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Selecting methods for water resources in coastal area: Comparative study cases of Hong Kong and Jakarta

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Abstract. *Environmental problems in coastal areas are related to water resources. This is due to the high demand as a result of population activities on the coast beside the water quality on the coast is less good than that on the mainland. The objective of this study is to review and compare the selection of clean water supply methods and their alternatives, especially in Hong Kong and Jakarta, from a public policy point of view. Hong Kong has a variety of water supply methods. Currently, the ones that are still used are seawater toilet flushing and water imports from China. In policy formation, Hong Kong has not looked at it holistically or is still traditional. In Indonesia, water resources are the obligation of the state to meet the needs of its population in accordance with the 1 945 Constitution. Jakarta's coastal areas have not fully experienced access to piped water to date, so the Provincial Government has chosen the method of providing water according to public acceptance.*

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INTRODUCTION

Water resources are one of the environmental problems faced by residents in coastal areas. The demand for fresh water in coastal areas puts pressure on the availability of freshwater sources, causing water shortages due to the exploitation of water resources and saltwater intrusion (Jeuken *et al.*, 2017). Factors causing the high demand for water in coastal areas include population growth and rapid social and economic growth, so there will be conflicts over freshwater demand (Liu *et al.*, 2019; Wang *et al.*, 2020). Intensive human activity is also a threat to the system's sustainability in urban areas, especially in the increasing consumption of water outside of household needs which must be considered when measuring water quantity. (Maurya *et al.*, 2020; Shen *et al.*, 2020). The problem of water supply is not only in terms of quantity. It is also related to water quality. Several factors influence people's perceptions of water quality, especially water intended for consumption, such as taste, perception of health risks, past experiences, trust in water services, the influence of impersonal and interpersonal information, and demographic variables (Doria *et al.*, 2009 in Ochoo *et al.*, 2017). For example, in one natural water source, groundwater is a water source that is often found with E. coli pathogens (Rinanti *et al.*, 2021), where this pathogen can pose a health risk to infants, and young children, and people with impaired immune systems, causing meningitis, and ground stream infections (Ananth *et al.*, 2018; Rohmah *et al.*, 2018).

In the article entitled "Economic and Environmental Sustainability of The Optimal Water Resources Application for Coastal and Inland Regions" written by Liu *et al*. in 2021 posted on *Journal of Cleaner Production*. The study addresses the global sensitivity of the critical influencing factors between water characteristics and geography and assesses water supply systems for coastal and inland areas from an economic and environmental perspective. The global sensitivity helps evaluate the sensitivity index of the parameters that affect the category to see alternative water sources according to the study location. That uses the south of Hong Kong as the coastal area and the northern part as the mainland. Overall, the area in Hong Kong to meet freshwater needs has been imported from Guangdong, China, since 1960 (Li *et al.*, 2021). The application of water resources using the Seawater Toilet Flushing (SWTF) system is an alternative to supplying freshwater implemented for six years in 85% of the population in Hong Kong. The SWTF system is considered the most feasible even though it requires quite a lot of piping for distribution and disposal of the waste back to the sea.

Currently, Jakarta is experiencing rapid population growth, causing a shortage of freshwater, a risk of flooding, and land subsidence due to overexploitation of groundwater (Luo *et al.*, 2019). However, groundwater conditions in the groundwater system in the northern area of Jakarta, especially in the western part, have experienced a high increase in salinity since 1994 (Asseggaf *et al.*, 2017). With high salinity conditions and land subsidence, one of the coastal areas in Jakarta is experiencing the impact, namely the Muara Angke fisherman settlement. According to Saniti (2012), piped water has not yet reached the settlement location, so residents in fishing settlements rely on groundwater purchased through traveling water merchants to meet their daily clean water needs.

Based on the article Liu *et al.* (2021), which discusses the selection of clean water supply methods in Hong Kong, this study discusses comparisons in the selection of clean water supply methods and alternatives that are carried out in Hong Kong and compared with supply methods in Indonesia from the point of view of public policy point of view. In Indonesia, it will be more precisely located on the coast of Jakarta, especially in the fishing settlements of Muara Angke. Based on the review and comparison of the two countries' selection of the clean water supply methods and their alternatives, it will be known that public policies can be implemented on the Jakarta Coast in the provision of clean water.

METHOD

The method used in this study to compare clean water supply methods from a public policy point of view is descriptive research. Descriptive research can use a quantitative approach by collecting and measuring data in the form of numbers or a qualitative approach by representing the situation using words. This study is more inclined to qualitative descriptions because it explains the differences between the two selection methods of the provision in a narrative manner.

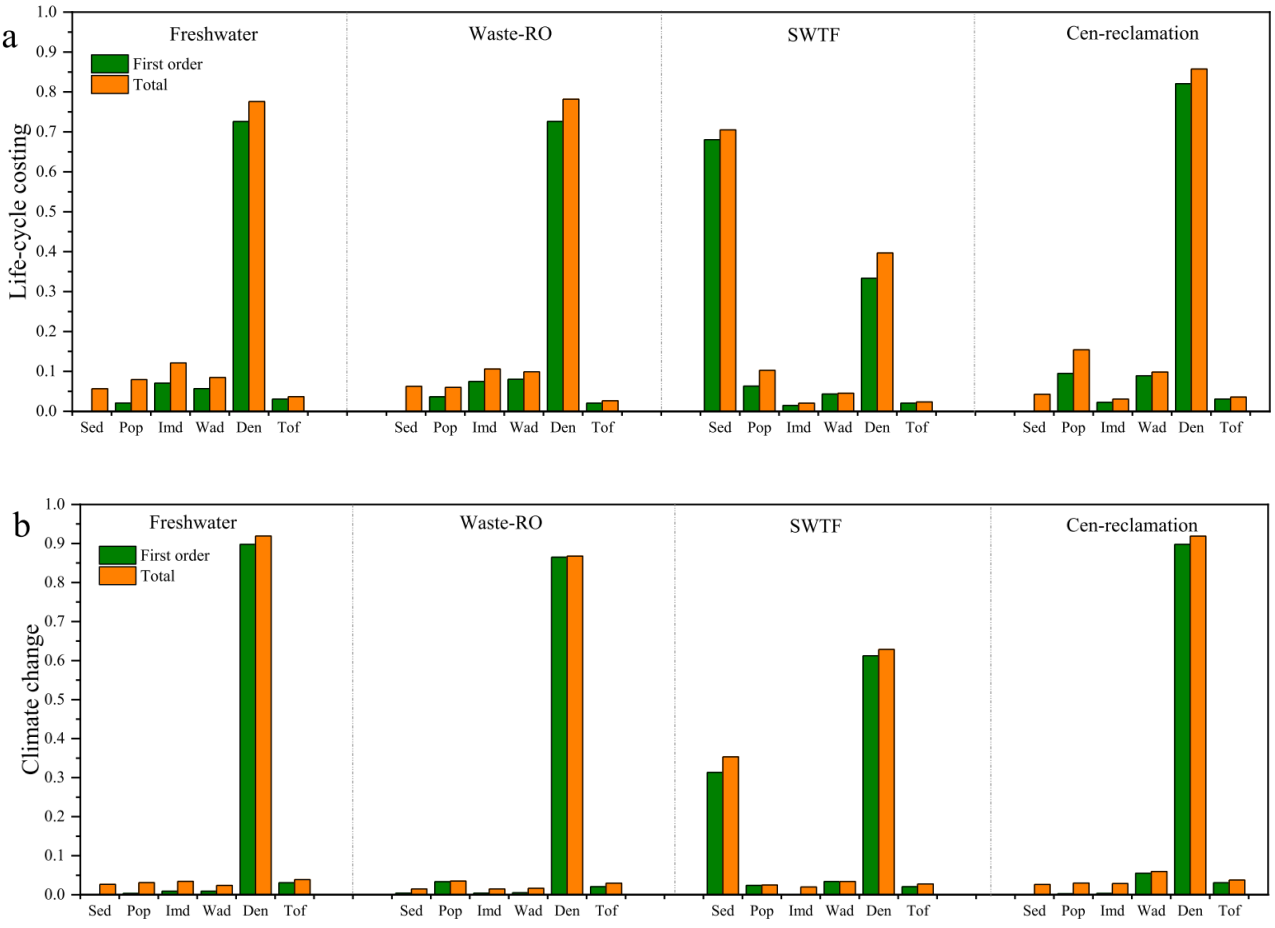
Each selection of water supply methods in the two countries is explained based on a similar study, namely government policies, perceptions, and economic effectiveness calculations from various water supply methods choices, especially in Hong Kong and Jakarta. It is necessary to analyze the DKI Jakarta provincial government's policy stating the provision and service of clean water. For selecting a water supply method, it is essential to consider the choice of an economic calculation approach and user perceptions. Calculations are thus dependent on data availability and data collection methods. The comparison of water supply methods in Jakarta is carried out by referring to related documents and research. By documenting several policies and regulations in Jakarta, this study illustrates the differences in the concept of water supply. The analysis of the differences, supported by a literature review of many studies related to coastal water supply, was synthesized to build conclusions on improving water supply in Jakarta.

RESULTS AND DISCUSSION

Water Supply Selection Method in Hong Kong

The feasibility of using water resources is changed for various regions. For example, wastewater reclamation and wastewater desalination are feasible in inland areas, while seawater desalination and SWTF are more feasible for coastal areas. The advantage of using SWTF is that the treatment process is simple but requires a separate distribution pipe and an additional pipe to discharge the brine waste back into the sea. Seawater desalination can share a single water distribution system, but high construction and operating costs hinder its implementation. Previous articles have evaluated and compared several water resources to optimize water supply, which was determined solely for water and specific geographic conditions on a case-by-case basis. Therefore, the scope and conclusions are limited to areas experiencing water shortages with similar water conditions and geography. Influential factors that affect the installation of potential water resources are also still lacking, and it is necessary to identify proper water use.

The use of global sensitivity analysis considers the sensitivity index of the factors that influence the output in terms of economic and environmental performance in this article. Variable-based global sensitivity analysis was conducted to analyze the uncertainty of the influencing factors. The variables were randomly sampled and realized independently by the Sobol sequence. The global sensitivity analysis results (Figure 1) produce several scenarios based on the possible water sources used in Hong Kong. As can be seen in Figure 1, the x-axis is water resources, and the y-axis is the index of the global sensitivity analysis index. In the Freshwater, Waste-RO, and Reclamation scenario, the most sensitive factor is the effective population density, the distance to the coast is also essential in the SWTF scenario. Distance to the beach is the most important factor from an economic point of view, while population density is the most important factor from an environmental point of view.



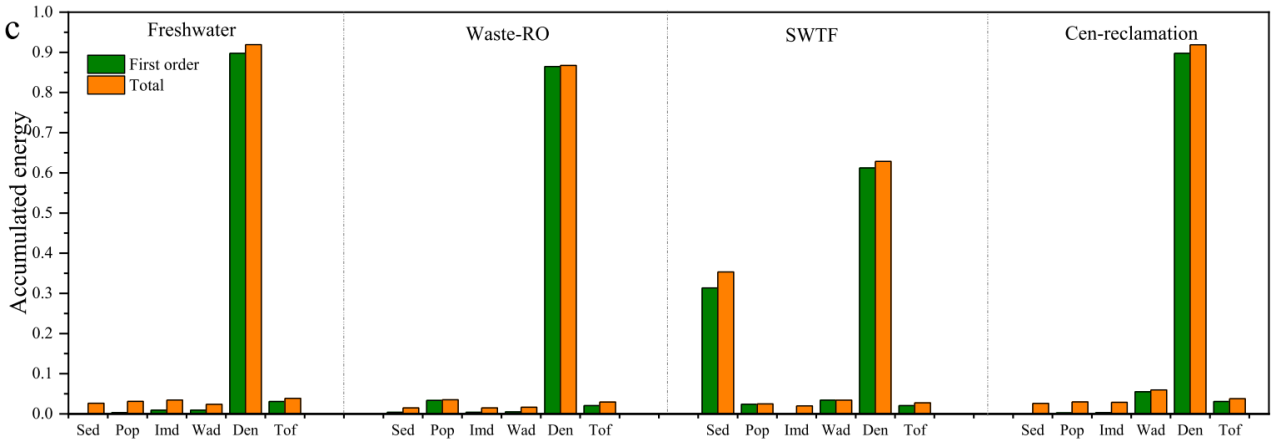


Figure 1 Results of Global Sensitivity Index of (a) life cost, (b) climate change, and (c) energy accumulation analysis with Global Sensitivity Method (Source: Liu *et al.*, 2021)

One reason is that the main factors affecting distance to shore and effective density are independent. Another reason is that they are separate from other factors. The demand for water multiplied by the population yields the total water demand. These factors affect the capacity of the water component. Global sensitivity analysis shows that effective population density and distance to shore are the two most influential factors.

From an economic point of view, it can be observed that the higher the population density, the lower the total cost. This is because pipe utilization increases in more densely populated areas. In addition, the unit cost of SWTF increases with increasing distance to the seafront due to the additional pipelines required to extract seawater and discharge saltwater waste back into the sea. Based on a comparison of several alternatives, the most suitable for economic and environmental conditions is the SWTF system. From an environmental perspective, the area far from the coast is 90 km, with the SWTF system the most potential, although the reclamation system is more environmentally friendly if the distance is far from the coast. Meanwhile, from an economic perspective, the SWTF system is most effective with a minimum population density of more than 17 000 people/km^2, while the RO-waste system is recommended if the population density is low or in remote areas.

From the public point of view, the use of SWTF is still expensive because of the distribution system. However, this article proves economically and environmentally feasible, especially in coastal areas with dense populations. Although the amount of water from toilet flushing was focused on and compared with alternative water sources, the findings of this article are not limited to water quantity. The attitude of the community will also affect the application of water resources. To build a double pipe network for seawater or reclaimed water for flushing toilets, it is necessary to repair the existing pipe system, which can cause inconvenience to the community. Moreover, desalinated wastewater for drinking purposes is not easily accepted psychologically because it is sourced from factory wastewater. So good water resource management is not only done from an economic and technical perspective but attention must also be paid to be accepted by the community. Environmental impacts only consider climate change and energy accumulated due to data limitations, implications of eutrophication, acidification, ozone depletion, etc. These are also essential impacts for ongoing evaluation and should be included in the future.

Water Supply Policy in Hong Kong

The article that examines alternative water supply systems for economic and environmental sustainability in coastal and inland areas is entitled "Economic and Environmental Sustainability of the Optimal Water Resources Application for Coastal and Inland Regions," written by Liu *et al.* (2021). Although many types of research on alternative water supply have been carried out, with a global sensitivity

analysis, there is still very little, especially considering the factors that influence the identification of proper water use. There are two types of areas experiencing water shortages: coastal areas with high population density and inland areas. The selection of freshwater sources with reclamation systems and RO (Reverse Osmosis) with water desalination systems requires high costs. Currently, to meet the need for freshwater, settlements on the coast of Hong Kong import water at the cost of 0.94 US$/$m^3$ in 2017. In the study by Li *et al.* (2021) the average household in Hong Kong spends USD 6 per month for clean water, but around 14% of customers are provided with free water access.

Currently, the water supply in Hong Kong consists of three sources, namely reservoir water, purchased water, and seawater for flushing. The policy implication in Eiff and Pommeret (2021) is that by using a varying risk profile approach, it is necessary to add water supply targets for the future by water supply managers, with a desalination system in Hong Kong being the right choice, even though it has high costs. While the alternative water supply carried out by (Liu *et al.*, 2021) uses a global sensitivity approach, it was found that for coastal areas using seawater for flushing is the most effective, but for some other areas using the most economical waste-RO system. Apart from the SWTF system, it is the most environmentally friendly water supply system for cities that are indicated to have water shortages.

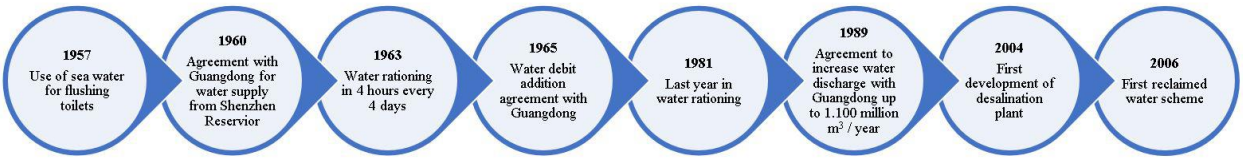


Figure 2 Water supply policy timeline in Hong Kong

Source: Water supply department the government of the Hong Kong Special Administrative Region

In the provinces of Guangdong and Hong Kong, the political ecology of water supply is regional. They were characterized by interdependence between cities in various aspects of water supply management, including institutional arrangements and shared infrastructure to facilitate. Hong Kong and China's administrative systems remain largely unintegrated, presenting challenges for collaboration on more strategic matters beyond water transfer. Hong Kong's executive and standard law systems differ from the top-down and politicized bureaucracy of China's central and local governments. A history of operational cooperation limits determines the regional governance of water resources between Hong Kong and Guangdong by water supply contracts. However, the challenges currently faced by Hong Kong are extreme weather and an increase in water demand in the long term, which will affect the relationship between the governments of Hong Kong and Guangdong. Therefore, collaboration is needed for managing water demand with a commitment to reducing the water footprint in each region. In addition, in the article, Hartley *et al.* (2018) require sacrifices, especially for Hong Kong, in water rationing or renegotiating water supply contracts.

Meanwhile, in the article “Hong Kong's water security: a governance perspective” written by (Wang and Dai, 2021), another challenge that Hong Kong faces in water security is in the science-policy sector, where the relationship between traditional technocracy and holistic and integrative policy development is not always the case—well coordinated. However, more important is that limited resources have been invested in the institutions and capacities to support policy reforms. One of the policies implemented by Hong Kong in 2008 was the total water management strategy by the Department of Water Supply. The drawback of water governance reform in Hong Kong is that it barely touches on the overall discrepancies that pose a fundamental challenge. The changes that take place are focused on practical problems that will occur depending on traditional governance systems and institutional segmentation.

Water Supply Policy in Jakarta

In the fourth paragraph of *Pembukaan Undang-Undang Dasar 1945*, the ideals of independence are written, namely realizing general welfare and educating the nation's life. The provision of sustainable clean water for the entire community is one of the efforts to realize these ideals. In addition, it is also stated in *Undang-Undang Dasar 1945 Pasal 33 ayat 3* that the earth, water, and natural resources contained therein are controlled by the state and used for the greatest prosperity of the people. More than 60% of Jakarta's population relies on groundwater to meet their clean water needs, whereas constructing complex wells requires high costs to reach uncontaminated water (Furlong and Kooy, 2017). The use of groundwater is very influential on land subsidence, especially on the north coast of Jakarta, which reaches 8.2 cm/year, especially in 2016-2017 (Cyntia, 2018). Unfortunately, piped water provided by the DKI Jakarta provincial government through the regional drinking water company has not flowed to all areas in Jakarta, especially in the fishing settlement of Muara Angke (Saniti, 2012).

To meet the need for clean water with groundwater conditions on the coast of Jakarta, which has experienced high salinity, rainwater harvesting methods can be used. This method is considered to have a high enough potential to overcome clean water in Jakarta if the people want to do water conservation with this method (Ruqoyyah *et al.*, 2018). Hargianintya (2019) conducted research and created a simple rainwater harvesting system for the citizens association or Indonesian called *rukun warga* (RW) scale in Muara Angke. Specifically the use of rainwater harvesting is intended for ablution water in the Islamic Prayer Room (*Musholla*). With this rainwater harvesting method, it can save residents' expenses to meet the needs of clean water that can be used for bathing, latrines, and ablution because it has met the clean water quality standards regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements For Sanitation Hygiene Purposes, Swimming Pools, Solus Per Aqua Solutions, And Public Bathings. This method is very dependent on the influence of community acceptance with this method compared to the use of groundwater which is usually the main source of water for the community in Muara Angke.

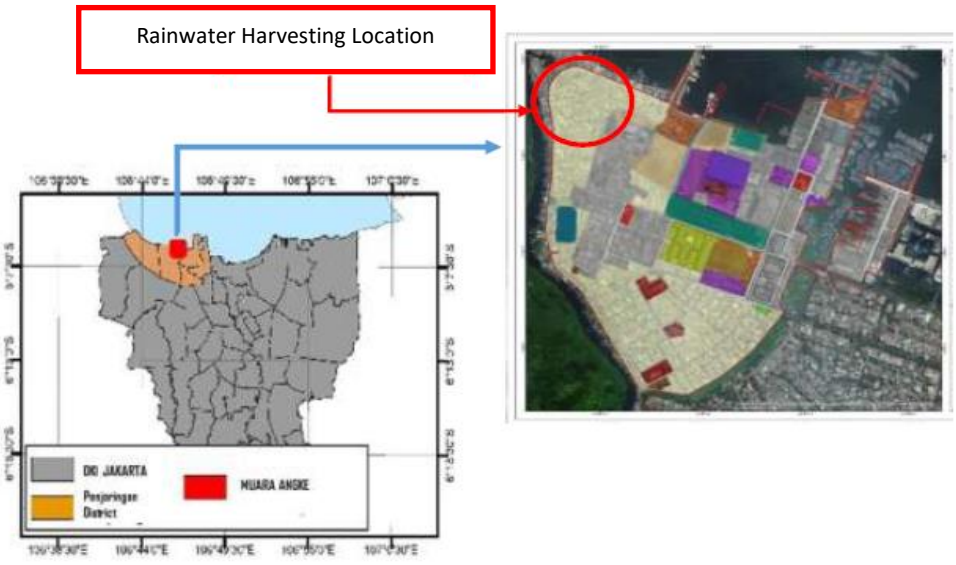


Figure 3 Location of Muara Angke rainwater harvesting system (Source: Hargianintya, 2019)

Based on a survey conducted by Rujak Center for Urban Studies and *Jaringan Rakyat Miskin Kota* in 2020, the average expenditure of the population to meet water needs is IDR 500 000-800 000 per month (Elisa, 2020a). To meet the need for clean water used for washing hands during the Covid-19 pandemic, the Rujak Center for Urban Studies invited PAM Jaya, the Urban Poor Consortium, and *Koperasi Rakyat Eceng*

Sejahtera to provide communal handwashing facilities. Construction and procurement capacity is still limited due to high costs. This activity is one of the temporary alternatives carried out by the DKI Jakarta provincial government with PDAM Jaya with the DKI Jakarta Governor's team for the acceleration of development and the regional apparatus work unit related to a program called water kiosk. This water kiosk is in the form of a water reservoir with a capacity of 4-5 cubic liters to facilitate settlements that do not have access to piped water. Until 2021, 50 kiosks have been built, and the target by 2022, the DKI Jakarta provincial government will build 100 kiosks. The tariff is set at IDR 400 per jerry can regulated in *Peraturan Gubernur DKI Jakarta Nomor 57 Tahun 2021*.

Figure 4 Communal handwashing installation and water kiosk deployment points (Source: Elisa, 2020b and Anandi and Sar, 2020)

In addition to water kiosks, in the 2020 DKI Jakarta TGUPP annual report (Anandi and Sar, 2020), it has also begun to build Sea Water Resource Osmosis (SWRO). Until 2021, SWRO coverage in Kepulauan Seribu has reached 90%. These two methods are carried out to cover the shortage of raw water, which is currently still under construction for PAM Jaya's Drinking Water Management System (SPAM), and communal ones whose capacity is limited to 5 000 liters/second, which can serve 500 000-700 000 people. The development of this drinking water management system in DKI Jakarta is dependent on the central government at the Ministry of Public Works and Public Housing. Meanwhile, the SWRO method is still focused on the Kepulauan Seribu and is installed on ten islands. Currently, the gubernatorial regulations and local regulations related to the construction of drinking water facilities are still in the finalization stage. One of the regulations that have been signed is the DKI Jakarta Governor Regulation No. 16 of 2020 concerning Procedures for Connecting and Using Drinking Water, where the contents of the regulation are changes related to PAM Jaya's authority to install pipes.

CONCLUSION

SWTF system is considered the most environmentally friendly but more expensive compared to the RO system. Using global sensitivity analysis, one would see alternative water supply from an economic and environmental point of view. The water supply policy in Hong Kong using three sources can be applied on the coast of Jakarta with high density, especially seawater sources for flushing. To achieve piped water supply, which requires time and high costs, DKI Jakarta has chosen an alternative, namely the water kiosk.

The RO system, which is considered expensive in Hong Kong, is one of the options for water supply in DKI Jakarta, especially in Kepulauan Seribu. The flushing system using seawater in DKI Jakarta is not an option, this method can be considered if the RO system still does not meet and the costs are high for the coastal areas of Jakarta. The rainwater harvesting system can be another alternative source to meet clean water needs if the community's acceptance of this system is high.

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