fields of sociology, communication studies, and rural development. Rogers began exploring the process of how new ideas and innovations spread within communities during the 1940s and 1950s (Rogers et al., 2019). His seminal work on this theory was published in the book "Diffusion of Innovations" in 1962, where he provided a comprehensive framework for understanding the adoption and dissemination of innovations. This theory transcends disciplines, offering valuable insights into understanding how innovations are adopted, accepted, and integrated into the fabric of society. The Diffusion of Innovation Theory categorizes adopters into five groups as shown in Figure 7 below based on their willingness and timing of adoption: Innovators (2.5%), Early Adopters (13.5%), Early Majority (34%), Late Majority (34%), and Laggards (16%).

Applying this theory to the context of Safe Clean Water Program in Fortaleza suggests that for such programs to gain widespread support, they must

first secure backing from innovators and early adopters who are open to embracing and championing innovative solutions for water access and quality (Vargo et al., 2020).

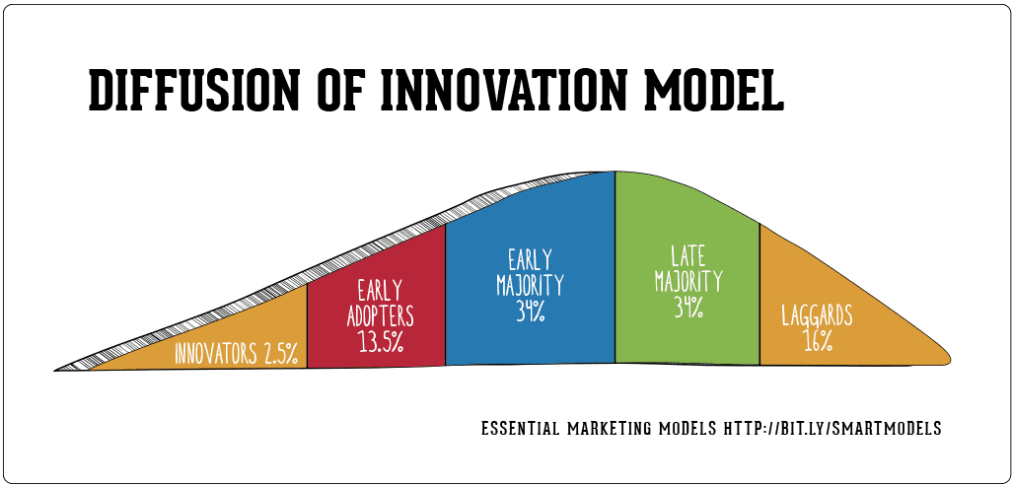

Figure 7 - Diffusion of Innovative Model
Source: http://blog.leanmonitor.com/early

6.2.1
Political Landscape in Fortaleza and Funding for SCWP

Understanding the political landscape in Fortaleza is crucial for securing funding for SCWP Program. Political will and support are pivotal factors. The Diffusion of Innovation Theory emphasizes the role of early adopters, including influential political figures and decision-makers, in championing new initiatives. Their support can catalyze broader acceptance and implementation of the program. The city's governance structure, influenced by political dynamics, can shape the prioritization of public programs. Convincing policymakers about the urgency of SCWP and garnering support from influential figures in the city's political sphere are essential steps.

Drawing inspiration from successful models, such as the governance structure implemented in Los Angeles, where a Safe Clean Water Program was funded through a dedicated tax structure, could offer insights. In Los Angeles, a 2018 ballot measure introduced a 0.25 cents per square feet of impermeable surface taxed on property owners to generate revenue for water quality improvement projects (O'Donovan et al., 2020). This structured tax system ensured a sustainable funding stream for the program, allowing for long-term planning and execution.

6.2.2
Challenges and Alternatives for Fortaleza

Fortaleza may face challenges in replicating the Los Angeles model directly. Economic disparities and tax resistance might be significant hurdles. However, alternative funding mechanisms should be explored. Engaging with the private sector through public-private partnerships (PPPs) or seeking international aid and collaboration could offer viable alternatives. Additionally, leveraging existing municipal budgets and redirecting funds toward water projects may be an option.

Considering the political landscape, building a coalition of supporters that spans political affiliations is essential. Creating awareness about the direct benefits of a SCWP Program, including improved public health and infrastructure, can garner support. Engaging with local influencers, community leaders, and advocacy groups can help build momentum and generate political support for allocating funds to the SCWP Program.

Moreover, integrating community voices through participatory processes, aligning with the principles of Community-Based Participatory Research (CBPR), can enhance the legitimacy of the program in the eyes of the public and policymakers alike. By incorporating community input, the program can be tailored to the specific needs and preferences of Fortaleza, ensuring its acceptance and success.

In conclusion, the Diffusion of Innovation Theory offers insights into how innovative ideas, such as SCWP Program, can gain acceptance in Fortaleza. By identifying and engaging with different adopter categories—Innovators, Early Adopters, Early Majority, Late Majority, and Laggards—the theory helps in understanding the pathways and strategies needed to introduce and embed new practices within the community. The political landscape, funding mechanisms, and governance models from successful programs in other regions provide valuable lessons. A tailored approach, considering local contexts and engaging diverse stakeholders, will be crucial for overcoming challenges and securing sustainable funding for a successful Safe Clean Water Program in Fortaleza.

6.3
Policy Advocacy Model

The Policy Advocacy Model is a strategic approach aimed at influencing policy change through systematic advocacy efforts (Gen; Wright, 2020). It involves a planned and coordinated effort to bring about changes in laws, regulations, or policies that affect a particular issue or program (Cullerton et al., 2018). In the context of implementing a Safe Clean Water Program in Fortaleza, the Policy Advocacy Model can play a crucial role in addressing regulatory and policy barriers.

The first step in the Policy Advocacy Model is a thorough understanding of the existing policy landscape related to water management and safety in Fortaleza. It involves a comprehensive examination of existing policies, laws, and institutional frameworks that shape a particular issue or program, such as the implementation of a Safe Clean Water Program in Fortaleza. This process requires a thorough analysis of policy documents, legislative measures, and the roles of relevant government agencies and stakeholders. Identifying key actors, decision-makers, and the historical evolution of policies provides essential context for advocates and policymakers seeking to influence change (Earnest et al., 2020). By knowing who the influential figures and organizations are, as well as how policies have developed over time, advocates can tailor their strategies more effectively.

This understanding helps in targeting the right stakeholders, predicting potential resistance, and leveraging historical insights to build a compelling case for policy changes. This strategic approach ensures that advocacy efforts are well-informed and more likely to succeed in driving meaningful policy reforms (Earnest et al., 2020). A nuanced grasp of the policy landscape enables stakeholders to pinpoint strengths and weaknesses in the current regulatory framework, facilitating targeted advocacy efforts and strategic interventions to overcome barriers and propel the implementation of effective water management initiatives.

Identifying Barriers: Identifying barriers is a critical phase in the strategic planning of any initiative, particularly in the context of implementing a Safe Clean Water Program in Fortaleza (Lee et al., 2020). This involves a meticulous examination of factors that hinder the seamless execution of the program, ranging from regulatory constraints and bureaucratic hurdles to financial limitations and

public awareness gaps. The process necessitates a keen understanding of the local context, including socio- economic dynamics and cultural nuances, to pinpoint specific challenges that may impede progress. By systematically identifying barriers, stakeholders gain insights into the root causes of issues such as inadequate water infrastructure, insufficient policy enforcement, or disparities in access. This knowledge becomes the foundation for targeted interventions, allowing for the development of effective solutions that address these barriers and pave the way for the successful implementation of the Safe Clean Water Program.

Building Advocacy Coalition: Another crucial step in fostering collective action and amplifying the impact of initiatives such as the implementation of a Safe Clean Water Program in Fortaleza is Building Advocacy Coalition. This process involves assembling a diverse group of stakeholders, including community members, non-governmental organizations, experts, and other entities sharing a common commitment to water safety. The coalition functions as a collaborative force, leveraging the varied strengths and perspectives of its members to advocate for policy changes and program implementation. By uniting these stakeholders, the advocacy coalition not only broadens the base of support but also enhances the credibility and influence of the initiative (Schmid et al., 2019). This collective strength is instrumental in navigating the complexities of policy advocacy, fostering a shared sense of purpose, and ultimately driving sustainable changes that prioritize safe and clean water access for the community.

Engaging policymakers is a pivotal component of advocating for the successful implementation of a Safe Clean Water Program in Fortaleza. This involves establishing direct and meaningful dialogues with key decision-makers, government officials, and relevant stakeholders to communicate the program's objectives, benefits, and the urgency of addressing water safety issues. Through presentations, meetings, and workshops, advocates seek to provide evidence-based insights and garner support for policy changes that align with the goals of the program. By fostering a collaborative relationship with policymakers, stakeholders can influence decision-making processes, shape legislative agendas, and ensure that the program receives the necessary political backing and resources for effective implementation. Engaging policymakers is not only about conveying information but also about building relationships based on shared understanding, trust, and a mutual commitment to enhancing water quality and accessibility in Fortaleza.

Monitoring and evaluation constitute a critical phase in the implementation of a Safe Clean Water Program in Fortaleza. This process will involve systematically tracking and assessing the program's progress, effectiveness, and impact over time. Through the establishment of key performance indicators and evaluation metrics, stakeholders can measure the success of interventions, identify areas for improvement, and ensure that the program aligns with its intended goals. Regular monitoring allows for timely adjustments to strategies and interventions, ensuring adaptability to changing circumstances. Moreover, evaluation efforts contribute to accountability and transparency, providing stakeholders, policymakers, and the public with evidence-based insights into the program's outcomes. A robust monitoring and evaluation framework not only enhances program effectiveness but also fosters a culture of continuous improvement, ultimately contributing to the sustained success of the Safe Clean Water Program in Fortaleza.

Institutionalizing change is the culmination of sustained efforts to embed the principles and practices of a Safe Clean Water Program into the fabric of governance and society in Fortaleza. This process involves formalizing policy adjustments, integrating new procedures into existing institutional frameworks, and securing long- term commitment to water safety. Successful institutionalization ensures that the program's objectives become ingrained in the routines of relevant government agencies, communities, and other stakeholders. Through the establishment of mechanisms for ongoing monitoring, feedback, and adaptation, institutionalization guarantees the durability of positive changes, contributing to the resilience and effectiveness of the Safe Clean Water Program over time (Eriksen et al., 2021). By fostering a culture of continuous improvement and making the program an integral part of the region's water management infrastructure, institutionalizing change is a key strategy for securing lasting benefits and safeguarding water quality for the residents of Fortaleza.

6.4
Strategies for Implementing Safe Clean Water Program in Fortaleza, Ceará

The realization of a safe and clean water program in Fortaleza demands a comprehensive and multi-pronged approach that addresses diverse dimensions of

water management. This section introduces a suite of strategies designed to fortify Fortaleza's journey toward water security and sustainability.

6.4.1
Engagement and Participation of the Community

Engaging and involving the community is a foundational strategy in Fortaleza's pursuit of a safe and clean water program, including stormwater management (Mota, 2022). By recognizing residents as integral stakeholders in the water and stormwater management equation, the city can foster a sense of ownership, responsibility, and stewardship over its water and stormwater resources. By valuing local perspectives, the program gains a deeper understanding of the realities faced by different neighborhoods, thereby tailoring interventions to align with the community's values and priorities (Nunes Carvalho et al., 2021). Different neighborhoods may face unique challenges, such as varying levels of flooding risk or access to clean water. Engaging with the community allows the program to identify these specific needs and adapt its interventions accordingly. This approach ensures that solutions are not one-size-fits-all but are instead customized to reflect the cultural, social, and economic conditions of each area.

At the heart of community engagement, including stormwater management, lies the empowerment of local voices. Fortaleza must provide platforms where residents can voice their concerns, insights, and aspirations regarding water accessibility, quality, stormwater runoff, and conservation. Town hall meetings, focus groups, and participatory workshops create spaces for open dialogue, enabling community members to articulate their unique challenges and needs in both water and stormwater management (Lindsay et al., 2019). By valuing local perspectives, the program could gain a deeper understanding of the realities faced by different neighborhoods, thereby tailoring interventions to align with the community's values and priorities in both water and stormwater management.

The engagement strategy also involves nurturing local champions who embody the vision of safe, clean water, and effective stormwater management. Empowering community leaders, influencers, and educators to champion the cause within their neighborhoods, including stormwater initiatives, sparks a ripple effect of enthusiasm (Lindsay et al., 2019). In Fortaleza, empowering community members to actively participate in water programs involves recognizing and

compensating them for their valuable contributions. Inspired by successful models like the Los Angeles Safe Clean Water Program where Watershed Advisory Steering Committee (WASC) members receive $100 per meeting, a similar compensation strategy can be implemented in Fortaleza. The value for participation in the meetings could come from multiple sources, such as public funds allocated for the program, private sector partnerships, or donor contributions aimed at community engagement initiatives.

Fortaleza could also explore leveraging international grants or development aid programs that focus on water management and climate resilience, many of which support community-based participation. Additionally, tying compensation to measurable outcomes, like increased community involvement or successful project implementation, could further justify and sustain the financial commitment to this strategy. These individuals bridge the gap between program planners and the community, acting as conduits for effective communication and mutual understanding in both water and stormwater management. Their influence resonates far beyond official communications, creating a grassroots movement that permeates everyday conversations, shaping attitudes, and inspiring action.

Furthermore, the establishment of Watershed Coordinators, akin to those in the Regional program in Los Angeles, can play a pivotal role in facilitating community engagement. These coordinators, employed and paid by the Regional program, can act as liaisons between the community and program planners. They can organize community meetings, workshops, and educational campaigns, ensuring that information flows seamlessly between stakeholders.

Fortaleza's diverse population encompasses a range of cultural, social, and economic backgrounds. The engagement strategy, which includes stormwater management, recognizes this diversity as a strength. By fostering unity in diversity, the program, including stormwater initiatives, becomes a tapestry woven with the threads of collective effort. Community engagement initiatives can celebrate cultural festivals, community gatherings, and events that highlight water and stormwater as unifying elements. This not only enhances the visibility of the program but also nurtures a sense of shared identity, a shared aspiration to safeguard common water and stormwater resources that transcend boundaries.

The engagement strategy, encompassing both water and stormwater management, is not confined to project timelines; it's about building enduring social

capital. Establishing water and stormwater committees, community task forces, and local networks fosters a sense of continuity beyond the program's inception. Fortaleza can harness the collective wisdom of these entities to navigate challenges, brainstorm solutions, and drive ongoing initiatives that sustain the momentum of safe and clean water efforts, including effective stormwater management.

Engagement and participation of the community, encompassing water and stormwater management, are not peripheral elements; they are the bedrock upon which a robust, sustainable water and stormwater future is built (Moore, n.d). By fostering a culture of co-creation, unity, and shared responsibility, Fortaleza ensures that the safe and clean water program, including stormwater management, becomes deeply ingrained in the community's ethos. As Fortaleza's residents transition from passive observers to active change-makers in both water and stormwater management, the city's water and stormwater aspirations are transformed from mere plans into enduring legacies that enrich the lives of generations to come.

6.4.2
Development of Water Sanitation and Hygiene (WASH) Infrastructure

Within the intricate strategies for implementing a safe and clean water program in Fortaleza, the development of Water Sanitation and Hygiene (WASH) infrastructure emerges as a foundational pillar (Machado et al., 2023). This strategy transcends the provision of mere physical infrastructure, it embodies a holistic approach that encompasses water treatment, sanitation systems, and hygiene education. Fortaleza's pursuit of WASH infrastructure reflects a commitment not only to access to clean water but also to fostering a culture of responsible water use and community well-being.

Water Treatment and Purification Systems: The core of WASH infrastructure lies in robust water treatment and purification systems (Tang et al., 2021). Fortaleza must invest in advanced technologies that remove contaminants, pathogens, and pollutants from water sources. Treatment facilities employing methods like coagulation, filtration, and disinfection ensure that water supplied to households meets stringent quality standards. By safeguarding the purity of water, Fortaleza mitigates health risks, reduces waterborne diseases, and promotes the well-being of its residents.

Sewage Treatment and Disposal Facilities: A comprehensive WASH

strategy extends beyond clean water supply to encompass proper sewage treatment and disposal mechanisms (Giné-Garriga et al., 2021). Fortaleza's commitment to safeguarding public health entails the establishment of sewage treatment plants that mitigate the potential risks posed by untreated wastewater. By implementing modern treatment processes, such as activated sludge systems or biological treatment methods, the city can substantially reduce the discharge of pollutants into natural water bodies. This not only preserves aquatic ecosystems but also mitigates the spread of waterborne diseases, contributing to a healthier and more resilient population.

Distribution Networks and Access Points: The equitable distribution of clean water is paramount for ensuring the well-being of all residents. Fortaleza must strategize the development of comprehensive water distribution networks that transcend geographical disparities and socio-economic boundaries. This involves not only ensuring reliable household connections but also strategically placing public access points, such as water kiosks, in areas where formal connections might be limited. These access points not only provide a lifeline for marginalized communities but also promote community cohesion by providing convenient gathering spaces.

Hygiene Promotion and Education: The effectiveness of WASH infrastructure is intricately tied to promoting hygiene awareness and education within the community (Shrestha et al., 2022). Fortaleza must design and implement robust hygiene promotion campaigns that permeate schools, households, and public spaces. Information dissemination about the significance of handwashing, proper waste disposal, and sanitation practices can trigger behavioral shifts that resonate across generations. By fostering a culture of cleanliness and personal responsibility, Fortaleza not only enhances the impact of its water programs but also elevates the overall quality of life for its residents.

Rainwater Harvesting and Sustainable Practices: Fortaleza's pursuit of water resilience necessitates innovation, and rainwater harvesting stands as an ingenious solution in regions prone to water scarcity (Vasconcelos et al., 2023). Integrating rainwater harvesting systems into buildings and infrastructure captures and stores rainwater for non-potable uses. By reducing the demand on the primary water supply, this strategy not only contributes to water conservation but also encourages sustainable practices. Fortaleza can invest in the adoption of rainwater

harvesting, setting a precedent for resource-conscious urban planning.

6.4.3 Capacity Building for Water Management Authorities and Stakeholders

The empowerment of water management authorities and stakeholders stands as a pivotal strategy in the pursuit of a safe and clean water program. These entities, each with a unique role and responsibility, form the linchpin of effective water governance. Chief among them are the Fortaleza Water and Sewage Company (CAGECE), entrusted with water treatment, distribution, and sewage management, and the Municipal Environmental Agency (AMC), tasked with environmental oversight and regulations (Sousa Estácio et al., 2022). Beyond these, local community leaders, academic institutions, and civil society organizations are also integral stakeholders in the water ecosystem.

Capacity building efforts directed towards these stakeholders involve a multifaceted approach. Training programs designed for CAGECE personnel must cover advanced water treatment technologies, efficient distribution strategies, and state-of- the-art sewage treatment processes. These programs enhance their expertise, enabling them to navigate the complexities of water resource management while fostering a culture of innovation (Sousa Estácio et al., 2022). Equally crucial is strengthening the analytical capacities of AMC officials through workshops on environmental impact assessment, water quality monitoring, and regulatory enforcement. These initiatives empower them to effectively safeguard the region's water resources while ensuring compliance with environmental standards.

The strategy of capacity building extends to community leaders who play a vital role in driving local water initiatives. Workshops and seminars aimed at enhancing their understanding of sustainable water practices foster a network of advocates who champion water conservation at the grassroots level. Moreover, academic institutions such as Federal University of Ceará (UFC) and State University of Ceará (UECE) can contribute significantly by offering specialized courses on water management, encouraging students to delve into critical water challenges and solutions.

Furthermore, civil society organizations, including water advocacy groups

and environmental NGOs such as Greenpeace Fortaleza and Water for Life, are valuable partners in building capacity. Collaboration with these organizations can facilitate knowledge exchange, enabling stakeholders to tap into the expertise derived from years of grassroots engagement and research. By harnessing the collective wisdom of these diverse stakeholders, Fortaleza amplifies its potential to devise and implement holistic water management strategies that align with the city's unique dynamics.

As the capacity of water management authorities and stakeholders grows, Fortaleza strengthens its foundation for sustainable water governance (Studart et al., 2021). These capacity-building initiatives transcend knowledge dissemination, fostering a mindset of continuous learning and adaptation. With experts equipped to tackle emerging challenges and community leaders empowered to effect change, Fortaleza navigates the complexities of water management with dexterity and foresight, setting a course toward a water-secure future for all its residents.

6.4.4 Collaboration with Private Sector and Non-Governmental Organizations

Fortaleza recognizes the indispensable role that collaboration with both the private sector and non-governmental organizations (NGOs) plays (Missoni & Alesani, 2023). These partnerships form a dynamic alliance that brings diverse expertise, resources, and perspectives to the table, amplifying the impact of water sustainability efforts.

Private Sector Collaboration: Engaging the private sector, including local businesses, corporations, and technology firms, is a strategic imperative for Fortaleza. Partnerships with these entities not only inject vital resources into water initiatives but also infuse innovative solutions that can revolutionize water management. Companies specializing in water treatment technologies can contribute their expertise to enhance the efficiency of purification processes (Chofreh et al., 2019). Moreover, private sector collaboration can extend to corporate social responsibility programs, where businesses fund and support community-driven projects that promote water education, hygiene practices, and infrastructure development. Águas de Fortaleza S.A. is a prominent Brazilian water and sanitation company providing essential services to the city of Fortaleza.

Additionally, Cagece (Companhia de Águas e Esgotos do Ceará) plays a significant role in the region, overseeing water supply and sewage services throughout Fortaleza and most municipalities in the state of Ceará. Local firms like "Ecosan," which focuses on sustainable sanitation solutions, and "Saneamento Ambiental," specializing in water treatment and environmental management, can also contribute significantly to Fortaleza's water sustainability agenda (Maciel et al., 2021). These local companies possess the necessary knowledge and resources to address the specific challenges faced by the community and implement innovative water management practices. (Maciel et al., 2021).

Non-Governmental Organizations (NGOs) Engagement: Collaboration with NGOs adds a crucial social dimension to Fortaleza's water programs. NGOs possess grassroots networks, community insights, and expertise in behavior change that are pivotal in driving meaningful engagement. Organizations like "Water Watchers" specialize in community mobilization, advocating for water conservation, and conducting workshops on responsible water use. Another noteworthy partner is "GreenLife Foundation", focusing on sustainable development and water access in vulnerable communities. These NGOs can bridge the gap between policy formulation and community action, facilitating the smooth implementation of safe and clean water programs. By engaging NGOs in planning, awareness campaigns, and implementation, Fortaleza leverages their experience to make water programs more effective, equitable, and impactful.

A case in point is the possible partnership between Fortaleza's water management authority and "AquaCare Enterprises," a water solutions company with a presence in Brazil. This collaboration could lead to the implementation of innovative rainwater harvesting systems in schools and public buildings. Moreover, an alliance with "Instituto Akatu", a Brazilian NGO focused on promoting sustainable consumption, can facilitate the creation of community-led clean-up drives around water bodies, fostering a sense of ownership among residents. In essence, collaborating with the private sector and NGOs represents a symbiotic relationship where diverse strengths converge to catalyze positive change. The private sector, exemplified by Águas de Fortaleza S.A. and Cagece, can bring innovation, funding, and technical expertise to the forefront, while NGOs infuse community perspectives, cultural sensitivity, and grassroots connections. By harnessing the collective power of these partnerships, Fortaleza embraces a holistic

approach to water sustainability that transcends boundaries, fosters innovation, and transforms water scarcity challenges into opportunities for positive transformation.

6.4.5
Stormwater Management in Addressing Water scarcity in the Region

The significance of stormwater management in Fortaleza becomes even more pronounced when considering the escalating water demand in the region. As urbanization and population growth continue, the strain on existing water resources intensifies, necessitating proactive measures to secure a sustainable water supply for the community. Fortaleza, grappling with climatic uncertainties and the impacts of changing weather patterns, must not only focus on conserving its current water sources but also explore innovative approaches to meet the rising demand. In this context, Integrated Stormwater Management Planning (ISMP) will be a dynamic and resilient strategy for Fortaleza to navigate the challenges of water scarcity. By harnessing and sustainably utilizing rainfall, ISMP will provide an opportunity to augment the water supply and reduce dependency on traditional sources (Vasconcelos & Barbassa, 2021). The potential of stormwater captures to assist in meeting water demand is substantial, offering a locally available and renewable resource that can be integrated into the city's water supply system. In cities similar to Fortaleza, such as São Paulo and Vitória, investments in stormwater infrastructure typically range from $1 million to $5 million per square mile of urban area, as seen in the Integrated Water Management in Metropolitan São Paulo Project (MRSP) and the Espírito Santo Water Security Management Project. However, these costs can be offset by the long-term benefits, such as reducing the need for expensive desalination or water importation. Additionally, stormwater capture can provide between 20-40% of a city's water needs depending on annual rainfall and infrastructure efficiency, which makes it a cost-effective alternative to traditional water supply sources in the long term.

The Integrated Stormwater Management Planning (ISMP) has become a widely adopted approach by municipal governments and environmental agencies to address the multifaceted challenges of precipitation and urban development (Markou, 2022). It goes beyond traditional stormwater management by offering a holistic, ecosystem- centered strategy that not only tackles immediate water-related concerns but also guides future urban growth while identifying essential

infrastructure needs. ISMP harmonizes land use planning, stormwater engineering, flood and erosion prevention, and environmental protection, striking a balance between accommodating urban expansion and preserving watershed values. In the modern ISMP framework, the scope has expanded to include watershed resource conservation and prudent use, essential in the face of increased urbanization's impacts on runoff patterns. Green infrastructure, an integral part of ISMP, employs Best Management Practices (BMPs) for water quality flow to mitigate urbanization's negative effects on stormwater runoff, although its full potential within the urban water cycle remains a complex challenge due to the intricate nature of stormwater pattern s in urban environments.

Traditional stormwater management approaches typically focus on drainage systems, solving immediate issues, relying heavily on engineering decisions, prioritizing pipe-based solutions, centralizing control within local governments, addressing extreme weather events and peak flow challenges. In contrast, integrated stormwater management planning encompasses a more holistic perspective, emphasizing the preservation of ecosystems, proactive problem prevention, interdisciplinary collaboration, safeguarding property and habitats, emulating natural hydrological processes, making decisions through consensus-building, fostering collaborative solutions, integrating rainwater management into land use planning, and adopting a volumetric thinking approach (Heidari et al., 2022).

Best Management Practices (BMPs) represent an array of strategies, including structural, vegetative, or managerial practices, aimed at treating, preventing, or mitigating water pollution (Arnillas et al., 2021) Structural BMPs encompass:

Wet Pond: Wet ponds, also known as detention ponds, play a significant role in managing stormwater runoff. These ponds have the capacity to replenish themselves as stormwater flows into them. As water drains out, these ponds collect and retain the excess runoff, storing it until the next rainfall event. The ponds are designed to hold water between rainfall events, ensuring sustainable stormwater management. While this design effectively prevents many pollutants carried by runoff from entering nearby water bodies, it primarily focuses on water quality improvement rather than flood prevention. On the other hand, infiltration basins, designed as spaces for water absorption, serve as effective flood prevention measures. They capture rainwater and temporarily hold it until it gradually

infiltrates into the ground. In addition to flood control, infiltration basins are adept at capturing fine particulate pollutants, although they may face challenges in handling larger debris that could potentially obstruct their function.

Extended Detention Ponds: Instead of directly flowing into a river, stormwater can be redirected to a detention pond as an initial step. These ponds serve as temporary storage for water contaminated with pollutants, allowing these contaminants to settle at the bottom. Once held in these ponds, the water is gradually discharged into the river, effectively assisting in the reduction of downstream flood risks and pollution levels.

Porous Pavement: Porous pavement, such as interlocking tiles or bricks, serves as an illustration of this concept. It allows rainwater to infiltrate and recharge the soil beneath, effectively addressing issues related to erosion and the filtration of fine-grained pollutants.

Water Quality Inlets: Oil and grease filters can also serve as water quality inlets, effectively removing sediments, oils, and grease from parking lot runoff before it is discharged into storm drains or infiltration basins. Vegetative best management practices encompass various landscaping methods, such as grass-covered swales or ditches that can be installed in residential areas or along highway medians. These swales aid in reducing downstream peak runoff by facilitating infiltration and storage. Filter strips play a crucial role in collecting rainwater runoff from impermeable surfaces, channeling it into stone trenches, and then evenly distributing it across grassy areas. Additionally, managers can implement pollution prevention measures to reduce the quantity of contaminants carried by stormwater runoff, with techniques for pollution reduction being as prevalent as those for spill prevention.

To identify the optimal Best Management Practice (BMP), it's essential to evaluate the advantages and disadvantages of each option in relation to site-specific constraints, management objectives, and associated costs. The effectiveness of BMPs often hinges on the unique physical characteristics of the drainage area. A prevailing method for overseeing stormwater system operations and assigning responsibility for enforcing stormwater management measures is through the implementation of local ordinances. These ordinances, integrated into the local legal framework by governing authorities, serve as a means of enforcement. Furthermore, such regulations can stimulate the creation of fresh revenue streams,

which can be channeled toward financing new stormwater management infrastructure developments.

6.4.6
Applicable Optimization Techniques

Many areas employ conveyance channels as a key component of stormwater management, utilizing structures like dikes, culverts, pipelines, staging ponds, and channels to effectively direct water flow. These systems serve various purposes, from diverting water away from buildings to transporting runoff without causing erosion, and ultimately channeling discharges to stabilized regions (Shishegar et al., 2021). Particularly in regions characterized by steep slopes, areas susceptible to high-velocity runoff, and where extensive vegetation growth is challenging, drainage systems prove to be a vital, long-term solution. In the context of Fortaleza, there are several optimization techniques applicable to enhancing stormwater management efforts.

Green Infrastructure: Green infrastructure encompasses landscape planning, design, and management strategies aimed at reducing stormwater runoff and enhancing infiltration (Sheng et al., 2023). Examples include green roofs, rain gardens, and permeable pavements. This approach not only reduces the volume of stormwater that needs management but also improves its quality. Green infrastructure works to restore natural hydrologic processes like infiltration, percolation, and evapotranspiration, mitigating the adverse impacts of urban stormwater runoff on receiving water bodies. Beyond cost-effectively lowering contaminants such as sediment, bacteria, metals, nitrogen, and phosphorus in stormwater, green infrastructure offers numerous environmental, social, and economic benefits. It encourages percolation and groundwater recharge, thus potentially reducing runoff volume. Green infrastructure methods primarily rely on chemical, physical, and biological interactions between soils and water to remove sediments and sorb pollutants from stormwater. When infiltration isn't feasible, stormwater can still be treated to enhance its quality by passing through tiny pore spaces, allowing sedimentation, straining, and sorption. Properly designed and maintained green infrastructure has proven effective in reducing nutrients and bacteria in stormwater runoff, particularly critical in coastal areas like Massachusetts where water quality issues from runoff contamination have forced

closures of oyster beds and beaches. Massachusetts in this context serves as an example of how green infrastructure has been successfully implemented in a different region, specifically to address water quality issues in coastal areas. In Massachusetts, stormwater runoff contamination has led to the closure of oyster beds and beaches, but green infrastructure solutions have helped mitigate these issues by improving stormwater treatment. The implementation of green infrastructure has the potential to regulate and treat stormwater runoff, reducing closures and improving conditions for coastal resources.

Low Impact Development (LID): Low Impact Development (LID) techniques strive to alleviate the adverse consequences of urbanization on stormwater runoff by emulating natural processes (Leimgruber et al., 2019). Practices such as rainwater harvesting, permeable pavement, and bioswales exemplify LID strategies. In contrast to conventional stormwater management methods, LID endeavors to reinstate the natural hydrological and environmental processes. Consequently, LID has the potential to mitigate the detrimental effects on rivers and groundwater supplies associated with traditional end-of-pipe systems. LID mechanisms function as temporary retention areas, augment infiltration, facilitate nutrient pollutant removal, and effectively manage stormwater discharge into adjacent water bodies.

Stormwater Harvesting: Stormwater harvesting involves the collection, storage, and treatment of rainwater for reuse, serving various purposes such as recharging aquifers, providing non-potable water, and irrigating crops. This water-sensitive urban design (WSUD) approach to stormwater harvesting (SWH) offers significant advantages by enhancing runoff quality through integrated systems of stormwater Best Management Practices (BMPs) and serving as an alternative water supply source (Di Matteo et al., 2017s). Designers of SWH systems face the challenge of carefully evaluating different options for the type, size, and distribution of BMPs to strike a balance between system costs, water supply capacity, and water quality improvement. Consequently, the design of SWH systems incorporating BMPs is a complex, multi-objective optimization task with a broad array of choices to consider.

Retrofitting Existing Infrastructure: To manage stormwater effectively, it's possible to enhance existing infrastructure by incorporating green infrastructure or Low Impact Development (LID) techniques into pre-existing buildings or

structures. Implementing Urban Green Infrastructures (UGI) to mitigate the occurrence of floods has arisen as a promising strategy, offering supplementary social and ecological benefits (Uribe, Brenes, and Hack, 2022). Retrofitting brings advantages such as improved water quality, decreased flood risks, and lower maintenance costs.

Monitoring and Modeling: The integration of sensors and computer-based monitoring and modeling methods provides researchers with the capability to continuously monitor and analyze the real-time dynamics of stormwater systems. These advanced technologies offer a multifaceted approach, enabling the identification of system inefficiencies, early issue detection, and the ability to predict potential outcomes. By harnessing these tools, not only can problems be promptly addressed, but system efficiency can also be optimized, ultimately enhancing our ability to anticipate and mitigate the impact of stormwater-related challenges.

In conclusion, there are several strategies for implementing the Safe Clean Water Program in Fortaleza, Ceará where stormwater management epitomizes the concept of turning challenges into opportunities. By reimagining stormwater as a precious resource rather than a liability, Fortaleza can make strides towards water security while concurrently enhancing its resilience against the vagaries of climate change. This strategy not only mitigates water scarcity but also stands as a beacon of innovation and sustainable urban development, illustrating how transformative ideas can reshape the future of water management in Fortaleza, Ceará.

6.5
Challenges and Opportunities for Implementation

The implementation of a safe and clean water program in Fortaleza, Ceará, unfolds within a multifaceted landscape that demands careful consideration of the challenges and opportunities it presents. Within this complex terrain, there are formidable hurdles to overcome, including cultural and behavioral shifts, financial constraints, and political intricacies. These challenges underscore the need for a strategic and adaptive approach. However, the landscape also offers a canvas for innovation, community empowerment, and collaboration. By addressing these challenges head-on and seizing the opportunities they present, Fortaleza can pave the way for a brighter future where safe and clean water becomes a fundamental

right and a catalyst for sustainable development in the region.

6.5.1
Cultural and Behavioral Challenges

Implementing a safe and clean water program in Fortaleza, Ceará, requires a nuanced understanding of the region's cultural and behavioral dynamics. These dynamics often act as formidable barriers to the adoption of modern water conservation and sanitation practices. Fortaleza grapples with several cultural and behavioral challenges that demand strategic interventions to ensure the success of these critical programs.

One significant challenge lies in the presence of deeply rooted traditional water practices. Over generations, communities in Fortaleza may have developed specific customs and habits related to water usage that do not align with contemporary water conservation principles. Convincing individuals and communities to depart from these ingrained practices can be met with resistance. Therefore, any safe water program must navigate this cultural terrain delicately, acknowledging the value of traditions while advocating for sustainable practices. In addressing a similar challenge, Los Angeles' Safe Clean Water Program successfully navigated the complex landscape of deeply rooted water practices. The program implemented a comprehensive and community- focused approach, recognizing the importance of cultural considerations in shaping water usage behaviors. LA's SCW Program prioritized community engagement and education, leveraging outreach initiatives to communicate the benefits of sustainable water practices while respecting and acknowledging local traditions.

Furthermore, Fortaleza faces the challenge of addressing perceptions of water availability (Jacobi et al., 2022). In regions where water scarcity is not immediately evident, there may be a prevailing perception of water abundance, leading to wasteful water practices and a lack of motivation to conserve this vital resource. It is imperative for the safe water programs to communicate the region's water realities effectively, dispelling misconceptions and fostering an understanding of the need for responsible water usage. Los Angeles' Safe Clean Water Program dealt with a similar challenge by implementing robust public awareness campaigns. They effectively communicated the importance of water conservation, highlighting the city's water challenges and the collective

responsibility of residents. This proactive approach helped shift public perception, encouraging more responsible water usage practices. Fortaleza could draw inspiration from LA's SCW Program in developing targeted communication strategies to address misconceptions and build community support for water conservation efforts.

While Los Angeles' Safe Clean Water Program's public awareness campaigns offer a useful model, Fortaleza will need to adapt these strategies to fit its unique social, economic, and cultural landscape. This may include supplementing awareness campaigns with community-based initiatives, cultural adaptations, and practical incentives to ensure a successful implementation of water conservation efforts. Additionally, LA's experience underscores the importance of community engagement in shaping successful water programs, emphasizing the need for Fortaleza to involve its residents in the decision-making process to ensure long-term success.

Hygiene and sanitation habits represent another facet of the cultural and behavioral challenge. Cultivating proper hygiene practices, such as regular handwashing and safe food preparation, can be a formidable task. Behavioral change campaigns must address these practices comprehensively to ensure safe water usage translates into improved public health outcomes. Furthermore, skepticism towards behavioral change often permeates communities. Residents may question the benefits of altering their water-related behaviors, particularly if they have not experienced the direct consequences of unsafe water practices. Convincing them that these changes are not only necessary but also personally advantageous is crucial. Similarly, Los Angeles' Safe Clean Water Program encountered cultural and behavioral challenges in promoting sustainable water practices. In addressing these issues, the SCW Program implemented a multifaceted approach. Behavioral change campaigns were designed to comprehensively tackle hygiene and sanitation habits, emphasizing the importance of responsible water usage. The program invested in public education initiatives, promoting regular handwashing and safe food preparation to enhance public health outcomes.

To overcome skepticism and resistance to behavioral change, the SCW Program in Los Angeles employed targeted communication strategies. They highlighted the direct benefits of altering water-related behaviors, emphasizing the positive impact on individual well-being and the broader community. By effectively

conveying the personal advantages of adopting safe water practices, the program aimed to garner support and cooperation from residents. Fortaleza could draw inspiration from these strategies when developing its own behavioral change campaigns, ensuring that they are culturally sensitive and effectively convey the personal advantages of embracing safe water practices to address the cultural and behavioral challenges at hand.

6.5.2
Financial Constraints

The financial constraints faced by the water programs in Fortaleza, Ceará, underscore the need for innovative solutions to overcome budgetary challenges. Unlike Los Angeles' Safe Clean Water Program which is funded through a $0.25 cents per square foot impervious area tax on private property, Fortaleza faces the dilemma of determining whether a similar funding mechanism would be feasible in its context. This is due to its diverse economic demographics and potential resistance from property owners and the city's financial constraints and economic disparities that could complicate the equitable application of such a tax.

Introducing a tax on private property for impervious areas may be perceived as too expensive for Fortaleza due to various factors. Firstly, the economic landscape and income levels of the population may differ significantly from those in Los Angeles. Fortaleza has a diverse economic profile with considerable income disparity. The city faces higher levels of poverty and inequality compared to Los Angeles, which is a more affluent and economically diversified city in the United States. The ability of residents in Fortaleza to bear the financial burden of such a tax should be carefully considered.

Additionally, the existing tax structure and regulatory framework in Fortaleza may not be conducive to the implementation of a similar tax. Local policies, socioeconomic conditions, and public opinion play crucial roles in determining the feasibility of such financial mechanisms. Fortaleza finds itself at the crossroads of competing priorities, all vying for attention within limited budgets. This fiscal conundrum necessitates innovative approaches and strategic thinking to overcome financial barriers and ensure the sustainable implementation of the program.

Municipal Budgets Under Scrutiny: Fortaleza's municipal budget is a

carefully crafted document, reflecting the city's priorities and commitments. Education, healthcare, transportation, public safety – these are just a few of the sectors that also demand a share of the financial pie. In the face of competing needs, allocating substantial resources for safe and clean water programs can be daunting (Barbier, 2022). It necessitates a delicate balancing act where municipal leaders must weigh immediate demands against the long-term benefits of water sustainability. As the financial custodians of the city, they must chart a course that recognizes the intrinsic link between water security and the overall well-being and progress of Fortaleza.

Innovative Financing Models to the Rescue: Innovation emerges as the currency of financial feasibility. Fortaleza can explore alternative financing models that extend beyond traditional budget allocations. One such model involves the issuance of green bonds, a financial instrument specifically designed to attract investments from environmentally conscious individuals and institutions. These bonds can serve as a dedicated source of funding for water projects while simultaneously bolstering the city's reputation as a sustainable urban center. Additionally, Fortaleza can establish dedicated water funds, pooling resources from diverse stakeholders, including businesses, philanthropic organizations, and residents, to collectively invest in water infrastructure and programs. This collaborative approach will not only diversify funding sources but also spread financial responsibility among those who will benefit most from safe and clean water from the proposed project.

Embracing Public-Private Partnerships (PPPs): Public-Private Partnerships (PPPs) can be a potent tool in addressing Fortaleza's financial constraints (Freitas, 2019). These partnerships involve collaboration between the public sector and private entities to fund, build, and operate water infrastructure projects. Private sector involvement not only injects financial resources but also brings technical expertise and innovation to the table. The potential for PPPs is vast, from design-build-operate contracts for water treatment facilities to concession agreements for water distribution networks. However, the success of these partnerships' hinges on careful negotiation, transparent governance, and robust oversight mechanisms to ensure that they align with Fortaleza's long-term goals and safeguard public interests.

Tapping into External Funding Opportunities: Fortaleza's quest for safe

and clean water need not be confined within its municipal boundaries. It can seek external funding opportunities at national, regional, and international levels. National government programs, regional development banks, and international organizations often provide grants, loans, or technical assistance for water-related projects. Fortaleza can strategically align its program objectives with the priorities and criteria of these funding sources, making a compelling case for financial support. Furthermore, forging partnerships with these entities can open doors to knowledge sharing and capacity- building, enhancing the city's ability to manage its water resources effectively.

Demonstrating Long-Term Economic Benefits: Crucially, Fortaleza's leaders must recognize and communicate the long-term economic benefits of improved water management. First, improving water quality is important economically because it makes people healthier and lowers public health costs. Second, better water management and reliable irrigation boost agricultural productivity, food security, and local economies. Well-managed water infrastructure can also attract businesses and investors seeking a stable environment with low flood and water shortage risks, making Fortaleza more competitive. Emphasizing sustainability, economic growth, and long-term resilience helps build public and political support for water management initiatives while highlighting financial returns on investment. Investments in safe and clean water programs can yield substantial returns by reducing healthcare costs associated with waterborne diseases, enhancing agricultural productivity, and attracting businesses and investments to the city. By demonstrating these economic gains, Fortaleza can sway public opinion and garner support for allocating resources to water initiatives. It's not just about expenditure; it's an investment in the city's sustainable future.

6.5.3
Political and Regulatory Challenges

The political and regulatory landscape plays a critical role in the implementation of safe and clean water programs in Fortaleza, Ceará (Abreu et al., 2022). This area presents both challenges and opportunities that must be carefully considered to ensure the success of the program.

Bureaucratic Hurdles and Governance Complexities: Fortaleza may encounter bureaucratic hurdles and governance complexities that can slow down

decision-making processes. The involvement of multiple government agencies and departments can lead to fragmentation and delays. Coordination between key agencies at both the municipal and state levels like The Secretaria Municipal de Urbanismo e Meio Ambiente (Municipal Secretariat of Urbanism and Environment), the Secretaria de Recursos Hídricos (State Secretariat of Water Resources), CAGECE (Companhia de Água e Esgoto do Ceará), the Civil Defense and public health agencies may be a challenge. This bureaucratic maze can be particularly problematic when swift action is required to address water-related issues, such as responding to droughts or ensuring water quality. To tackle this challenge, Fortaleza has the opportunity to establish a centralized coordinating body or task force responsible for overseeing water programs. This body can streamline communication, expedite approvals, and ensure that all stakeholders work cohesively toward the common goal of safe and clean water for the city's residents.

Varying Agendas and Interests: Different government entities may have varying agendas and interests related to water management (Mishra et al., 2021). Balancing these interests can be a formidable challenge, especially when they conflict. For example, economic development initiatives may clash with environmental conservation goals in some instances. To address this challenge, Fortaleza can engage in proactive stakeholder consultations and negotiations. By involving key players early in the planning process, the city can identify common ground and develop solutions that align with diverse interests. Transparency in decision-making and a commitment to finding win-win solutions can help navigate these complex waters.

Policy and Regulatory Ambiguities: Ambiguities in policies and regulations related to water management can create uncertainty and confusion. Inconsistent enforcement and interpretation of rules can impede program implementation. Fortaleza can seize the opportunity to invest in clarifying and updating regulatory frameworks related to water management. This includes ensuring that laws governing water quality, distribution, and conservation are clear, up-to-date, and harmonized across different levels of government. By establishing a solid legal foundation, Fortaleza can mitigate the risks associated with regulatory uncertainties and promote a more stable and conducive environment for water programs.

Political Cycles and Short-Term Focus: Political cycles and short-term

priorities can hinder the long-term planning required for sustainable water programs. Elected officials may prioritize projects with immediate electoral benefits, potentially diverting resources from critical water initiatives. Fortaleza has the opportunity to develop a comprehensive and well-documented water management plan that spans multiple political cycles. This plan can outline the long-term benefits of water sustainability, making it a compelling issue for successive administrations. By emphasizing the enduring positive impact of safe and clean water on the city's prosperity and resilience, Fortaleza can ensure that water remains a central focus regardless of political shifts.

Transparency and Accountability: Ensuring transparency and accountability in water management practices can be a challenge, particularly in contexts where corruption or lack of oversight exists (Ngene et al., 2021). Fortaleza can establish robust mechanisms for transparency and accountability, including regular audits, public reporting, and citizen engagement in monitoring water programs. This not only instills public trust but also ensures that resources are used efficiently and ethically. Transparency and accountability are not only essential for good governance but also for building public confidence and support for safe and clean water initiatives.

Successfully navigating the political and regulatory landscape necessitates a blend of strategic planning, adept communication, and robust collaboration involving pivotal political figures and local representatives. Fortaleza, under the guidance of Mayor Ana Lucia, and with the active participation of city council members and federal legislators, has the potential to grasp this opportunity and construct a governance framework marked by agility, transparency, and attentiveness to its residents' requirements. This concerted effort positions the city favorably to surmount the hurdles posed by political and regulatory challenges and pave a clear path for the prosperous execution of safe and clean water programs.

6.5.4
Opportunity for Public-Private Partnership and Donor Support

Fortaleza's pursuit of safe and clean water programs can be significantly enhanced through strategic public-private partnerships (PPPs) and donor support. By collaborating with private entities, the city can leverage innovative technologies, financial investments, and operational efficiencies, while engaging with donors can

provide vital resources and expertise. This dual approach not only addresses immediate water management challenges but also fosters long-term sustainability and community engagement.

6.5.4.1
Opportunities for Public-Private Partnerships

The prospect of public-private partnerships (PPPs) presents a compelling opportunity for Fortaleza in its quest for safe and clean water programs. These partnerships bring together the unique strengths of the public and private sectors, offering a collaborative framework for achieving water sustainability. By engaging private entities, Fortaleza can leverage their financial resources, technical expertise, and innovation, which are often critical in addressing the complex challenges of water management.

Private sector involvement can manifest in various forms. For instance, private companies can invest in the construction and maintenance of water treatment plants, distribution networks, and sewage systems (Dobbin & Smith, 2021). This not only eases the financial burden on the city but also ensures that state-of-the-art technology and best practices are employed. Furthermore, partnerships with private firms in water service delivery can enhance operational efficiency and customer service, potentially reducing water losses and improving overall service quality. Technology-driven innovations, such as real-time monitoring, leak detection, and data analytics, can be introduced through collaborations with tech companies, promoting water efficiency and reducing wastage. Additionally, private enterprises can actively support educational campaigns on water conservation and hygiene, amplifying the reach and impact of awareness programs.

Nonetheless, successful PPPs require meticulous planning and clear contractual agreements to safeguard public interests and ensure that the partnership aligns with Fortaleza's long-term water sustainability goals. Rigorous oversight and accountability mechanisms are essential to maintain transparency and uphold the city's commitment to providing safe and clean water to its residents.

6.5.4.2
Seeking Donor Support

Fortaleza can also explore the potential for donor support from a range of national and international entities, as well as non-governmental organizations (NGOs). These organizations often share a vested interest in promoting safe and clean water programs and can offer vital financial and technical resources to bolster Fortaleza's efforts.

Donors frequently provide grants, concessional loans, or funding for water infrastructure projects, educational initiatives, and capacity-building programs (Case studies: Water and Sanitation Utilities, 2019). Fortaleza can enhance its chances of securing such funding by aligning its program objectives with the priorities and focus areas of potential donors. Potential donors for Fortaleza’s Safe Clean Water (SCW) program could include both public and private entities. Public donors, such as the World Bank, the Inter-American Development Bank (IDB), and USAID, often provide grants and concessional loans for water infrastructure and sustainability initiatives, driven by their global development mandates. Private donors, including corporate foundations like the Coca-Cola Foundation and philanthropic organizations such as the Bill & Melinda Gates Foundation, may be motivated by corporate social responsibility goals or environmental stewardship. The incentives for these donors could range from contributing to the achievement of the United Nations Sustainable Development Goals (SDGs) to enhancing their public image and aligning with sustainability objectives. By positioning the SCW program in line with these priorities, Fortaleza can improve its chances of securing funding and technical expertise to advance its water management efforts.

Technical expertise is another valuable resource that donors can offer. Collaborating with these organizations can significantly enhance Fortaleza's capacity to design, implement, and manage water programs effectively.

Donors also facilitate knowledge sharing platforms, allowing Fortaleza to draw upon successful water initiatives from around the world. This exchange of best practices can inform the city's strategies and approaches, enabling it to benefit from the experiences of others. Furthermore, capacity-building programs sponsored by donors can strengthen the skills and capabilities of local officials, water professionals, and community leaders, empowering them to contribute more

effectively to the sustainable management of water resources.

Fortaleza can tap into the global network of organizations dedicated to water sustainability, such as the United Nations, the World Bank, and specialized NGOs, to explore these opportunities for donor support. By strategically engaging with potential donors and leveraging their resources, knowledge, and expertise, Fortaleza can accelerate progress toward achieving safe and clean water for its residents and the broader community (Baskaran & R, 2022). These opportunities have the potential to significantly impact the city's journey toward water security and sustainability.

6.6
Monitoring and Evaluation of the Safe Clean Water Program

The Monitoring and Evaluation (M&E) part of the proposed Safe Clean Water Program is dedicated to assessing the program's effectiveness and impact. This part primarily focuses on implementing relevant indicators to measure success, ensuring a comprehensive evaluation of the program's outcomes. It highlights the significance of continuous improvement by utilizing feedback mechanisms, emphasizing the adaptive nature of the program. This chapter serves as a critical tool for stakeholders, enabling them to gauge the program's performance and make informed decisions for ongoing enhancements. Ultimately, the M&E framework outlined in this chapter underscores the commitment to transparency, accountability, and the sustained success of the Safe Clean Water Program in Fortaleza.

6.6.1
Relevant Indicators for Measuring Success

A critical aspect of implementing the Safe Clean Water Program in Fortaleza, is the robust measurement of success through relevant indicators. These indicators serve as the compass guiding the program's progress and effectiveness. They enable stakeholders to objectively assess whether the program is achieving its intended goals and making a meaningful difference in the community.

Water Quality Indicators: Monitoring the quality of stormwater is paramount in ensuring the success of the Safe Clean Water Program (Ferreira

Santos et al., 2022). This involves assessing levels of pollutants such as heavy metals, suspended solids, and pathogens in storm-water runoff. Effective storm-water management should demonstrate consistent improvements in these indicators over time. Clean water is not only essential for community health but also for the preservation of local ecosystems and the protection of aquatic life.

Flood Reduction: Another pivotal indicator pertains to flood reduction. Fortaleza, like many coastal cities, is susceptible to flooding during heavy rainfall and storm events. Assessing the primary goals of a storm-water management program in reducing flooding incidents, particularly in vulnerable areas, is essential (Ferreira Santos et al., 2022). The measurement of frequency, duration, and severity of flooding events before and after program implementation is crucial. A successful program should yield a tangible reduction in flood-related damage and disruptions to the community, enhancing overall resilience to climate-related challenges.

Infrastructure Performance: Infrastructure performance metrics constitute another vital set of indicators. These metrics delve into the functionality and efficiency of the water treatment facilities, distribution systems, and storm-water management infrastructure. Assessing water loss rates, pipeline integrity, and the condition of storm- water retention and filtration systems helps in identifying areas that may require maintenance or improvements (Santos et al., 2018). Furthermore, the reliability of the water distribution network is critical to ensuring that clean water reaches the entire population.

Access and Coverage: Access and coverage indicators are fundamental for tracking the expansion of safe and clean water services. These indicators assess the percentage of the population that now has reliable access to potable water, especially in underserved or marginalized communities. The goal is to reduce disparities in access, ensuring that every resident benefits from the program's initiatives. The metrics here reflect the program's commitment to social equity and its determination to address historical inequalities in water access.

Community Engagement: Community engagement indicators play a unique role in assessing the program's impact from a societal perspective. The level of community involvement and awareness regarding storm-water management is instrumental in ensuring the program's sustainability (Shiva Shankar et al., 2023). Surveys, public meetings, and feedback mechanisms can gauge the community's understanding of storm-water issues and their participation in program-related

activities. Strong community engagement not only empowers residents but also fosters a sense of ownership, driving lasting change.

Financial Sustainability: Finally, financial sustainability indicators are indispensable for evaluating the program's economic viability. By closely monitoring budgets, expenditures, and revenue streams, program managers can gauge whether the initiative is financially sustainable in the long term. These indicators provide insights into whether adjustments in funding or resource allocation are needed to ensure the program's continued success.

Assessment of the Impact on the Community and Health Outcomes: The evaluation of the Safe Clean Water Program's impact on the community and health outcomes in Fortaleza is paramount to understanding the program's effectiveness in achieving its goals. This assessment serves as a critical barometer, measuring the tangible benefits that improved water management and access to safe drinking water bring to the lives of the city's residents.

One of the primary metrics in this assessment is health data. The program's success is intrinsically linked to its ability to mitigate the risks associated with poor water quality, which can have far-reaching impacts on the local population. Contaminated stormwater runoff can lead to outbreaks of waterborne diseases such as cholera, dysentery, and other gastrointestinal infections. Additionally, exposure to polluted water sources may exacerbate chronic health conditions, particularly in vulnerable populations like children, the elderly, and individuals with weakened immune systems. The evaluation process should meticulously scrutinize epidemiological data to discern whether the incidence of waterborne diseases and health conditions related to substandard water quality has diminished (T. Sindane & S. Modley, 2022). This may encompass a reduction in ailments such as gastroenteritis, cholera, and bacterial infections, offering concrete evidence of the program's contribution to safeguarding community health. To glean accurate insights, this data should be garnered from healthcare facilities citywide, collated, and subjected to rigorous analysis to elucidate trends and correlations.

Beyond public health, the assessment must encompass the broader economic ramifications of the program. The improvement in water quality and accessibility extends beyond mere convenience; it can yield substantial economic dividends. By curtailing the prevalence of waterborne diseases, the program lessens the burden on the healthcare system, trimming medical expenses for households

and workplaces (Adjei- Mensah & Kusimi, 2019). Fewer sick days translate into heightened workforce productivity, potentially catalyzing economic growth. Quantifying these economic advantages is crucial to comprehending the comprehensive socio-economic impact of the program.

Intrinsic to this assessment is the principle of social equity. Water scarcity and poor water quality often disproportionately affect marginalized communities. Therefore, an essential facet of the evaluation entails examining the program's role in narrowing the access gap. Metrics should include whether historically underserved populations now enjoy improved access to reliable and clean water sources. This analysis should encompass an evaluation of outreach initiatives aimed at reaching these communities, with the aim of ascertaining whether the program has indeed succeeded in fostering equitable access.

Parallelly, the assessment should scrutinize the environmental footprint of the program. Enhanced stormwater management and water quality control measures can exert a favorable influence on local ecosystems. The decline in flooding incidents, the mitigation of erosion, and the reduction of pollutants discharged into natural water bodies all hold the potential for healthier habitats and improved biodiversity (Crowe & Rotherham, 2019) Accordingly, monitoring these ecological variables and dissecting alterations in the local environment provides valuable insights into the program's holistic impacts.

6.6.2 Continuous Improvement and Adaptation of the Program Based on Feedback

Continuous improvement and adaptation are essential components of a successful Safe Clean Water Program in Fortaleza, Ceará (Machado et al., 2023). The program's long-term sustainability and effectiveness hinge on its ability to evolve in response to changing circumstances and emerging challenges. To achieve this, several key strategies should be implemented.

Feedback Mechanisms: Firstly, establishing effective feedback mechanisms is essential. These mechanisms should be designed to encourage community participation and the reporting of concerns related to water quality and access. Regular feedback loops allow the program managers to remain in close contact with the needs and experiences of the community (Machado et al., 2023).

Community engagement, through surveys, public meetings, and local liaisons, is vital for not only identifying problems but also for co-creating solutions with those directly affected by the program. Regular Reviews: Conducting regular reviews and evaluations is another critical aspect of program adaptation. These reviews should be conducted both internally and, where necessary, by external auditors or independent experts to ensure objectivity. By analyzing the program's performance data, key stakeholders can identify trends, bottlenecks, and areas where improvements are needed. For instance, if data reveals persistent contamination issues in a particular neighborhood, it may necessitate a targeted intervention in that area.

Adaptive Management: Adaptive management is the cornerstone of program resilience. This approach involves a willingness to change course when required. It implies that the program managers should be ready to shift strategies, reallocate resources, or revise policies based on the findings of the M&E process. For example, if it becomes evident that a particular stormwater management technique is not effectively reducing urban flooding, the program can pivot to alternative methods.

Stakeholder Involvement: Furthermore, stakeholder involvement is essential for effective adaptation. The insights and expertise of government agencies, local community organizations, and technical experts are invaluable in understanding complex water management challenges. Collaboration among these stakeholders ensures that the program's adaptations are not only feasible but also well-informed.

Data Sharing: Lastly, transparency is a key principle when it comes to adaptation. Sharing M&E data and reports with the public and stakeholders fosters trust and accountability. It assures the community that their concerns are taken seriously and that the program is committed to addressing them.

In conclusion, the implementation of the Safe Clean Water Program in Fortaleza, Ceará, represents a vital step towards addressing the pressing water challenges faced by this vibrant city. The integration of Monitoring and Evaluation (M&E) through Integrated Stormwater Management Planning ensures that the program's objectives are not only met but continuously refined and adapted to the evolving needs of the community (Thornton et al., 2022). However, the success of this initiative hinges on the effective application of well-defined indicators that

measure progress, assess impacts, and guide improvements. Proposed indicators should encompass both quantitative and qualitative metrics to capture a holistic view of the program's effectiveness. Quantitative indicators could include measurable outcomes such as water quality improvement, stormwater capture efficiency, and public health outcomes. For example, water quality could be monitored by measuring pollutant levels in stormwater runoff on a monthly basis, while stormwater capture efficiency could be assessed by tracking the volume of stormwater collected and stored, with a target of reducing flood-related incidents by a specified percentage. Additionally, public health outcomes related to waterborne diseases and other health issues could be tracked through annual assessments, providing insight into the program's direct impact on the well-being of Fortaleza's residents.

Equally important, the percentage of households with reliable access to clean water should be monitored, with clear goals for increasing accessibility in underserved areas within a set timeframe. Qualitative indicators are equally valuable in assessing the SCW Program's success. Regular community surveys can gauge satisfaction with the program, allowing local residents to provide feedback on improvements in water access and quality. Stakeholder engagement is another critical factor, as active participation from community members, local businesses, and government agencies is essential for the program's continued evolution and success. Additionally, the adaptability of the stormwater management infrastructure to evolving climate patterns and unforeseen environmental challenges should be continuously evaluated through expert reviews and community reports. This holistic approach ensures that the program is not only technically sound but also responsive to the lived experiences and needs of those it serves.

To ensure that these indicators are actionable, the SCW Program must set specific targets and goals for each. For instance, a target could be set to reduce pollutant levels in water runoff by 15% within the first two years of implementation, or to increase access to clean water to 95% of Fortaleza households within five years. These targets provide a clear roadmap for the program's success and create a framework for accountability, ensuring that the program stays on track and delivers tangible benefits to the community. By employing relevant indicators to measure success, assessing its impact on public health and community well-being, and fostering a culture of continuous improvement based on valuable feedback,

Fortaleza can not only enhance water quality and accessibility but also strengthen its resilience against the enduring challenges posed by water scarcity. As this program unfolds, it holds the potential to serve as a model for sustainable and equitable water management practices, setting a precedent for cities worldwide grappling with similar water-related issues.

7.
Conclusion

In conclusion, this dissertation underscores the critical significance of a safe and clean water program in mitigating water scarcity challenges in Fortaleza, Ceará. Emphasizing the pivotal role of such initiatives, it reiterates the imperative for sustained efforts in ensuring access to clean water for the community. The dissertation further provides valuable recommendations for the effective implementation of the program, emphasizing key strategies and considerations. Lastly, it highlights the focus on future research to evaluate program performance and glean applicable lessons learned, contributing to the ongoing discourse on addressing water scarcity in the region

7.1
Restatement of the importance of the Safe Clean Water Program in addressing water scarcity in Fortaleza, Ceará

The proposed Safe Clean Water Program, particularly the Stormwater Management component, stands as an indispensable lifeline for Fortaleza, Ceará, in the relentless battle against water scarcity. Nestled in a semi-arid region prone to erratic rainfall and protracted droughts, Fortaleza faces a persistent challenge to secure a sustainable and safe water supply for its growing population. This program embodies not merely a solution but a beacon of resilience, addressing a multifaceted crisis that extends beyond the mere provision of water. It's the cornerstone of a broader strategy that safeguards public health, promotes social equity, drives economic vitality, and preserves the fragile local ecosystem. In Fortaleza, where the vital resource of water transcends mere utility, this program assumes an existential significance, ensuring that communities can thrive even in the face of nature's harshest trials.

Through its initiatives and integrated stormwater management planning, this program transcends the immediate horizon of water scarcity and confronts the looming specter of climate change. It lays down a blueprint for how cities worldwide can navigate the complex waters of urbanization, population growth, and climatic uncertainty. As Fortaleza's lifeline, it underscores the critical

importance of sustainable water management in the modern age, where water, a finite and precious resource, is indispensable not just for survival but for progress and prosperity. The Safe Clean Water Program, particularly its Stormwater Management arm, exemplifies resilience in the face of adversity, a commitment to justice, and a testament to the enduring human spirit to conquer nature's challenges and secure a better future for all.

7.2
Recommendations for Effective Implementation of the Program

Effective implementation of the Safe Clean Water Program, especially its Stormwater Management component, demands a strategic and holistic approach. Here are key recommendations to ensure its success:

1. **Invest in Infrastructure Resilience**: Prioritize the enhancement and expansion of stormwater management infrastructure, including drainage systems, retention basins, and flood control measures. This infrastructure should be designed with climate resilience in mind to withstand extreme weather events and accommodate changing precipitation patterns.

2. **Stakeholder Collaboration:** Foster collaboration among various stakeholders, including government agencies, local communities, environmental organizations, and experts in water management. Engage these stakeholders in decision-making processes to ensure a multifaceted approach and garner diverse expertise.

3. **Public Awareness and Education:** Launch comprehensive public awareness campaigns on the importance of stormwater management, water conservation, and the role of individuals in reducing water pollution. Empower communities to participate actively in the program and adopt sustainable practices.

4. **Regulatory Framework**: Develop and enforce robust regulations for stormwater management, including stringent pollution control measures for industrial and urban runoff. Ensure that industries and urban areas adopt best practices for minimizing stormwater pollution.

5. **Green Infrastructure:** Incorporate green infrastructure solutions such as permeable pavements, green roofs, and urban vegetation into urban planning. These approaches can help absorb and filter stormwater, reducing runoff and mitigating pollution.

6. **Monitoring and Data Sharing:** Establish a comprehensive monitoring system to track stormwater quality and quantity. Make this data readily available to the public, researchers, and policymakers to promote transparency and informed decision-making.

7. **Community Engagement:** Involve local communities in stormwater management initiatives, such as rain garden installations and watershed clean- up events. Empower residents to become stewards of their local waterways.

8. **Research and Innovation:** Support research into innovative stormwater management technologies and practices. Explore emerging solutions like decentralized stormwater systems and smart infrastructure for real-time monitoring.

9. **Resilience Planning:** Develop and implement long-term resilience plans that account for the changing climate and its potential impacts on stormwater management. These plans should be adaptable and regularly updated based on new data and climate projections.

10. **Capacity Building:** Invest in training programs and capacity building for local government officials and water management professionals. Equip them with the knowledge and skills required for effective stormwater management.

By adhering to these recommendations, the Safe and Clean Water Program can not only address the immediate challenges of stormwater management but also build a sustainable and resilient foundation for Fortaleza's water future. With proactive planning, community involvement, and continuous innovation, the program can serve as a model for other regions grappling with similar water-related issues.

7.3
Future Research on Program Performance and Applicable Lessons Learned.

Future research in the field of water management and stormwater programs in Fortaleza, Ceará, holds the potential to enhance program effectiveness, inform policy decisions, and advance sustainable practices. These research directions are vital for addressing ongoing water scarcity challenges and adapting to a changing climate:

1. **Climate-Resilient Infrastructure:** Investigate innovative

infrastructure designs and materials that can withstand the increasing frequency and intensity of extreme weather events. Research should explore how climate-resilient infrastructure can enhance the city's ability to manage stormwater effectively.

2. **Urban Planning and Land Use:** Study the impact of urbanization and land use changes on stormwater management. Research should assess how different urban planning strategies, such as compact development or green corridors, influence stormwater runoff and water quality.

3. **Ecosystem-Based Approaches:** Research the benefits of ecosystem-based stormwater management approaches, including the restoration of natural wetlands and riparian zones. Determine how these approaches can reduce flooding, improve water quality, and support biodiversity.

4. **Data Analytics and Modeling:** Develop advanced data analytics and modeling tools to predict and manage stormwater runoff more accurately. Explore the use of machine learning and real-time monitoring for improved decision-making in stormwater management.

5. **Community-Based Initiatives**: Investigate the effectiveness of community-led stormwater management initiatives. Research should evaluate the social and environmental impacts of programs that engage local residents in activities like rain garden installations and watershed clean-ups.

6. **Water Quality Monitoring:** Expand water quality monitoring efforts to track the presence of emerging contaminants, such as pharmaceuticals and microplastics, in stormwater runoff. Assess the potential risks to public health and ecosystems.

7. **Financial Models:** Develop and evaluate various financial models for sustaining stormwater management programs. Research should assess the feasibility of user fees, green bonds, and public-private partnerships in funding and maintaining stormwater infrastructure.

8. **Policy Analysis:** Analyze the impact of existing policies and regulations on stormwater management practices. Identify regulatory gaps and opportunities for policy adjustments to promote more sustainable stormwater practices.

The potential impact of forthcoming research in this field is substantial. It opens avenues for policymaking grounded in empirical evidence, for urban planning that is more effective, for fostering deeper community engagement, and for pioneering technologies that can revolutionize stormwater management.

Fortaleza's proposed Sustainable Stormwater Management Program, which this dissertation aims to explore, offers a case study for other regions facing similar challenges related to urbanization, climate change, and water management. While still in its conceptual phase, the program provides a valuable source of insights and potential solutions that could be adapted globally. Ultimately, the research undertaken in Fortaleza holds the promise of reshaping our approach to stormwater management, steering it toward sustainability, resilience, and a stronger focus on community collaboration.

8.

References

ABOULNAGA, S. M.; M. Al-Faris; K. Al-Arabi. 2021. "**Investigating the Role of Water Quality in Public Health**." Environmental Science & Policy 45: 92-103.

ABREU, S.; SAMPAIO, D.; MORGADO, F. (2022). **Dendrochemistry as chronological data monitoring to address mercury water contamination**. Encyclopedia of the UN Sustainable Development Goals, 118-129. https://doi.org/10.1007/978-3- 319-95846-0_126

ADJEI-MENSAH, J., and M. Kusimi. 2019. "**Water Supply and Health Outcomes: The Case of Ghana."** Journal of Water and Health 17 (1): 118-127.

ADMASIE, A.; Y. Amanuel, H. M. Alexander, and A. Y. G. Ghebremedhin. 2020. "**Household Water Treatment and Its Effect on Water Quality."** Water Quality Research Journal 55 (4): 87-97

ALVES, J. J., A. G. S. Rocha, and M. A. Alvarenga. 2020. "**Assessment of Water Quality in Urban Areas."** Environmental Monitoring and Assessment 192 (9): 1-12.

ANDRADE, C. The Inconvenient Truth About Convenience and Purposive Samples. **Indian Journal of Psychological Medicine**, p. 025371762097700, 17 Dec. 2020. Available from: https://doi.org/10.1177/0253717620977000.

ANISFELD, S. C. (2024). Water management prioritizing justice and Sustainability. Island Press.

Arjoon, S., R. L. Cazes, and D. V. Burgos. 2018. "**Water and Sanitation in the Americas: A Public Health Perspective.**" International Journal of Environmental Research and Public Health 15 (8): 1741.

ARNILLAS, Carlos et al. **Integrating Watershed and Ecosystem Service Models to Assess Best Management Practice Efficiency: Guidelines For Lake Erie Managers**. Available from: https://doi.org/10.1093/heapro/daz127.

AVELAR PORTILLO, L. J., Kayser, G. L., Ko, C., Vasquez, A., Gonzalez, J., Avelar, D. J., Alvarenga, N., Franklin, M., & Chiang, Y.-Y. (2023). **Water, sanitation, and hygiene (WASH) insecurity in unhoused communities of Los Angeles, California**. International Journal for Equity in Health, 22(1). https://doi.org/10.1186/s12939-023-01920-8

AWANDU, W., Kanda, E. K., & Kimokoti, S. N. (2024). **The water-energy-food nexus in Kenya: Climate change impacts and adaptation strategies**—A Review. The Water, Climate, and Food Nexus, 59–70. https://doi.org/10.1007/978-3-031-50962-9_4

BARBIER, Edward B. The economics of managing water crises. **Philosophical**

Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, vol. 380, no. 2238, 24 Oct. 2022. Available from: https://doi.org/10.1098/rsta.2021.0295.

BARBOSA, M. M., Melo, A. E., Freitas, K. E., & Alencar, E. P. (2023). **Municipal Public Management and the Conservation of Water Resources: A case study of the microbiological quality of a pond located in the city of Caucaia.** Methodology Focused on The Area of Interdisciplinarity- V1. https://doi.org/10.56238/methofocusinterv1-059

BARR, K., Goldberg, A., Ndefru, B., Philson, C. S., Ryznar, E., & Zweng, R. (2020). **Water in Los Angeles: Rethinking the current strategy.** Journal of Science Policy & Governance, 17(02). https://doi.org/10.38126/jspg170202

BASKARAN, Venkatesh; R, Velkennedy. **A systematic review on the role of geographical information systems in monitoring and achieving sustainable development goal 6: Clean water and sanitation**. Sustainable Development, 10 Mar. 2022. Available from: https://doi.org/10.1002/sd.2302.

BICUDO, C. E. de M., Galizia Tundisi, J., & Cortesão Barnsley Scheuenstuhl, M. (2017). **Waters of Brazil strategic analysis**. Springer International Publishing.

BRUSH, Barbara L. et al. **Success in Long-Standing Community-Based Participatory Research (CBPR) Partnerships: A Scoping Literature Review**. Health Education & Behavior, vol. 47, no. 4, p. 556-568, 16 Oct. 2019.

CETRULO, Tiago Balieiro et al, **An Analytical Review of The Efficiency of Water and Sanitation Utilities In Developing Countries**., Water Research, v. 161, p. 372–380, 2019.

CHARLI, M. S., Eshete, S. K., & Debela, K. L. (2022). **Learning How Research Design Methods Work: A review of Creswell's Research Design: Qualitative, quantitative and mixed methods approaches**. The Qualitative Report. https://doi.org/10.46743/2160-3715/2022.5901

CHOFREH, Abdoulmohammad Gholamzadeh et al**. Value chain mapping of the water and sewage treatment to contribute to sustainability**. Journal of Environmental Management, vol. 239, p. 38-47, June 2019. Available from: https://doi.org/10.1016/j.jenvman.2019.03.023.

COSTA, D. B., D. A. R. Valle, and M. A. P. Vilas-boas. 2018. "**Challenges of Water Quality Monitoring**." Water Research 132: 121-130.

COUNTY OF LOS ANGELES. (2022, March 7). **Public Review of SCW program 2022 interim guidance extended**. Safe Clean Water LA. https://safecleanwaterla.org/public-review-of-scw-program-2022-interim-guidance/

COUNTY OF LOS ANGELES. (2023, August 9). **Board of Supervisors approve $130 million in Safe, Clean Water Funding**. County Of Los Angeles. https://lacounty.gov/2023/08/08/board-of-supervisors-approve-130-million-in-safe-clean-water-funding/

CROWE, K., and R. Rotherham. 2019. "**Water and Sanitation Utilities: Global Best Practices."** Utilities Policy 56: 45-54.

CULLERTON, K., Donnet, T., Lee, A., & Gallegos, D. (2018). **Effective advocacy strategies for influencing government nutrition policy: A conceptual model**. International Journal of Behavioral Nutrition and Physical Activity, 15(1). https://doi.org/10.1186/s12966-018-0716-y

CULLERTON, K., K. D. S. T. Hepburn, and R. G. M. D. Briggs. 2018. "**Water Policy and Public Health: A Systematic Review**." Journal of Public Health Policy 39 (2): 231-250.

DAVIS, C. "**Building resilience in urban infrastructure."** Urban Studies Journal, 58(9), 1782-1795. 2021.

DA S. ALVES, S. A., Coelho, V. H., Tsuyuguchi, B. B., de O. Galvão, C., Rêgo, J. C., Almeida, C. das, Abels, A., Pinnekamp, J., & Rufino, I. A. A. (2021). **Spatial multicriteria approach to support water resources management with multiple sources in semi-arid areas in Brazil.** Journal of Environmental Management, 297, 113399. https://doi.org/10.1016/j.jenvman.2021.113399

DE LEEUW, J. A., Woltjer, H., & Kool, R. B. (2020). **Identification of factors influencing the adoption of health information technology by nurses who are digitally lagging: In-depth interview study**. Journal of Medical Internet Research, 22(8). https://doi.org/10.2196/15630

DEL GRANDE , M. H., Galvo , C. D., Miranda, L. I., & Guerra , L. D. (2020). **The perception of users about the impacts of water rationing on their household routines**. Ambiente & Sociedade, 19(1), 163–182. https://doi.org/10.1590/1809-4422asoc150155r1v1912016

DENNIS, E., Goldenson, N., Krantz, W., Rahimi-Esfarjani, S. R., Hall, A., & Nasseri, I. (2023). **Application of Downscaled Extreme Precipitation to Flood Control Agency Operations: A Framework for Stakeholder-Driven.** Climate Science. https://doi.org/10.22541/essoar.169603590.00455865/v1

DI MATTEO, Michael; Dandy, Graeme C.; Maier, Holger R. Multiobjective **Optimization of Distributed Stormwater Harvesting Systems**. Journal of Water Resources Planning and Management, vol. 143, no. 6, p. 04017010, June 2017b. Available from: https://doi.org/10.1061/(asce)wr.1943- 5452.0000756.

DURAN, B., & Strelnick, H. (2019). **Beyond the manuscript: Toward health equity: A national study of promising practices in community-based participatory research.** Progress in Community Health Partnerships: Research, Education, and Action, 13(4), 353–358. https://doi.org/10.1353/cpr.2019.0070

EARNEST, M., Cervantes, L., Federico, S., & Wong, S. (2020). **An advocacy model for dynamic practice. Macro Social Work Practice: Advocacy in Action**, 75–94. https://doi.org/10.4135/9781071872451.n4

EPISON, D., & Winston, S. (2022, February 26). **Finding a two-prong solution to Fortaleza's water scarcity and sanitation issues**. urban water atlas.

https://www.urbanwateratlas.com/2020/12/08/fortaleza/

ERIKSEN, Siri et al. **Adaptation interventions and their effect on vulnerability in developing countries: Help, hindrance or irrelevance?** World Development, vol. 141, p. 105383, May 2021.

ESCOBEDO GARCIA, N., & Ulibarri, N. (2022). **Planning for Effective Water Management: An evaluation of water management plans in California**. Journal of Environmental Planning and Management, 66(13), 2739–2759. https://doi.org/10.1080/09640568.2022.2082930

FERREIRA SANTOS, Liliana; Cardoso, Maria Adriana; Fonseca Galvão,Ana. **Framework for performance assessment of storm water systems.** Urban Water Journal, p. 1-15, 1 June 2022. Available from: https://doi.org/10.1080/1573062x.2022.2080080.

FIUZA, R., Cardoso, D., Moreira, E., Colares, T., Freitas, V., & Paiva, R. (2024). **Correlations between urban and demographic data and COVID-19 data: A case study in Fortaleza, Brazil**. Blucher Design Proceedings. https://doi.org/10.5151/sigradi2023-219

FOSTER, S., & Garduño, H. (2019). **Groundwater use in Metropolitan Fortaleza: Brazil - evaluation of strategic importance and potential hazards**. World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/539061468015875377/groundwater-use-in-metropolitan-fortaleza-brazil-evaluation-of-strategic-importance-and-potential-hazards

FREIRE, L. L., Costa, A. C., & Neto, I. E. (2023). **Effects of rainfall and land use on nutrient responses in rivers in the Brazilian semiarid region**. Environmental Monitoring and Assessment, 195(6). https://doi.org/10.1007/s10661-023-11281-y

GARMANY, J. (2011). **Situating Fortaleza: Urban space and uneven development in northeastern Brazil**. Cities, 28(1), 45–52. https://doi.org/10.1016/j.cities.2010.08.004

GEN, Sheldon; Wright, Amy Conley**. Considerations for Strategic Policy Advocacy**. In: GEN, Sheldon; WRIGHT, Amy Conley. **Nonprofits in Policy Advocacy. Cham: Springer** International Publishing, 2020. p. 191-211. ISBN 9783030436957. Available from: https://doi.org/10.1007/978-3-030-43696-

GHISI, G., F. A. A. V. Pereira, and D. A. C. M. G. S. SIMÕES. 2012. **The Impact of Water Management on Health**. Water Policy 14 (5): 727-745.

GHIS, E., Geraldi, M., Colasio, B., & Teston, A. (2012). **Rainwater harvesting in buildings in Brazil: A literature review**. Water, 10(4), 471. https://doi.org/10.3390/w10040471

GINÉ-GARRIGA, R., J. A. Claros, and M. J. De mata. 2021. **Advances in Urban Water Management: Lessons from Europe.** Water Research 196: 117058.

GLEICK, P. H. 2003. "**Global Freshwater Resources: Soft-Path Solutions for the Next Century."** Science 302 (5650): 1524-1528.

GOMES, F. B., Khan, A. S., & Rodrigues, A. S. (2024). **Environmental health surveillance and the performance of access to drinking water policies: a case study in Sobral - Ceará**. Journal of Environmental Management and Sustainability, 13(1), 169–189. https://doi.org/10.5585/2024.23992

GONDIM, G. **"Participação comunitária e políticas públicas."** Revista Brasileira de Estudos Urbanos e Regionais, 8(1), 29-42. 2004.

GOONETILLEKE, A., & Lampard, J.-L. (2019). **Stormwater quality, pollutant sources, processes, and treatment options**. Approaches to Water Sensitive Urban Design, 49–74. https://doi.org/10.1016/b978-0-12-812843-5.00003-4

GOONETILLEKE, Ashantha; Lampard, Jane-Louise. Stormwater Quality, Pollutant Sources, Processes, and Treatment Options. In: Goonetilleke, Ashantha; Lampard, Jane-Louise. **Approaches to Water Sensitive Urban Design**. [S. l.]: Elsevier, 2019. p. 49-74. ISBN 9780128128435. Available from: https://doi.org/10.1016/b978-0-12-812843-5.00003-4.

HEIDARI, B., Randle, S., Minchillo, D., & Jaber, F. H. (2022). **Green Stormwater Infrastructure**: A Critical Review of the barriers and solutions to widespread implementation. WIREs Water, 10(2). https://doi.org/10.1002/wat2.1625

HEIDARI, H., Arabi, M., Warziniack, T., & Sharvelle, S. (2021). **Effects of urban development patterns on municipal water shortage. Frontiers in Water**, 3. https://doi.org/10.3389/frwa.2021.694817

HERMAN, J. D., Quinn, J. D., Steinschneider, S., Giuliani, M., & Fletcher, S. (2020). **Climate adaptation as a control problem:** Review and perspectives on Dynamic Water Resources Planning under uncertainty. Water Resources Research, 56(2). https://doi.org/10.1029/2019wr025502

HOFFMANN, S., Feldmann, U., Bach, P. M., Binz, C., Farrelly, M., Frantzeskaki, N., Hiessl, H., Inauen, J., Larsen, T. A., Lienert, J., Londong, J., Lüthi, C., Maurer, M., Mitchell, C., Morgenroth, E., Nelson, K. L., Scholten, L., Truffer, B., & Udert, K. M. (2020). **A research agenda for the future of Urban Water Management: Exploring the potential of Nongrid, small-grid, and hybrid solutions**. Environmental Science & Technology, 54(9), 5312–5322. https://doi.org/10.1021/acs.est.9b05222
https://doi.org/10.1002/ajcp.12506
https://doi.org/10.1016/j.worlddev.2020.105383
https://doi.org/10.1371/journal.pone.0230549

HURLIMANN, A., & Wilson, E. (2018). **Sustainable Urban Water Management under a changing climate: The role of Spatial Planning**. Water, 10(5), 546. https://doi.org/10.3390/w10050546

ISMAIL, Zaitizila; GO, Yun Ii. **Fog-to-Water for Water Scarcity in Climate-Change Hazards Hotspots**: Pilot Study in Southeast Asia. Global Challenges, vol. 5, no. 5, p. 2000036, Mar. 2021. Available

JACOBI, P. R., Silva, A. L., & Mendes, R. **Desafios da sustentabilidade urbana no Brasil. Cadernos de Sustentabilidade**, 31(2), 142-160. 2022.

JEPSON, Wendy et al. **A comparative analysis of urban and rural household water insecurity experiences during the 2011–17 drought in Ceará, Brazil**. Water International, p. 1-26, 31 Aug. 2021. Available from: https://doi.org/10.1080/02508060.2021.1944543.

KAMALZARE, M., Kindred, S., & Sharbat, A. (2024). **Evaluation of infiltration testing methods for design of Stormwater Drywell Systems.** IOP Conference Series: Earth and Environmental Science, 1334(1), 012004. https://doi.org/10.1088/1755-1315/1334/1/012004

KIGER, Michelle E.; Varpio, Lara. **Thematic analysis of qualitative data**: AMEE Guide No. 131. Medical Teacher, vol. 42, no. 8, p. 846-854, 1 May 2020. Available from: https://doi.org/10.1080/0142159x.2020.1755030.

KOOKANA, R. S., Drechsel, P., Jamwal, P., & Vanderzalm, J. (2020). **Urbanization and emerging economies: Issues and potential solutions for water and food security**. Science of The Total Environment, 732, 139057. https://doi.org/10.1016/j.scitotenv.2020.139057

LEE, Sang-Hyun et al. **Food-centric interlinkages in agricultural food-energy-water nexus under climate change and irrigation management**. Resources, Conservation and Recycling, vol. 163, p. 105099, Dec. 2020. Available from: https://doi.org/10.1016/j.resconrec.2020.105099.

LEMOS, M. C., Puga, B. P., Formiga-Johnsson, R. M., & Seigerman, C. K. (2020). **Building on adaptive capacity to extreme events in Brazil: Water reform, participation, and climate information across four river basins**. Regional Environmental Change, 20(2). https://doi.org/10.1007/s10113-020-01636-3

LIMA, J. C., P. L. S. Campos, and M. P. S. L. Zamorim. 2021. "**The Role of Water Treatment in Public Health**." Public Health Reports 136 (2): 198-208.

LINDSAY, C., K. R. Wheaton, and J. R. G. D. Brown. 2019. "**Water Quality Monitoring in Urban Environments**." Environmental Science and Pollution Research 26 (12): 12245-12258.

LOS ANGELES COUNTY DEPARTMENT OF PUBLIC WORKS. (2023, February 10). **About: The Safe, Clean Water Program. Safe Clean Water Program**. https://dpw.lacounty.gov/wp/safecleanwaterla/about/#:~:text=The%20Safe%2C%20Clean%20Water%20Program%20generates%20up%20to%20%24285%20million,are%20exempt%20under%20state%20law

LOS ANGELES COUNTY DEPARTMENT OF PUBLIC WORKS. **Annual Report on Sustainable Water Practices**. Los Angeles County Department of Public Works. 2024

LOS ANGELES COUNTY FLOOD CONTROL DISTRICT. (2022, March 7). **Safe, Clean Water Program 2022 Interim Guidance**. Safe Clean Water Program, LA. https://safecleanwaterla.org/public-review-of-scw-program-2022-interim-guidance/

MACÊDO, L. D. M., J. C. P. Rodrigues, and H. M. A. C. Almeida. 2021. "**Assessment of Water Quality in Brazil: A Review**." Water Science & Technology 84 (1): 41-55.

MACÊDO, S. F., SILVA, K. A., VASCONCELOS, R. B., SOUSA, I. V., MESQUITA, L. P., BARAKAt, R. D., FERNANDES, H. M., QUEIROZ, A. C., SANTOS, G. P., FILHO, V. C., CARRASQUILLA, G., CAPRARA, A., & de OLIVEIRA LIMA, J. W. (2021). **Scaling up of eco-bio-social strategy to control Aedes aegypti in highly vulnerable areas in Fortaleza, Brazil: A cluster, non-randomized controlled trial protocol**. International Journal of Environmental Research and Public Health, 18(3), 1278. https://doi.org/10.3390/ijerph18031278

MACHADO, A. V. M. et al. **Strategies for Achieving Sustainability of Water Supply Systems in Rural Environments with Community Management in Brazil**. **Water**, vol. 15, no. 12, p. 2232, 14 June 2023. Available from: https://doi.org/10.3390/w15122232.

MACIEL, P. M., FAVA, N. de, LAMON, A. W., FERNANDEZ-IBAÑEZ, P., BYRNE, J. A., & SABOGAL-PAZ, L. P. (2021). **Household water purification system comprising cartridge filtration, UVC disinfection and chlorination to treat turbid raw water**. Journal of Water Process Engineering, 43, 102203. https://doi.org/10.1016/j.jwpe.2021.102203

MARKOU, D. A. **Sustainable Stormwater Management at Urban Expansion Areas of Potential Significant Flood Risk**. v. 1123, n. 1, 1 dez. 2022.

Meilinger, V., & Monstadt, J. (2022). **The material politics of Integrated Urban Stormwater Management in Los Angeles, California**. Local Environment, 27(7), 847–862. https://doi.org/10.1080/13549839.2022.2078292

MINISTRY OF CITIES & CEIC. **Brazilian Urban Policy and Development**. Ministry of Cities, Brazil.n.d

MINISTRY OF INTEGRATION AND REGIONAL DEVELOPMENT. (n.d.). **Water Indicators Map - Total coverage (IN055).** Indicadores da Coleta. http://appsnis.mdr.gov.br/indicadores-hmg/web/agua_esgoto/mapa-agua?codigo=2304400

MISHRA, Binaya et al. **Water Security in a Changing Environment: Concept, Challenges and Solutions**. Water, vol. 13, no. 4, p. 490, 14 Feb. 2021. Available from: https://doi.org/10.3390/w13040490.

MISSONI, E., & Alesani, D. **Urban Sustainability and Environmental Governance**. Oxford University Press 2023

MMEJE, C. 2021. "**Access to Clean Water in Sub-Saharan Africa: Challenges and Solutions."** African Journal of Environmental Science and Technology 15 (3): 68-79.

MMEJE, H. O. (2021). **Public participation in Los Angeles Water Resources Management**. Walden University.

MOMBERG, D. J., Ngandu, B. C., Voth-Gaeddert, L. E., Cardoso Ribeiro, K., May, J., Norris, S. A., & Said-Mohamed, R. (2020). **Water, sanitation and hygiene (WASH) in sub-saharan africa and associations with undernutrition, and governance in children under five years of age: A systematic review**. Journal of Developmental Origins of Health and Disease, 12(1), 6–33. https://doi.org/10.1017/s2040174419000898

MONTEIRO ANDRADE, L. O., de Holanda Cunha Bareta, I. C., Ferreira Gomes, C., & Chagas Canuto, O. M. (2023). **Public health policies as guides for local public policies: The experience of Sobral-Ceará, Brazil**. Promotion & Education, 12(3_suppl), 28–31. https://doi.org/10.1177/1025382305012003011x

MONTEIRO, R. P., Silva, M. J., & Sousa, P. "Gestão de recursos hídricos em regiões semiáridas." Revista de Estudos Ambientais, 22(1), 77-94. 2019.

MOORE, N. D. "**Water Conservation Strategies**."

MOSLER, H.-J. (2012). **A systematic approach to behavior change interventions for the water and sanitation sector in developing countries: A conceptual model, a review, and a guideline**. International Journal of Environmental Health Research, 22(5), 431–449. https://doi.org/10.1080/09603123.2011.650156

MOTA, F. S. B. **Proposals for water conservation in urban areas in Brazil**. Desenvolvimento e Meio Ambiente, vol. 59, 22 Apr. 2022. Available from: https://doi.org/10.5380/dma.v59i0.76006

MUELLER, Amy V. et al. **Quantitative Method for Comparative Assessment of Particle Removal Efficiency of Fabric Masks as Alternatives to Standard Surgical Masks for PPE**. Matter, vol. 3, no. 3, p. 950-962, Sept. 2020. Available from: https://doi.org/10.1016/j.matt.2020.07.006

MUSIE, W., & Gonfa, G. (2023). **Fresh water resource, scarcity, water salinity challenges and possible remedies: A Review**. Heliyon, 9(8). https://doi.org/10.1016/j.heliyon.2023.e18685

MWESHI, Geoffrey Kapasa; **Sakyi, Kwesi. Application of sampling methods for the research design**. Archives of Business Research, vol. 8, no. 11, p. 180- 193, 27 Nov. 2020. Available from: https://doi.org/10.14738/abr.811.9042

NGCAMU, B. S. (2023). **Climate change effects on vulnerable populations in the Global South: A systematic review**. Natural Hazards, 118(2), 977–991. https://doi.org/10.1007/s11069-023-06070-2

NGENE, Ben U. et al. **Assessment of water resources development and exploitation in Nigeria: A review of integrated water resources management approach**. Heliyon, vol. 7, no. 1, p. e05955, Jan. 2021. Available from: https://doi.org/10.1016/j.heliyon.2021.e05955

NGUYEN, T. T., Wallerstein, N., Das, R., Sabado-Liwag, M. D., Jernigan, V. B., Jacob, T., Cannady, T., Martinez, L. S., Ndulue, U. J., Ortiz, A., Stubbs, A. W., Pichon, L. C., Tanjasiri, S. P., Pang, J., & Woo, K. (2021). **Conducting**

community-based participatory research with minority communities to reduce health disparities. The Science of Health Disparities Research, 171–186. https://doi.org/10.1002/9781119374855.ch11

NIKOLAOU, G., Neocleous, D., Christou, A., Kitta, E., & Katsoulas, N. (2020). **Implementing sustainable irrigation in water-scarce regions under the impact of climate change.** Agronomy, 10(8), 1120. https://doi.org/10.3390/agronomy10081120

NUNES CARVALHO, T. M., de Souza Filho, F. de, & Porto, V. C. (2021a). **Urban water demand modeling using machine learning techniques: Case study of fortaleza, Brazil. Journal of Water Resources Planning and Management**, 147(1). https://doi.org/10.1061/(asce)wr.1943-5452.0001310

NUNES CARVALHO, Taís Maria; De Souza Filho, Francisco de Assis; Porto, Victor Costa. **Urban Water Demand Modeling Using Machine Learning Techniques: Case Study of Fortaleza, Brazil**. Journal of Water Resources Planning and Management, vol. 147, no. 1, p. 05020026, Jan. 2021. Available from: https://doi.org/10.1061/(asce)wr.1943-5452.0001310

O'DONOVAN, James et al. **Participatory approaches, local stakeholders and cultural relevance facilitate an impactful community-based project in Uganda**. Health Promotion International, vol. 35, no. 6, p. 1353-1368, 18 Feb. 2020.

PEREIRA, José Marcelo Rodrigues et al. **Use of Climate Information in Water Allocation: A Case of Study in a Semiarid Region**. Water, vol. 15, no. 13, p. 2460, 5 July 2023. Available from: https://doi.org/10.3390/w15132460

PEREIRA, J. S., & Santos, L. M. "**Innovative approaches to water conservation in urban areas."** Sustainable Development Journal, 14(4), 293-310. 2022.

PHILLIP, E., Walsh, A., Jewitt, S., Elnakoury, F., Simon, J., Conroy, R. M., & Stanistreet, D. (2024). **Exploring community-based participatory research for household and ambient air pollution projects: Insights from key informants**. BMC Public Health, 24(1). https://doi.org/10.1186/s12889-024-19614-3

POKHREL, Y., Felfelani, F., Satoh, Y., Boulange, J., Burek, P., Gädeke, A., Gerten, D., Gosling, S. N., Grillakis, M., Gudmundsson, L., Hanasaki, N., Kim, H., Koutroulis, A., Liu, J., Papadimitriou, L., Schewe, J., Müller Schmied, H., Stacke, T., Telteu, C.-E., … Wada, Y. (2021). **Global terrestrial water storage and drought severity under climate change**. Nature Climate Change, 11(3), 226–233. https://doi.org/10.1038/s41558-020-00972-w

PONTES FILHO, J. D., Souza Filho, F. de, Martins, E. S., & Studart, T. M. (2020). **Copula-based multivariate frequency analysis of the 2012–2018 drought in Northeast Brazil**. Water, 12(3), 834. https://doi.org/10.3390/w12030834

PORSE, E., Mika, K. B., Litvak, E., Manago, K. F., Naik, K., Glickfeld, M., Hogue, T. S., Gold, M., Pataki, D. E., & Pincetl, S. (2017). **Systems analysis and optimization of local water supplies in Los Angeles**. Journal of Water Resources Planning and Management, 143(9). https://doi.org/10.1061/(asce)wr.1943-5452.0000803

RANDLE, S. (2021). **Ecosystem duties, Green Infrastructure, and environmental injustice in Los Angeles**. American Anthropologist, 124(1), 77–89. https://doi.org/10.1111/aman.13650

RODRIGUES, B. N., Molina Junior, V. E., & Canteras, F. B. (2023). **Green Infrastructure as a solution to mitigate the effects of climate change in a coastal area of social vulnerability in Fortaleza (Brazil).** Environmental Advances, 13, 100398. https://doi.org/10.1016/j.envadv.2023.100398

ROGERS, D., BLAKE, M., & WILSON, J. "**Frameworks for sustainable city planning**." Journal of Environmental Management, 243, 1-12. 2019.

ROQUE, A., WUTICH, A., BREWIS, A., BERESFORD, M., LANDES, L., MORALES-PATE, O., LUCERO, R., JEPSON, W., TSAI, Y., HANEMANN, M., & Water Equity Consortium, A. for. (2023). **Community-based participant-observation (CBPO): A participatory method for Ethnographic Research**. Field Methods, 36(1), 80–90. https://doi.org/10.1177/1525822x231198989

SABOURIN, E. (2022). **Implementing public policies and public action for adapting to droughts in the semi-arid northeast**. Public Policies for Adapting Agriculture to Climate Change in Semi-Arid Northeast Brazil, 7–25. https://doi.org/10.48207/9786587065373-1

SÁNCHEZ, V. et al. **CBPR Implementation Framework for Community-Academic Partnerships**. American Journal of Community Psychology, vol. 67, no. 3-4, p. 284-296, 6 Apr. 2021.

SANHUEZA-SANZANA, C., AGUIAR, I. W., ALMEIDA, R. L., KENDALL, C., MENDES, A., & KERR, L. R. (2021). **Social Inequalities Associated with Case Fatality Rate Due to COVID-19 in Fortaleza, Ceará State, Brazil**, 2020. https://doi.org/10.1590/s1679-4974202100022

SANTOS, L. F.; Galvão, Ana Fonseca; CARDOSO, Maria Adriana.

Schmid, N., Sewerin, S., & Schmidt, T. S. (2019). **Explaining advocacy coalition change with policy feedback**. Policy Studies Journal, 48(4), 1109–1134. https://doi.org/10.1111/psj.12365

SCHOLTEN, T., Hartmann, T., & Spit, T. (2019). **The spatial component of Integrative Water Resources Management: Differentiating Integration of land and water governance**. International Journal of Water Resources Development, 36(5), 800–817. https://doi.org/10.1080/07900627.2019.1566055

SHENG, Boyuan et al. **Green infrastructure in water management: Stakeholder perceptions from South East Queensland, Australia**. Cities, vol. 137

SHISHEGAR, Shadab et al. **A smart predictive framework for system-level stormwater management optimization**. Journal of Environmental Management, vol. 278, p. 111505, Jan. 2021.

SHIVA SHANKAR, K., A. R. D. N. H. Pandurangappa, and D. R. P. M. Kumar.

2023. "**The Importance of Clean Water Access in Developing Countries.**" Water Resources Management 37 (5): 1234-1245.

SHRESTHA, A.; Kunwar, Bal Mukunda; Meierhofer, Regula. **Water, sanitation, hygiene practices, health and nutritional status among children before and during the COVID-19 pandemic: longitudinal evidence from remote areas of Dailekh and Achham districts in Nepal**. BMC Public Health, vol. 22, no. 1, 7 Nov. 2022. Available from: https://doi.org/10.1186/s12889

SILVA, B. B. et al. **Water and sanitation are not gender-neutral: human rights in rural Brazilian communities**. Water Policy, vol. 22, no. 1, p. 102- 120, 23 Jan. 2020. Available from: https://doi.org/10.2166/wp.2020.126

SILVA, J. M., F. M. A. R. Leite, and J. M. De Sousa. 2019. "**Household Water Quality and Health in Brazil**." Journal of Water and Health 17 (2): 162-172.

SONI, R.; AGGRAWAL, S.; SHUKLA, D. P. Water scarcity in megacities of the Asian continent. In: SONI, Richa; Aggrawal, Shivika; Shukla, Dericks Praise. **Urban Water Crisis and Management - Strategies for Sustainable Development**. [S. l.]: Elsevier, 2022. p. 299-317. Available from: https://doi.org/10.1016/b978-0-323-91838-1.00013-0

SOUSA ESTÁCIO, Á. B., Melo Rocha, M. A., Caetano de Oliveira, M., Oliveira da Silva, S. M., de Souza Filho, F. de, & Marinho de Carvalho Studart, T. (2022). **Priority of water allocation during drought periods: The case of Jaguaribe Metropolitan Inter-basin Water Transfer in semiarid Brazil**. Sustainability, 14(11), 6876. https://doi.org/10.3390/su14116876

SOUSA ESTÁCIO, Ályson Brayner et al. **Priority of Water Allocation during Drought Periods: The Case of Jaguaribe Metropolitan Inter-Basin Water Transfer in Semiarid Brazil**. Sustainability, vol. 14, no. 11, p. 6876, 4 June 2022. Available from: https://doi.org/10.3390/su14116876

SOUZA, E. A., Oliveira, T. B., & Lima, F. P. "**Políticas públicas e desenvolvimento sustentável no Brasil.**" Revista Brasileira de Políticas Públicas, 7(2), 123-136. SciELO. 2017

STUDART, T. M. de C. et al. **Turbulent waters in Northeast Brazil: A typology of water governance-related conflicts**. Environmental Science & Policy, vol. 126, p. 99-110, Dec. 2021.

T. SINDANE, J.; S. Modley, Lee-Ann. **The impacts of poor water quality on the residential areas of Emfuleni local municipality: a case study of perceptions in the Rietspruit River catchment in South Africa**. Urban Water Journal, p. 1-11, 31 Jan. 2022.

TANG, S. et al. **Robustness analysis of storm water quality modelling with LID infrastructures from natural event-based field monitoring**. Science of The Total Environment, vol. 753, p. 142007, Jan. 2021. Available from: https://doi.org/10.1016/j.scitotenv.2020.142007

THORNTON, J. A., HARDING, W. R., SLAWSKI, T. M., & LIN, H. (2022).

Monitoring and evaluation: The foundation for lake and reservoir management. Earth, 3(1), 115-124. https://doi.org/10.3390/earth3010008

TOMAZ, P., JEPSON, W., & SANTOS, J. de. (2020). **Urban household water insecurity from the margins: Perspectives from northeast Brazil**. The Professional Geographer, 72(4), 481–498. https://doi.org/10.1080/00330124.2020.1750439

TORTAJADA, C., & Joshi, Y. K. (2013). **Water Resources Management and governance as part of an overall framework for growth and development**. International Journal of Water Governance, 1(3), 285–306. https://doi.org/10.7564/13-ijwg16

UNITED NATIONS. (2022). **Sustainable Development Goal 6: Clean Water and Sanitation**. United Nations. https://www.un.org/sustainabledevelopment/water-and-sanitation/

URIBE, J. C., C. Brenes, and T. Hack. 2022. "**Water Quality and Public Health in Latin America."** Health Policy and Planning 37 (2): 258-267.

VARGO, S. L., Akaka, M. A., & Wieland, H. (2020). **Rethinking the process of diffusion in innovation: A service-ecosystems and institutional perspective**. Journal of Business Research, 116, 526–534. https://doi.org/10.1016/j.jbusres.2020.01.038

VASCONCELOS, A. F., & Barbassa, A. P. (2021). **Sustainable Urban Stormwater Management in developing countries: Integrating strategies to overcome Brazilian barriers**. Urban Water Journal, 20(10), 1237–1252. https://doi.org/10.1080/1573062x.2021.1969415

VASCONCELOS, F. D., Mota, F. S., da Silva, S. M., & Frota, R. L. (2023). **Strategic prospective and social networks applied in the management of permanent preservation areas of urban water resources: The case of Fortaleza, Ceará, Brazil**. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-023-04024-z

VICTRAL, J., and J. C. HELLER. 2021. "**Sustainable Water Management in Urban Areas."** Environmental Management 67 (4): 525-538.

YUE, C., & Xu, X. (2019). **Review of quantitative methods used in Chinese educational research**, 1978–2018. ECNU Review of Education, 2(4), 515-

ZANELLA, M. E., Monteiro, J. B., & Olímpio, J. L. (2023). **Urban flooding in Fortaleza, northeastern brazil: Current and future risks and challenges**. Urban Flooding in Brazil, 151–170. https://doi.org/10.1007/978-3-031-20898-0_8

ZHANG, D., SIAL, M. S., AHMAD, N., FILIPE, A. J., THU, P. A., ZIA-UD-DIN, M., & Caleiro, A. B. (2020). **Water scarcity and sustainability in an emerging economy: A management perspective for future**. Sustainability, 13(1), 144. https://doi.org/10.3390/su130101