

Identification of Adaptive and Sustainable Water Provision for a Healthy and Resilient City

A Case Study of Coastal Area in Bandar Lampung

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Abstract

Bandar Lampung's coastal slum areas face challenges accessing clean water worsened by the climate crisis. Current solutions like extending PDAM pipelines and using bottled water from wells are insufficient for long-term sustainability. Bandar Lampung's coastal slum areas face challenges accessing clean water worsened by the climate crisis. Current solutions like extending PDAM pipelines and using bottled water from wells are insufficient for long-term sustainability. The study utilized a mixed-methods approach, combining qualitative interviews with stakeholders and quantitative analysis of water access data. Data collection involved surveys, site visits, and archival research. The research identified the inadequacy of current water provision methods and emphasized the need for adaptive and integrated solutions. Stakeholder interviews revealed the importance of collaborative governance in addressing water access challenges. Quantitative analysis highlighted disparities in water access between different areas within the slums. The study's significance lies in its contribution to urban resilience theory by proposing integrated approaches to water provision in vulnerable coastal areas. Practically, it informs policymakers and planners on the importance of inclusive governance and sustainable infrastructure development for addressing water access challenges exacerbated by climate change.

Keywords

Coastal slum areas, Water access challenges, Climate crisis impact, Mixed-methods approach, Collaborative governance, Urban resilience theory.

1. INTRODUCTION

1.1. Problem and Research Gap

Indonesia, particularly in coastal cities like Bandar Lampung, has experienced significant population growth, reaching 1.1 million people (BPS, 2024). Globally, urbanization trends indicate that over half of the world's population now resides in urban areas, with projections showing this figure will exceed 70% by 2050 (Liu et al., 2020; UN DESA, 2018 in Guerry et al., 2021). This rapid urbanization, combined with the climate crisis, presents numerous challenges, especially in coastal areas where urban settlements are concentrated. As a major trade and service center in southern Sumatra, Bandar Lampung faces high population density and inadequate infrastructure, fostering the growth of vulnerable slum settlements that are prone to disasters such as floods, which in turn impact public health (BAPPENAS, 2014).

Urban infrastructure is becoming increasingly critical in light of global urbanization, necessitating improvements in public service delivery. The World Economic Forum has identified five major challenges cities face: environmental threats, energy resource scarcity, inequality, technology, and governance (Schwab, 2018). Among these challenges, ensuring access to safe and adequate drinking water for domestic and daily needs is fundamental to human well-being. Urban activities put immense pressure on water resources, especially in densely populated areas, making comprehensive urban water planning essential to meet both present and future demands. Moreover, government stakeholders play a crucial role in facilitating water supply through market-based paradigms (Maharani et al., 2019.).

Bandar Lampung, as a hub of commerce and services, is increasingly vulnerable to climate change, particularly in coastal areas (Ilmi et al., 2020). Climate change exacerbates hydrometeorological disasters and worsens water scarcity, affecting agriculture and public health due to insufficient drainage systems, particularly in congested urban areas like Bandar Lampung (Boer, 2012 in Dai et al., 2018). Flooding incidents, intensified by extreme rainfall, pose significant risks to community health and water security in coastal slum areas (Ilmi et al., 2021). Consequently, water resource management is vital for urban water supply amidst the climate crisis (Suprpto, 2012). However, public awareness of climate change in Bandar Lampung remains limited, increasing the city's vulnerability compared to Jakarta (Manik et al., 2013).

With growing urban populations, the demand for water continues to rise, further exacerbated by the COVID-19 pandemic. The lack of efficient water distribution infrastructure and limited capacity for sustainable urban water management aggravates the water crisis in densely populated areas (Feizizadeh et al., 2021). Through literature reviews and field studies, this research aims to identify inclusive and sustainable urban water supply strategies to address both current and future water needs. The complexity of slum settlements requires a holistic approach that considers social, cultural, and economic aspects to tackle water supply challenges (Geddes, 1915; Obie, 2018). Bandar Lampung's coastal slum areas serve as a representative case study, underscoring the importance of inclusive and sustainable urban water provision in regions vulnerable to climate change.

2. METHOD & CONCEPT

This study employs a descriptive analysis with mixed-methods approach, focusing on inclusive and sustainable characteristics and efforts in response to the climate crisis. The research aims to develop an inclusive, sustainable, and healthy city, emphasizing adherence to specific standards for drinking water quality and sustainable water use for hygienic sanitation, as regulated in *Permenkes RI No. 32 of 2017*. Additionally, one of the specific indicators used is the "Healthy Residential Area Infrastructure," outlined in the *Minister of Health Regulation No. 34 of 2005* on Healthy City Implementation.

The data analysis method in this study adopts a descriptive qualitative approach based on Creswell (2016), used to describe results from field observations, questionnaire-based interviews, and literature reviews.

The analysis focuses on inclusive and sustainable efforts in responding to the impacts of the climate crisis. Inclusivity is based on resilience criteria from the *Evaluation Handbook Resilience Coastal Communities against Tsunamis and Other Coastal Hazards* (2007), while sustainability is aligned with the 2030 Sustainable Development Goals, specifically Goal 6: Clean Water and Sanitation, and the *Minister of Health Regulation No. 492 of 2010* on Drinking Water Quality Standards.

According to Kodoatie (2003:5), clean water is water that can be used for washing, bathing, cooking, and consuming after it is boiled. Similarly, Suipin (2003:13) defines clean water as water that is colorless, odorless, and has a fresh taste suitable for consumption by health standards. On the other hand, water used for hygienic sanitation must meet adequate quality for daily needs but differs from drinking water standards (*Minister of Health Regulation No. 32 of 2017*).

The data collection in this study includes both primary and secondary sources, with the main method being questionnaire-based interviews conducted directly by the researchers (Suyanto & Satinah, 2005) to understand the characteristics of slum settlements in coastal areas and efforts to supply clean water with a focus on inclusivity and sustainability (Suryani et al., 2020). Field observations were made to examine the patterns, forms, and adaptation mechanisms of communities in mitigating the impacts of the climate crisis. Secondary data was used to strengthen and complement field findings and the researchers' arguments. The research sites included districts directly adjacent to the coast of Bandar Lampung City, such as Teluk Betung Timur, Teluk Betung Selatan, Bumi Waras, and Panjang, as shown in Figure 1.

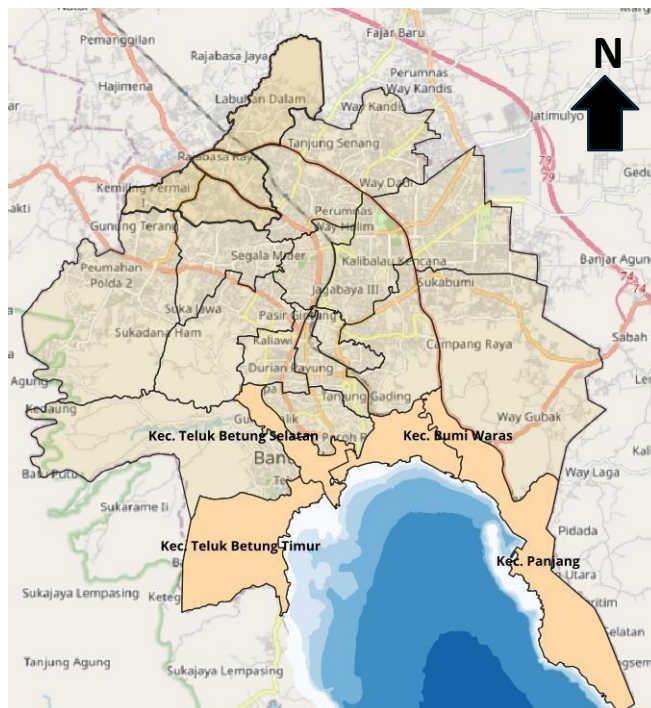


Figure 1. Editing the Headline. Source: ISOCARP.

In determining the sample size for the survey, the Isaac and Michael method is used, which requires the following conditions: (1) the population size is known; (2) a chosen level of error (significance level) of 1%, 5%, or 10%; and (3) this method is specifically applicable for samples with a normal distribution. The sample size is calculated in more detail using the Isaac and Michael formula (Sugiyono, 2013) as follows:

Formula:

S: Sample size

Λ^2 : Chi-Square value

N: Total population

P: Probability of success (0.5)

Q: Probability of error (0.5)

d: Margin of error (the difference between the sample mean and the population mean)

Table 1. Proportion and sample size of the study

District	Total Population	Proportion in the city	Sample size
Bumi Waras	14.018	0,2433	93
Panjang	20.203	0,3506	135
Teluk Betung Utara	4.512	0,0783	30
Teluk betung Timur	12.580	0,2183	84
Total			342

3. RESULTS AND DISCUSSION

2.1. Results

This section discusses the findings from field data based on questionnaires and observations. The results reveal trends in efforts to address the impacts of the ongoing climate crisis, based on the existing conditions in the field.

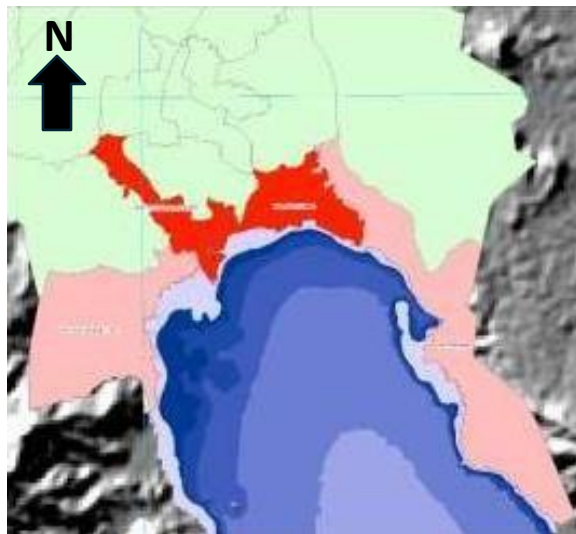


Figure 2. Sanitation Hazard Map in Coastal Areas of Bandar Lampung City.

The level of vulnerability to poor sanitation is particularly severe in two of the 20 sub-districts in Bandar Lampung's coastal areas, with two others rated as low risk. However, in all four sub-districts, the slum level is quite high, with over 50% of the total area classified as slum settlements. The four most affected sub-districts are Teluk Betung Timur, Teluk Betung Selatan, Bumi Waras, and Panjang. These areas are directly adjacent to the coast and face the highest risk from the climate crisis, which includes poor sanitation, lack of clean water, disease outbreaks, and hydrometeorological disasters such as floods, tidal waves, and extreme weather conditions.

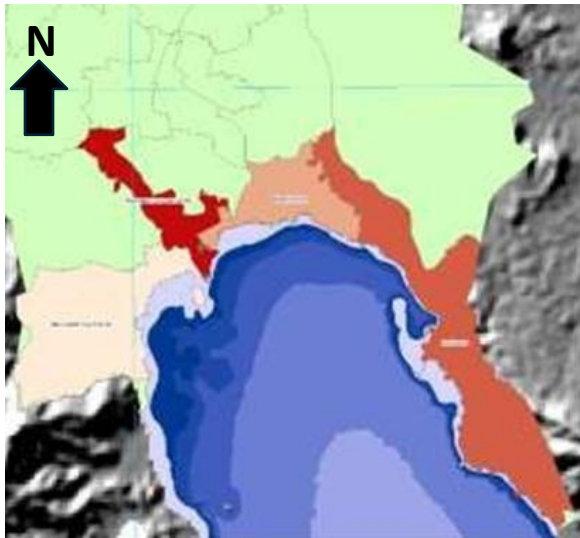


Figure 3. Level map settlement seedy coast of Bandar Lampung City

This increased risk becomes neither inclusive nor sustainable if these issues are not adequately addressed, as it negatively impacts the vulnerable populations living in these areas.

The level of slums in the coastal areas of Bandar Lampung City varies significantly, but the total slum area now accounts for more than half of the overall region. This is particularly evident in settlements directly bordering the coast, most of which are built on illegally occupied land. The high level of slum development is an indication that the communities living there are becoming increasingly vulnerable and at greater risk from the impacts of the ongoing climate crisis.

These conditions heighten the threat to these populations, emphasizing the need for special attention to the coastal slum areas of Bandar Lampung City. In particular, there is a pressing need to address inclusivity and sustainability in the provision of clean water, as access to clean water is a fundamental human right that must be fulfilled

A. Urbanization and Climate Change Challenges In Coastal Area

Hydrometeorological disasters are increasingly frequent, a trend that has profound implications for coastal communities in Bandar Lampung, particularly those residing in slum settlements. These areas, characterized by high population density, such as North Teluk Betung and Bumi Waras, face significant vulnerabilities exacerbated by climate change.

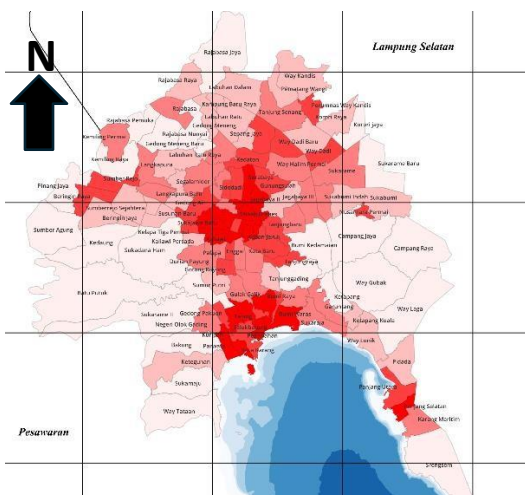


Figure 4. Density Map

The impacts of these disasters manifest in various forms, including tidal flooding and inundation during tidal surges, which lead to extensive disruptions in daily life. Residents in these densely populated sub-districts often endure prolonged interruptions to their daily activities and suffer considerable material losses. Floodwaters can damage not only buildings but also electronic devices and other valuable possessions, further compounding the economic and emotional toll on affected families.

Access to safe, clean drinking water emerges as one of the most critical challenges during and after these flooding events. The inundation often contaminates local water supplies, making it exceedingly difficult for residents to obtain clean water for consumption. With drainage systems frequently clogged due to debris and urban runoff, the problem is exacerbated during intense rainfall, leading to severe flooding that can engulf entire neighborhoods.

In light of these challenges, effective disaster management efforts must prioritize ensuring that basic needs, including access to clean water and sanitation, are met both during the disaster and throughout the recovery and post-disaster transition phases. This requires implementing sustainable practices that guarantee continuous access to safe water under all conditions, which is essential for safeguarding public health and well-being.

Furthermore, addressing the specific vulnerabilities of coastal areas is crucial in developing resilience strategies. As these regions face increasing threats from climate change, including flooding and poor sanitation, it is imperative to invest in robust infrastructure improvements, such as better drainage systems and reliable water supply networks. Such measures will not only enhance immediate disaster response capabilities but also contribute to long-term community resilience against future hydrometeorological challenges.

Table 2. Community Water Sources

District	Sub District	River overflow	Clogged drainage	High rainfall
Bumi Waras	Garuntang		1	5
	Kangkung			5
	Sukaraja			1
Teluk Betung Timur	Keteguhan	1	1	
	Perwata		1	

The table above shows the daily water demand, measured in liters, for slum settlements in the coastal areas of Bandar Lampung City. The Bumi Waras District has the highest percentage of water demand because its settlements are relatively more congested compared to other districts. A total of 3,130 liters per day is required by residents in the slum areas along the coast, which represents a significant amount and a considerable proportion of household expenses.

Access to reliable water sources is already difficult, and the local PDAM (municipal water utility) has struggled to extend its reach to these areas. As a result, residents rely on bottled or gallon water and water from vendors as short-term solutions. However, these options are not sustainable, particularly during disasters when the regular water distribution is disrupted. This leaves the community in a precarious position, highlighting the need for a more reliable and long-term solution to their water needs.

The current need for clean water in coastal communities is primarily met through daily water sources that residents rely on. Most areas face significant challenges in obtaining clean water, with many people resorting to using bottled gallon water or water in containers to meet their daily needs, as well water from

wells is no longer viable. This is particularly true for districts like Bumi Waras and Panjang, which are located directly along the coast.

Residents in these areas rely on repeated daily deliveries of water via containers and gallon refills transported by water carts. These water sources are located in the more inland districts, a considerable distance from the coast, where groundwater is still accessible. However, not all settlements have access to PDAM water pipe networks. Dense settlements, many of which are illegal, pose significant barriers to water distribution due to limited access for infrastructure development.

As a result, residents spend a significant amount of money on water. Public awareness of how difficult it is to access water in these overcrowded coastal slum areas is limited, especially since many of these settlements are informal or illegal, making it challenging for government assistance to reach them. Despite these hardships, residents continue to rely on informal means to survive and meet their water needs (Ilmi et al., 2021).

Urban flooding has significantly impacted local communities, particularly in the Bumi Waras and Teluk Betung areas. This issue is also believed to affect two other sub-districts. Incidents of tidal flooding, river overflow, and water accumulation due to heavy rainfall have been observed annually over the past decade.

In response to these conditions, local residents have adapted their building practices by using materials such as concrete to reinforce structures. They have also raised the height of their buildings and created storage spaces beneath the roofs of their homes to safeguard belongings during emergencies. Additionally, they have elevated the floors of their houses, especially in kitchen areas, to mitigate the risks associated with flooding and tidal surges (Ilmi et al., 2020).

B. Slum Conditions and Water Scarcity

Environmental conditions play a crucial role in shaping the health outcomes of local communities, particularly in the context of climate crises. The interplay of changing weather patterns—such as rising temperatures and humidity—creates an environment conducive to the proliferation of disease-carrying mosquitoes, notably those responsible for dengue fever. This health risk is further compounded by declining water quality resulting from increased contamination, which can lead to waterborne diseases like diarrhea.

In Bandar Lampung City, these challenges are acutely felt by residents of coastal slum areas, where over 50% of the land in four coastal districts—Teluk Betung Timur, Teluk Betung Selatan, Bumi Waras, and Panjang—is occupied by slum settlements. The high population density in these areas heightens the risks associated with poor environmental conditions, making them more vulnerable to health crises.

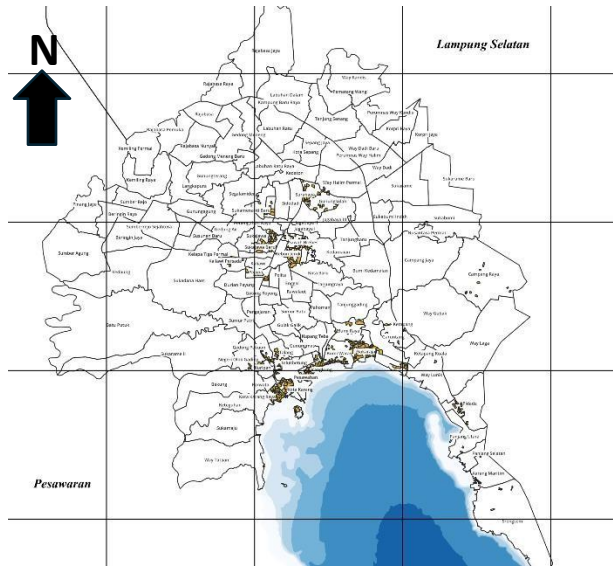


Figure 5. Slum Map

Access to clean water is limited in these coastal districts, forcing residents to rely on expensive alternatives such as refillable water gallons and water cart deliveries. This dependence on costly water sources exacerbates existing economic challenges, particularly in slum areas where financial resources are already constrained. Alarming, only 0.02 percent of the water needs in these coastal areas can be formally met by government provisions, with Teluk Betung Selatan and Timur facing the lowest availability of clean water services. This inadequate formal supply correlates closely with the prevalence of slum settlements, highlighting the systemic challenges faced by these communities.

Table 3. Water Provision

District	Refill water	Cart	Well water	Formal (PDAM)
Bumi Waras	3205lt	0	150lt	65lt
Panjang	368lt	95lt	0	45lt
Teluk Betung Selatan	120lt		1000lt	15lt
Teluk Betung Timur	100lt		1980lt	20lt
Total	3793lt	95lt	3130lt	145lt

However, amid these challenges, informal methods of water provision have emerged as a crucial lifeline for residents. While not sustainable in the long term, these informal sources can temporarily alleviate the immediate water scarcity and help communities cope with the adverse effects of flooding and climate change. Nevertheless, these solutions are not a substitute for comprehensive, sustainable urban water management strategies.

Therefore, efforts to ensure urban water provision must be integrated with initiatives aimed at improving environmental conditions and promoting healthy lifestyles. If these deteriorating environmental and health conditions are left unaddressed, they will worsen over time, increasing the vulnerability of coastal communities. This necessitates a holistic approach that incorporates environmental management strategies alongside urban water supply solutions, thereby safeguarding public health and enhancing community resilience against the challenges posed by climate change.

C. Economic and Health Impact

Public access to water in Bandar Lampung City demonstrates significant disparities, closely linked to household income and expenditure on daily water consumption. Analysis of the income and expenditure data reveals that a substantial portion of household income—up to 50%—is allocated for water needs, particularly among residents in the Bumi Waras and Panjang sub-districts. Here, the economic burden of water costs is felt acutely, as many residents rely on purchasing refilled water and gallon containers to meet their daily consumption requirements. This reliance on expensive water alternatives is compounded by a lack of subsidies for basic needs, which places additional strain on already tight household budgets.

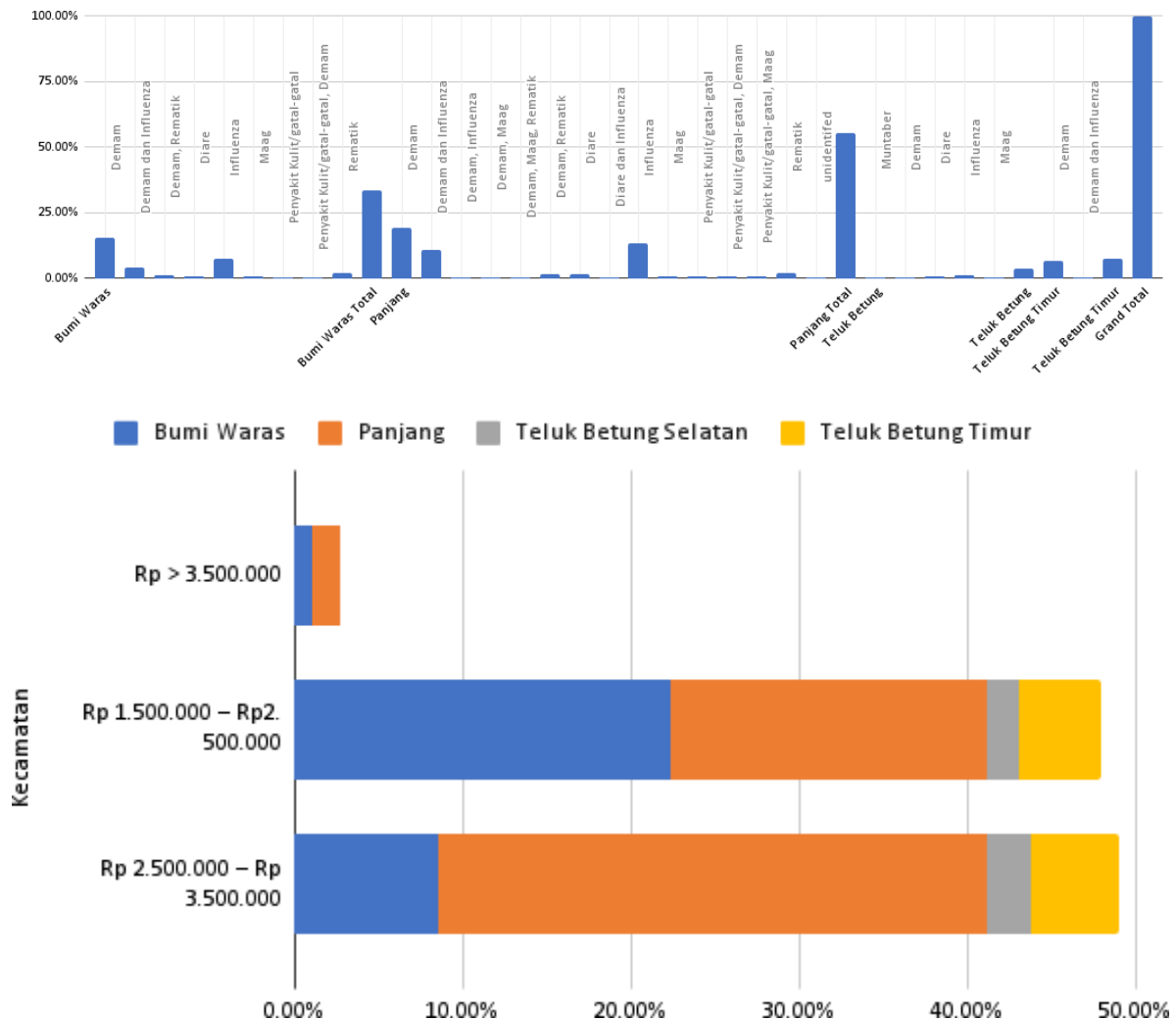


Figure 6. Income and Expenditure for Water Consumption

In some cases, households may spend as much as 1 million rupiah solely to access water, highlighting a significant financial commitment that underscores the vulnerability of informal coastal communities. This suggests that if a formal water supply system were available, residents could potentially afford a more stable and reliable source of water, alleviating some of the financial pressures they currently face.

Moreover, the challenges associated with accessing safe, clean water are exacerbated by the frequent flooding and poor sanitation conditions prevalent in coastal slum areas. These environmental factors contribute to a range of public health issues, including the spread of waterborne diseases such as diarrhea and vector-borne diseases like dengue fever. During flooding events, the difficulty of obtaining clean water becomes even more pronounced, as contaminated water sources pose severe risks to community health.

To effectively address these interconnected challenges, there is a critical need for enhanced urban water supply systems, particularly in the coastal slum areas of Bandar Lampung City. Investments in urban infrastructure that improve access to clean water are essential. Additionally, ongoing improvements to drainage networks and river basins are necessary to maintain surface water quality and mitigate the impacts of flooding.

Incorporating alternative water supply solutions, such as rainwater harvesting and brackish water distillation, can also play a pivotal role in providing residents with more reliable sources of clean water. Such measures would not only help to meet current demands but also contribute to long-term sustainability and resilience against the adverse effects of climate change and urban flooding. Through a comprehensive approach that prioritizes both formal water supply systems and alternative methods, the health and well-being of coastal communities can be significantly improved. Figure 6. Health Conditions in Slum Areas.

2.2. Discussion

A. Inclusivity

Access to drinking water is a shared responsibility among the central government, provincial authorities, and local governments. In many developing countries, even with ample water supplies, inadequate regulations can lead to exploitation by private companies, mirroring issues observed in developed nations where profits from water supply often benefit unrelated sectors (Handipuro, 2003). This mismanagement can jeopardize sustainability.

In Lampung Province, including Bandar Lampung City, local authorities are focusing on developing a clean water supply system through improved piping networks. This effort is outlined in the 2022 Government Plan for Drinking Water Provision (PKPCK Service, 2021). Interviews and observations indicate that the public desires an inclusive and sustainable water supply system, with potential subsidies from local governments through regional enterprises.

Efforts to enhance urban water access in coastal areas of Bandar Lampung City are crucial, especially in the face of climate change. Inclusivity in this context reflects the diverse and heterogeneous nature of coastal communities, which embrace various cultural and social activities. Despite facing challenges from rising tides and increased flooding, many households now have access to basic necessities like clean water and electricity.

However, simply adapting homes to higher elevations is insufficient. There is a pressing need for mitigation strategies to address climate-related risks. Efforts to provide clean water must consider local social and cultural aspects to ensure fair and equitable access. This holistic approach will enhance sustainability and improve the overall well-being of coastal residents.

B. Sustainable

In sustainable development, governance involves collaborative efforts that integrate human development, economic growth, and environmental protection. Key principles for effective governance include participation, the rule of law, fairness, inclusiveness, efficiency, responsiveness, transparency, accountability, and consensus-building (BAPPENAS, 2020).

In Bandar Lampung City's coastal slum settlements, the community has demonstrated these principles while striving for sustainable urban water supply. Residents allocate a significant portion of their expenses to meet clean water needs and have shown resilience in responding to disasters, even without fully understanding the climate crisis. Research by Ilmi et al. (2020) indicates that these coastal communities have adapted to environmental challenges by leveraging local resources and fostering strong communal ties, particularly during disasters.

Moreover, the community plays a vital role in supporting initiatives from central and local governments, such as the KOTAKU program, PNPM, and PAMSIMAS, although these programs may not always operate optimally. To enhance sustainable clean water provision, it is crucial to consider local environmental conditions and optimize future water availability.

Utilizing regional water supply systems (SPAM) and harnessing dams on major rivers, such as the Way Sekampung and Way Tulang Bawang, can create sustainable water sources. However, this must be accompanied by environmental restoration activities to enhance ecological functions within river watersheds and urban ecosystems. This collaborative approach to clean water management not only ensures access for all communities, especially those in vulnerable coastal slum areas but also fosters good governance, responsive to community aspirations and capable of managing strategic environmental changes effectively.

C. Healthy and Resilient City

Healthy and resilient cities require an inclusive and sustainable approach to providing clean water. Inclusivity means ensuring equal access to drinking water for all communities, especially marginalized coastal areas, supported by strong regulations to prevent the exploitation of water resources. The strategic development of the Lampung Province Regional Drinking Water Supply System is aimed at ensuring a fair distribution of clean water through a comprehensive pipe network.

Sustainable water governance also necessitates collaboration among government, society, and the private sector to utilize water sources efficiently and sustainably. By adhering to principles such as participation, transparency, and accountability, this initiative aims to meet basic societal needs while enhancing resilience against the climate crisis, particularly in disaster-prone regions like the coastal areas of Bandar Lampung City. Effective and inclusive water resource management will lead to a healthier and more resilient urban environment for all communities.

3. CONCLUSION

Efforts to provide urban water in Bandar Lampung City must be inclusive and sustainable, especially for coastal slum areas. These communities face significant vulnerabilities due to the climate crisis, poor economic conditions, and external factors that threaten their quality of life.

To build healthy cities, equitable access to safe and clean water is crucial for public health and resilience. Expanding urban water infrastructure and improving drainage systems will enhance access and mitigate flooding. Incorporating alternative solutions like rainwater harvesting and brackish water desalination can effectively address water shortages and flood risks while promoting community participation.

Additionally, raising public health awareness about clean water practices and disaster preparedness is essential. Community-based initiatives can empower residents to adopt safe water habits and better prepare for environmental challenges.

Sustainable and inclusive governance requires collaboration among all stakeholders to ensure safe, adequate clean water and sanitation. Upholding principles of participation, fairness, and efficiency will lead to a healthier, more resilient urban environment for all residents in Bandar Lampung's coastal slums.

4. Acknowledgements

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