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# Strategy Analysis for the Fulfilment of Clean Water Needs Through Piped-Water Service in Metropolitan City during the COVID-19 Pandemic

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**Abstract.** This study aimed to conduct a strategy analysis to anticipate water scarcity and provide recommendations for the fulfillment of clean water needs through the Regional Drinking Water Company (PDAM) piped-water service in a metropolitan city during the COVID-19 pandemic. Several efforts have been made by PDAM, such as uprating the existing water treatment plant (WTP) and planning to build new ones. The analysis covered the piped-water service target in 2021, customer water consumption, PDAM production efficiency, and the non-revenue water (NRW) in the city before and during the pandemic. Subsequently, the existing strategy and targets were analyzed based on the comparison results. The outcomes would serve as the basis for the recommendations to overcome water scarcity. The results showed that there was an increase in customer water consumption during the pandemic by 5% (147 L/person/day) from the normal condition. Considering the 35% piped-water service coverage target set in 2021, the existing capacity of PDAM has not been able to meet customer needs both under normal condition and during the increase in consumption. Based on the results, technical recommendations include uprating the WTP capacity up to 2.13 times, reducing the water loss by 25%, and utilizing backup unit system to prevent disturbance to water distribution for 24 hours. These recommendations must be synchronized with the Drinking Water Security Plan (RPAM) in the city.

*Keywords:* Clean water supply; COVID-19 pandemic; Drinking water distribution; Piped-water service; Water scarcity

## 1. Introduction

Rising population and climate change are reportedly complicating the challenge of providing clean water worldwide. Approximately 2.2 billion people, accounting for a quarter of the global population, lack safe drinking water services, while 4.2 billion do not practice safe sanitation, and 3 billion are deprived of basic handwashing facilities (World Health Organization, 2019). In Indonesia, the National Medium-Term Development Plan (RPJMN) 2020–2024 is consistent with the 2030 Sustainable Development Goals (SDGs), aiming for 100% access to proper drinking water, including 15% safe drinking and 30% piped-water (Indonesian Ministry of National Development Planning, 2019). With a total population of 272.7 million (BPS-Statistics Indonesia, 2022), Indonesia currently has 90.8% access to proper drinking water, as well as 11.9% and 19.06% safe drinking, and piped-

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water respectively (Directorate General of Human Settlements-Indonesian Ministry of Public Works and Housing, 2022). The COVID-19 pandemic heightened the importance of clean water for handwashing and sanitation, as recommended by the World Health Organization (2020). Domestic water consumption during the pandemic increased from 147 L/person/day in 2018 (Depok City Government, 2021) to 157 L/person/day in 2020 (Iswara, 2021). According to the Indonesia Water Institute (2022), public clean water consumption surged to 3 to 5 times the normal levels.

Water scarcity results from a growing population using unsustainable resources, often compounded by drought due to climate change (Van-Loon and Van-Lanen, 2013). In Indonesia, areas facing both drought and water scarcity are projected to increase from 6.0% in 2000 to 9.6% in 2045 (Indonesian Ministry of National Development Planning, 2019). This scarcity arises from critical conditions in upstream catchment areas and excessive urban groundwater extraction, particularly in Java, Bali, and Nusa Tenggara (Indonesian Ministry of National Development Planning, 2019). The shortage extends to drinking water, with access to national piped-water reaching only 19.06% of the 30% target by 2024, and distribution remains uneven. Therefore, the government faces a substantial challenge in developing the national clean water infrastructure.

Ali *et al.* (2019) found that in Depok, six districts out of 11 faced moderate water stress, with three experiencing high stress, and two had very high-stress levels. To combat the expanding water scarcity, transitioning to piped-water is a primary solution. The COVID-19 pandemic has made clean water even more critical, specifically for proper handwashing to prevent virus transmission (Berawi *et al.,* 2020). Also, the challenge of accessing drinking water in West Java depends on efforts to establish household-level access and to enhance the currently limited capacity of PDAM to serve its customers through the pipeline network system (Sukoco, 2017). This poses a challenge for PDAM to increase piped-water service coverage. However, there is a lack of comprehensive analysis on addressing the increased demand for clean water during the pandemic, particularly in water-stressed areas. This study aimed to analyze clean water needs to ensure sufficient availability during the pandemic. Although immediate changes in clean water capacity are not possible, the results offer recommendations to stakeholders in making strategic plans for meeting clean water demands.

## 2. Methods

### *2.1. Study Area*

This study focused on Depok City, West Java, Indonesia, a metropolitan area with a population of 2,085,935 (BPS-Statistics of Depok Municipality, 2022). The proximity to the Indonesian capital has led to a population growth rate of 1.92%, up from the previous year (BPS-Statistics of Depok Municipality, 2022). This rapid growth, along with urban development and economic expansion, has increased the water consumption of residents (Herdiansyah and Putra, 2018). During the COVID-19 pandemic, 66% of city respondents reported increased water usage (Indonesia Water Institute, 2022). However, in 2020, only 13.9% of residents received water from PDAM (National Agency for Water Supply System Improvement, 2021). The remaining 86.1% relied on groundwater or other sources, which could be affected by seasonal variations (Hartono, Gusniani, and Adityosulindro, 2010).

### *2.2. Study Concept Framework*

This study was conducted in several steps, namely (1) data collection, (2) analysis of piped-water service based on the data obtained to compare conditions before and during the pandemic; (3) analysis of piped-water service coverage target based on the target set at

35% in 2021 to determine the capacity of PDAM in fulfilling the clean water needs, specifically during the pandemic, with two conditions, including increase and no increase in water consumption; and (4) recommendations for stakeholders in fulfilling the clean water. The detailed flow of steps for this study can be seen in Figure 1.

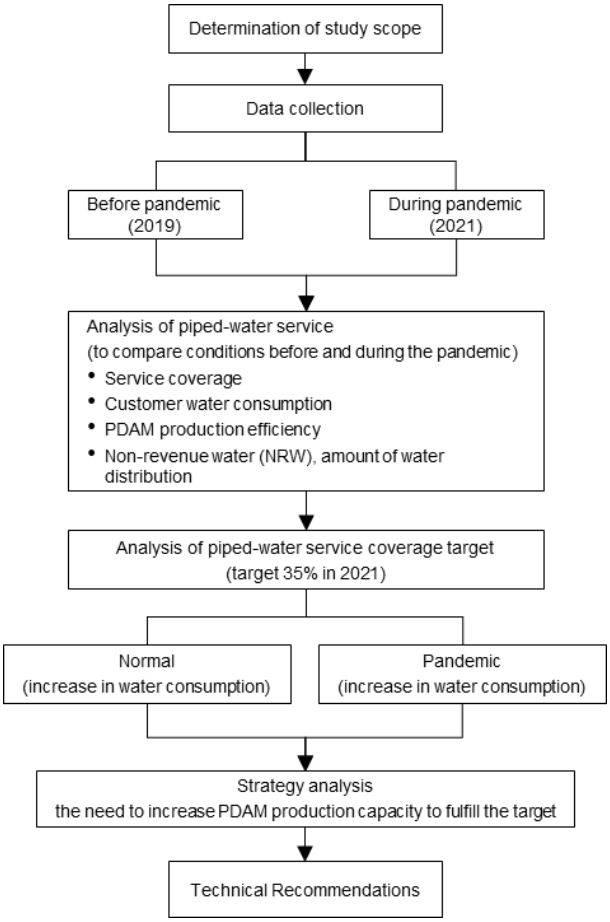


**Figure 1** Study concept framework

*2.3. Data Collection*

This study used both quantitative and qualitative approaches, utilizing data from PDAM and literature sources. The data collected comprised various factors, including city population, customer counts (house connections/HC), residents served by PDAM, monthly water usage, installed capacity, actual clean water production, and water loss (non-revenue water or NRW). The sources were the PDAM Performance Book 2020 (National Agency for Water Supply System Improvement, 2020), providing pre-pandemic 2019 data, and the Municipality in Figures 2022 (BPS-Statistics of Depok Municipality, 2022), offering information for the pandemic year of 2021.

*2.4. Analysis of Piped-water Service before and during the Pandemic*

The data collected were used to assess various parameters including piped-water service coverage, customer water consumption, PDAM production efficiency, and NRW calculations. These parameters were then compared before and during the COVID-19 pandemic. Calculations were conducted using equations from the Technical Guidelines of PDAM Performance Evaluation (National Agency for Water Supply System Improvement, n.d.). Table 1 shows an overview of the parameters and equations used.

In Table 1, parameter 1 calculated the population served by multiplying the number of active customers with an average of 4 people per household, according to BPS-Statistics of

Depok Municipality (2022). Parameter 2 assessed the total water usage as the average monthly consumption per PDAM customer, using the number of active customers. Parameter 3 measured PDAM production efficiency (equation 3), referred to as the utilization factor, gauging how installed capacity was effectively utilized. This parameter compared real production volume to the planned installed capacity. Furthermore, parameter 4, NRW, measured the disparity between water entering the distribution system and reaching PDAM customers. Water distribution quantifies the volume sent through pipelines, while usage records customer consumption.

**Table 1** The parameters for analyzing the piped-water service condition

| No. | Parameter | Unit | Equation[a] |
|---|---|---|---|
| Equation1 | Service coverage | % | $= \frac{Population\ served\ by\ PDAM\ (people)}{Total\ population\ in\ the\ administrative\ area\ (people)} \times 100$ |
| Equation2 | Customer water consumption | L/month /customer | $= \frac{Total\ water\ usage\ (L/month)}{Number\ of\ PDAM\ customers}$ |
| Equation3 | PDAM production efficiency | % | $= \frac{Real\ production\ volume\ (L/s)}{PDAM\ installed\ capacity\ (L/s)} \times 100$ |
| Equation4 | Non-revenue water (NRW) | % | $= \frac{Water\ distribution\ (L/s) - Water\ usage\ (L/s)}{Water\ distribution\ (L/s)} \times 100$ |

[a] National Agency for Water Supply System Improvement (n.d.)

### *2.5. Strategy analysis for the fulfillment of piped-water needs during the pandemic*

The use of urban water pipelines significantly impacts water availability for the population and influences network performance (Fontanazza *et al.,* 2007). Based on parameters calculated in the previous step, this study analyzed the provision of clean water during the COVID-19 pandemic in 2021, with a targeted 35% PDAM piped-water service coverage. This optimistic target aims to motivate residents in switching from ground to piped-water. The target is also in line with the government's plan to achieve 35% piped-water service coverage in 2021. The analysis considered two conditions: (1) normal water consumption with no increase, and (2) a pandemic scenario with increased water consumption (as calculated in Table 1). The results showed the need for uprating PDAM production capacity to ensure an adequate water supply, specifically during the pandemic when domestic water consumption increased. Uprating PDAM production capacity can be determined using the equation:

$$Uprating\ PDAM\ production\ capacity = \frac{Planned\ capacity\ (L/s)}{Existing\ capacity\ (L/s)} \quad (5)$$

The planned capacity was obtained from the result analysis as the level required by PDAM to meet the piped-water service coverage target of 35%, while the existing capacity referred to the current level in the production unit.

## 3. Results and Discussion

### *3.1. Overview of Regional Drinking Water Company (PDAM) in Depok City*

The Regional Drinking Water Company (PDAM) supplies clean water with a total production capacity of 1,080 L/s across three active water treatment plants: WTP 1 (620 L/s), WTP 2 (360 L/s), and WTP 3 (100 L/s). PDAM sources raw water from the Ciliwung River and Angke River, using a supervisory control and data acquisition (SCADA) system for precise operation. According to the National Agency for Water Supply System Improvement (2021), the overall performance of PDAM is rated at 3.91 as a Regionally

Owned Enterprise (BUMD) in the drinking water sector. This assessment considered various aspects, including financial, operational, service, and human resources. Customer water quality was rated at 4(good) on a scale of 1 to 5. However, piped-water service coverage, according to service coverage's equation number 1 (Equation1), remained significantly low at 17.15%, below the 20% threshold. In 2020, during the initial year of the COVID-19 pandemic, only 13.9% of the population used PDAM piped-water, while the remaining 86.1% relied on groundwater and other sources, causing a 20 cm/year drop in the groundwater level. The government has urged the use of piped-water systems to reduce reliance on non-piped sources, posing a challenge for PDAM to expand the service coverage to meet the clean water demands of the city.

### *3.2. Comparison of Piped-water Service Conditions before and during the Pandemic*

A comparison was conducted to assess whether customer water consumption increased during the pandemic compared to pre-pandemic conditions. This provided reference values for further analysis. Piped-water service coverage increased from 13.25% in 2019 to 14.42% in 2021 during the pandemic. Compared to 2020, the coverage increased by 0.5% (National Agency for Water Supply System Improvement, 2021). However, not all areas have PDAM piped-water service, as of September 2021, the coverage was at 14.05% (Figure 2). Most PDAM customers were located around water treatment plants (WTPs), with Limo, Cipayung, and Bojongsari Districts still having limited access. These districts were identified as having the highest water stress levels (Ali *et al.,* 2019). Special attention is needed to provide piped-water service to the areas, specifically those with high water stress, in the future.

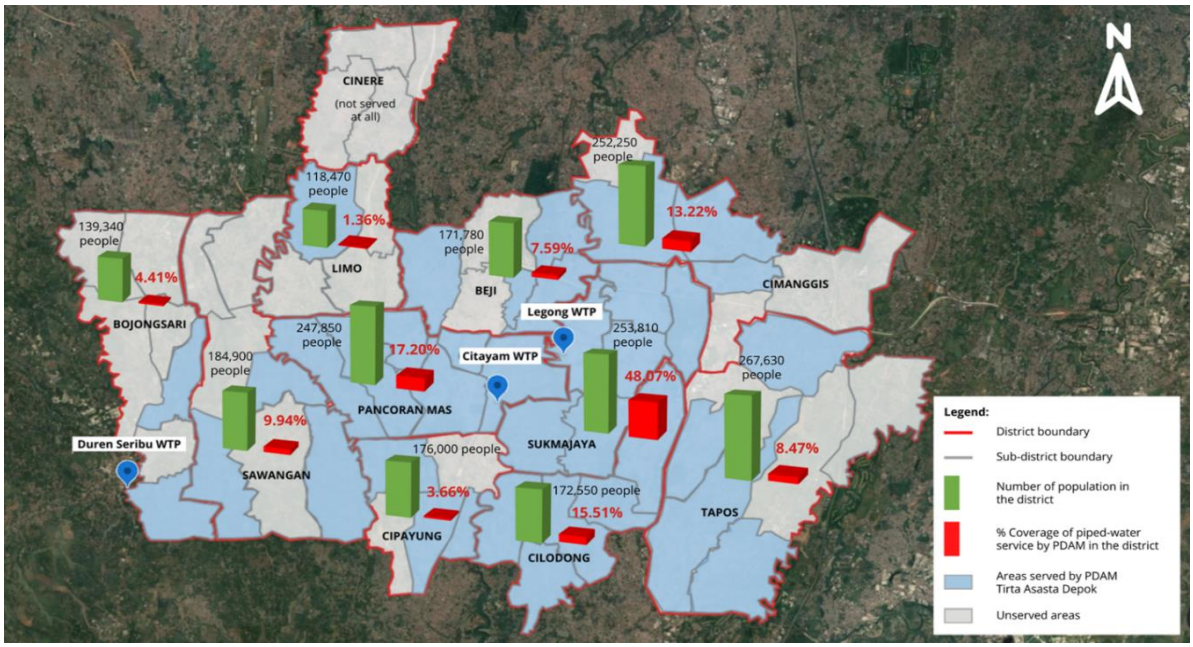


**Figure 2** Coverage of piped-water service by PDAM as of September 2021

Based on the rise in the piped-water service coverage, the total PDAM water usage has also increased, where the service coverage in 2013 was only 1.9% of the total population (Rachman *et al.,* 2019). By using Equation2, the results showed that the water consumption by customers increased by 5% compared to before the pandemic, from 139 L/person/day to 147 L/person/day. This value was higher than the water adequacy standard based on the World Health Organization (n.d.), which was 50–100 L/person/day, as the amount of water to meet basic needs and reduce negative impacts on health. The increase in water usage during the COVID-19 pandemic was also in accordance with a study conducted by the

Indonesia Water Institute (2022) in 2021, where 66% of the respondents in the city experienced elevated water usage during the pandemic, specifically for household sanitation activities. The customer water consumption before and during the pandemic obtained from the analysis was used as the reference value for the subsequent calculation.

The 2021 data obtained from PDAM included installed capacity (1,080 L/s), real production volume (865 L/s), and NRW level (35%). Based on these data, the production efficiency was 80%. Compared to the year before the pandemic, this value has increased, resulting in the use as a reference for the next calculation analysis. The 35% NRW value obtained was considered high, because the normal range should ideally be between 18 and 20% based on the Indonesian Ministry of Public Works and Housing (2018). This value was also far above the national NRW target of RPJMN 2020–2024, which was 25% (National Agency for Water Supply System Improvement, 2021). Therefore, the 25% NRW value was set to be the reference for the next calculation analysis. The NRW level is calculated from unbilled authorized consumption, customer meter inaccuracies, leaks in distribution pipes, leaks in customer pipelines to the point of water utilization by the customer (Farley et al., 2008). From the existing 35% NRW value by referring to equation4, the distribution was calculated, reaching 90% of water distributed in the real production volume. This indicated that there was still <10% of production water that was not distributed to the pipeline system.

### *3.3. Analysis of the Fulfilment of Piped-Water Needs during the Pandemic*

Determining a society's urban water needs is crucial (Johnstone *et al.,* 2012), this evaluation considered two scenarios: (1) normal conditions with no increase in water consumption, and (2) pandemic conditions, reflecting increased water demand. The 35% service coverage target set by the government for 2021 did not anticipate the pandemic. Consequently, the analysis demonstrated the necessity of enhancing PDAM production capacity to meet clean water demands, specifically during the pandemic. Table 2 in Section 3.2 summarizes the results, providing a comparison of piped-water services in 2021 under both normal and pandemic conditions.

**Table 2** Piped-water service analysis with service coverage target of 35% in 2021

| No. | Parameter | Unit | Year 2021 | |
|---|---|---|---|---|
| | | | Normal condition[a] | Pandemic condition[b] |
| 1 | Customer water consumption | L/person/day | 139 | 147 |
| 2 | Total PDAM water usage | L/s | 1,177 | 1,241 |
| 3 | Amount of water distribution | L/s | 1,569 | 1,655 |
| 4 | Real production volume | L/s | 1,743 | 1,839 |
| 5 | PDAM installed capacity (planned) | L/s | 2,176<br>≈ 2,200 | 2,296<br>≈ 2,300 |
| 6 | PDAM needed capacity | L/s | 1,120 | 1,220 |
| 7 | Uprating value of PDAM production capacity[d] | - | 2.04 | 2.13 |

[a] no increase in water consumption (as before the pandemic)
[b] there is an increase in water consumption by 5%
[c] using national target of NRW based on the RPJMN 2020–2024 (National Agency for Water Supply System Improvement, 2021)
[d] was calculated using equation in Section 2.5 (equation5)

Based on a service coverage target of 35%, approximately 730,077 residents were expected to be served by PDAM piped-water in 2021. As shown in Table 2, under normal condition, the amount of water distributed to the customers was lesser compared to during the pandemic. An increase in customer water consumption by 5% during the pandemic

significantly impacted the PDAM supply. To balance the optimistic service coverage target, the NRW of 25% was used as the water loss level based on the national target of RPJMN 2020-2024 (National Agency for Water Supply System Improvement, 2021). Therefore, actions are needed to reduce or control the existing NRW level which remains above 35%, specifically by repairing as well as maintaining the distribution network and the components.

The existing capacity of PDAM, namely 1,080 L/s, cannot meet the 35% target of service coverage in 2021, both in normal condition and with the increase in water consumption level during the pandemic. Based on the required real production volume of >1,700 L/s and 80% production efficiency determined by the calculations, the PDAM capacity needed was around >2,100 L/s. As stated in Table 2, water consumption during normal condition reached 2,200 L/s. Meanwhile, during the pandemic, the value was 2,300 L/s., suggesting the need for PDAM to increase the capacity to efficiently meet water needs.

The planned capacity required by PDAM to meet the customer water needs during the pandemic was 2.13 times the existing capacity. This term is known as uprating or doubling the production capacity of drinking water in the existing operation of WTP with higher treatment process performance. Uprating can increase the production capacity by 2-3 times (Pinheiro and Wagner, 2001), with a lower investment cost than building a new WTP (Sarbidi, 2018). The uprating project carried out, specifically at WTP 1, increased the existing capacity from 620 L/s to 1,300 L/s or about 2.1 times. Given the uneven distribution of piped-water service (Figure 2), new WTPs will also be built in Cimanggis and Cinere Districts. This development aims to expand the PDAM piped-water service in the eastern and western areas.

Based on the data as of September 2021, 10 out of 11 districts in the city have received PDAM piped-water service. Although the coverage of service remained relatively low (14.42%) and not evenly distributed, the customer water needs have continued to increase, specifically during the COVID-19 pandemic. This period requires more water than usual due to health protocols (Indonesia Water Institute, 2022). Therefore, this study is expected to provide an overview regarding the fulfilment of clean water needs of the people served by PDAM piped-water service.

### *3.4. Recommendations to Fulfil Piped-water Needs*

The performance of PDAM was relatively limited in meeting the clean water needs of the city. Ensuring an adequate water supply for all users is a crucial aspect of water resources management (Hapsari, Suryadi, and Tajalla, 2022). The interest of the residents in becoming PDAM customers was also low, due to the abundant access to groundwater which has reached 44.94% according to Indra and Ali (2018), leading to inefficiencies in the procurement and management of the piped-water network. Based on the analysis, the performance of PDAM must be improved, not only to meet the clean water needs of the residents but also to attract non-customers. Thus, a proper distribution system requires optimization (Rezagama *et al.,* 2020). Some recommendations for the piped-water service in the city are summarized in Figure 3.

To prevent disruptions in water supply for customers in the city, specifically during floods, proper system management is required. This is necessary because the production capacity tends to decrease during floods due to the turbidity of raw water. Proper management entails regulating the queue time for water supply to production units, ensuring readiness for distribution (Tadesse, Bosona, and Gebrensebet, 2013). There is also a need for network expansion as a backup and regular system maintenance (Sabara, Afiah, and Umam, 2022). Furthermore, upgrading clean water infrastructure is crucial, specifically during the pandemic and to prevent wider scarcity. A comprehensive plan is

needed to enhance the capacity in anticipating disruptions and meeting the increased demand for water as a basic necessity (Berawi, 2021). This result is in line with the study by Van-Loon and Van-Lanen (2013) stating that water scarcity can be influenced by managers. The availability of safe and clean water will also contribute to long-term improvements in public health (Purwanto, 2020). The success of program development largely depends on community involvement (Aja, Kartono, and Soleman, 2022). The sustainable management plan should emphasize ongoing enhancements in stakeholder engagement and infrastructure development (Russo, Alfredo, and Fisher, 2014). In general, stakeholders must continue improving service delivery to meet the clean water needs of the residents through piped-water systems, as outlined in the City Spatial Planning 2012-2032 (Depok City Government, 2015).

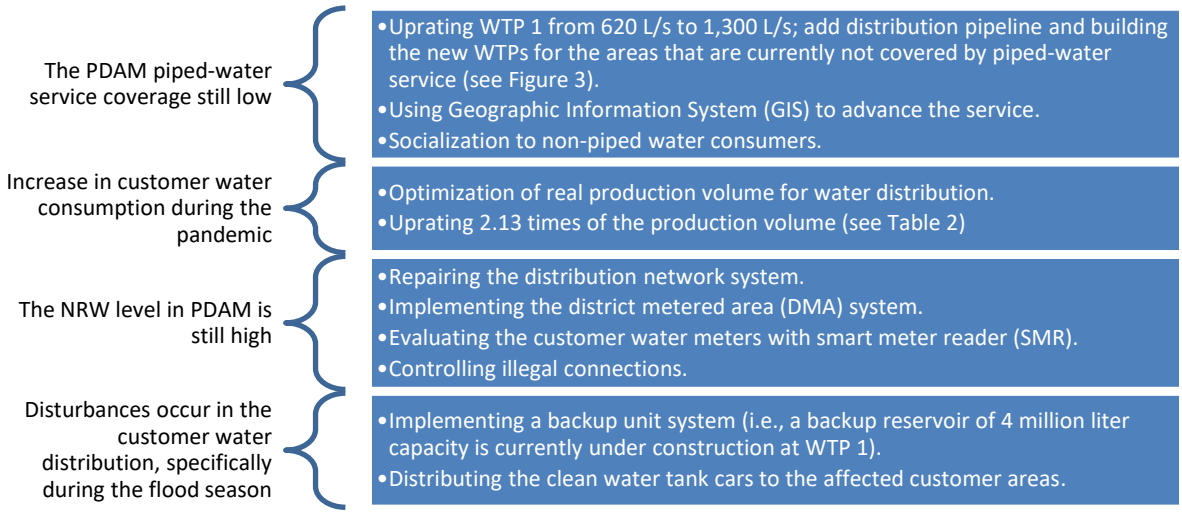


**Figure 3** Recommendations to improve the piped-water service

## 4. Conclusions

In conclusion, the COVID-19 pandemic has underscored the importance of the clean water sector as a critical defense against the virus. During the pandemic, customer water consumption increased by 5% to 147 L/person/day. Based on the 35% piped-water service target for 2021, the current capacity of PDAM was found to be below the required level. To address this challenge, the production capacity should be increased by 2.13 times, with optimization of water distribution. Reducing water loss by 25% was also in line with the RPJMN 2020-2024 goals for improved PDAM performance. Although immediate changes in clean water supply capacity might not be feasible, this study underscored the urgency of upgrading infrastructure to enhance the well-being of the people and prevent broader water scarcity. These recommendations should be consistent with the Drinking Water Security Plan (RPAM) to ensure proper fulfilment of public clean water needs.

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## References

Aja, N., Kartono, D.T., Soleman, S.H., 2022. Optimization of The Ake Gaale Regional Drinking Water Company on Sea Water Pollution and Sanitation in Clean Water Management in

Ternate City. *International Journal of Science, Technology & Management*. Volume 3 (4) pp. 1195-1201

Ali, F., Lestari, D.L., Putri, M.D., Azmi, K.N., 2019. Optimization of Water Resources Management of Depok City with Water Stress Index and SWOT Analysis. *CSID Journal of Infrastructure Development*, Volume 2(1), pp. 84–94

Berawi, M.A., 2021. World Agenda on Sustainable Recovery from the Covid-19 Pandemic: Recover Together, Recover Stronger. *International Journal of Technology*, Volume 12(4), pp. 671–675

Berawi, M.A., Suwartha N., Kusrini, E., Yuwono, A.H., Harwahyu, R., Setiawan E.A., Yatmo, Y.A., Atmodiwirjo, P., Zagloel, Y.T., Suryanegara, M., Putra, N., Budiyanto, M.A., Whulanza, Y., 2020. Tackling the COVID-19 Pandemic: Managing the Cause, Spread, and Impact. *International Journal of Technology*, Volume 11(2), pp. 209–214

BPS-Statistics Indonesia, 2022. *Statistical Yearbook of Indonesia 2022*. Catalog: 1101001. BPS-Statistics Indonesia, Jakarta

BPS-Statistics of Depok Municipality, 2022. *Depok Municipality in Figures 2022*. Catalog: 1102001.3276. BPS-Statistics of Depok Municipality, Depok

Depok City Government, 2015. *Regional Spatial Plan of Depok City 2012-2032*. Depok City Government, Depok

Depok City Government, 2021. *Medium-Term Development Plan of Depok City 2021-2026*. Depok City Government, Depok

Directorate General of Human Settlements-Indonesian Ministry of Public Works and Housing, 2022. Workshop on Specializing in Urban and Rural Drinking Water Grants Program Funding Sources of APBN 2023. YouTube. Available online at: https://www.youtube.com/watch?v=xUlmqs3WJVo, Accessed on May 29, 2022

Farley, M., Wyeth, G., Ghazali, Z.B.Md., Istandar, A., Singh, S., 2008. *The Manager's Non-Revenue Water Handbook: A Guide to Understanding Water Losses*. International Development (USAID), Bangkok

Fontanazza, C.M., Freni, G., Loggia, G.L., 2007. Analysis of Intermittent Supply Systems in Water Scarcity Conditions and Evaluation of the Resource Distribution Equity Indices. *WIT Transaction on Ecology and the Environment*. Volume 103 (May), pp. 635-644

Hapsari, R.I., Suryadi, A., Tajalla, A.N., 2022. Optimization of Water Distribution in Pagerwojo District Tulungagung, Indonesia, using Linear Programming Model. *Civil Engineering Dimension*, Colume 24(1), pp. 38-45

Hartono, D.M., Gusniani, I., Adityosulindro, S., 2010. Evaluation and Optimization Performance of Citayam Drinking Water Treatment Plant, PDAM Tirta Kahuripan Toward Population Increase in Depok. *Lingkungan Tropis*, Volume 4(2), pp. 81–92

Herdiansyah, H., Putra, G.A.Y., 2018. Towards a Sustainable City: Planning the Fulfilment of Urban Fresh Water Needs of Depok in Both Dry and Rainy Seasons. *Water Practice & Technology*, Volume 13(4), pp. 1–9

Indra, T.A., Ali, F., 2018. Water Scarcity in The Depok Area. *International Journal of GEOMATE*. Volume 15 (47), pp. 118-123

Indonesia Water Institute, 2022. *Study of Clean Water Consumption Patterns during Covid-19 Pandemic*. Full Report. Indonesia Water Institute, Jakarta

Indonesian Ministry of National Development Planning, 2019. *The National Medium-Term Development Plan (RPJMN) 2020–2024*. Government of Indonesia, Jakarta

Indonesian Ministry of Public Works and Housing, 2018. *Module of Non-revenue Water*. Indonesian Ministry of Public Works and Housing, Jakarta

Iswara, M.A., 2021. Clean Water Crisis That Gets Worse When the Pandemic Hits. Available online at: https://tirto.id/krisis-air-bersih-yang-kian-memburuk-saat-pandemi-menerjang-gcmz, Accessed November 18, 2021

Johnstone, P., Adamowicz, R., De Haan, F.J., Ferguson, B., Wong, T., 2012. Liveability and the Water Sensitive City – Science-Policy Partnership for Water Sensitive Cities. Melbourne, Australia. Cooperative Research Centre for Water Sensitive Cities

National Agency for Water Supply System Improvement, n.d. *Technical Guidelines of PDAM Performance Evaluation*. Jakarta: National Agency for Water Supply System Improvement

National Agency for Water Supply System Improvement, 2020. *PDAM Performance Book 2020: Region II*. Jakarta: National Agency for Water Supply System Improvement

National Agency for Water Supply System Improvement, 2021. *PDAM Performance Book 2021: Region II*. Jakarta: National Agency for Water Supply System Improvement

Pinheiro, R., Wagner, G., 2001. *Upgrading Water Treatment Plants*. London: CRC Press

Purwanto, E.W., 2020. Development of Clean Water Access After the Covid-19 Crisis. *The Indonesian Journal of Development Planning*, Volume 4(2), pp. 207–214

Rachman, L.M, Rachman, R.A., Rahmalia, N., Ain, A.Q., Wahjunie, E.D., 2019. Development of Technique for Assessing Urban Water Security in Depok City. *IOP Conference Series: Earth and Environmental Science*. Volume 535 (012015), pp. 1-12

Rezagama, A., Handayani, D.S., Zaman, B., Putra, R.R.S., 2020. Design Optimization of Water Distribution Suburban Area in Mranggen, Semarang, Indonesia. *IOP Conference Series: Earth and Environmental Science*. Volume 448 (012066), pp. 1-10

Russo, T., Alfredo, K., Fisher, J., 2014. Sustainable Water Management in Urban, Agricultural, and Natural Systems. *Water*. Volume 6 (12), pp. 3934-3956

Sabara, Z., Afiah, I.N., Umam, R., 2022. Integration of Green Ergonomics in Robust Decision-Making Approach in Water Resources Management in Makassar City. *International Journal of Technology*, Volume 13(2), pp. 264–273

Sarbidi, 2018. Nontechnical Study of Uprating Application Water Treatment Installation in Drinking Water Supply System. *Jurnal Permukiman*, Volume 13(1), pp. 1–12

Sukoco, I., 2017. Optimization Strategy Regional Water Company in Business Communication Perspective: Study in West Java. *Review of Integrative Business and Economics Research*. Volume 6 (1), pp. 102-115

Tadesse, A., Bosona, T., Gebrensebet, G., 2013. Rural Water Supply Management and Sustainability: The Case of Adama Area, Ethiopia. *Journal of Water Resource and Protection*, Volume 5(2), pp. 208–221

Van-Loon, A.F., Van-Lanen, H.A.J., 2013. Making the Distinction Between Water Scarcity and Drought Using an Observation-Modeling Framework. *Water Resources Research*, Volume 49(3), pp. 1483–1502

World Health Organization, 2019. 1 in 3 people globally do not have access to safe drinking water – UNICEF, WHO. News release 18 June 2019. Available Online at: https://www.who.int/news/item/18-06-2019-1-in-3-people-globally-do-not-have-access-to-safe-drinking-water-unicef-who, Accessed on May 29, 2022

World Health Organization, 2020. Water, Sanitation, Hygiene, and Waste Management for the COVID-19 Virus. Interim guidance 23 April 2020. Available Online at: https://apps.who.int/iris/bitstream/handle/10665/331846/WHO-2019-nCoV-IPC_WASH-2020.3-eng.pdf, Accessed on November 17, 2021

World Health Organization, n.d. The Human Right to Water and Sanitation. Media brief. Available Online at: https://www.un.org/waterforlifedecade/pdf/human_right_to_water_and_sanitation_media_brief.pdf, Accessed on November 18, 2021