International Research Journal of Engineering, IT & Scientific Research
Available online at https://sloap.org/journals/index.php/irjeis/
Vol. 10 No. 5, July 2024, pages: 109-121
ISSN: 2454-2261
https://doi.org/10.21744/irjeis.v10n4.2456

Analysis of the Clean Water Use Index for the Development of an Integrated and Sustainable Clean Water Service Program in Bali Province

I Gusti Lanang Made Parwita [a]
I Nyoman Anom PW [b]
Made Mudhina [c]
IGAG Siryanegara [d]
IGA Dewi Paramita [e]

Article history:

Submitted: 27 May 2024
Revised: 18 June 2024
Accepted: 09 July 2024

Keywords:

clean water;
integrated;
sustainable;
water usage index;

Abstract

The water usage index according to the Ministry of Public Works is a comparative value between water needs divided by water availability. In this regard, there are four categories of water usage index, namely non-critical, light critical, medium critical and heavy critical categories. This category is important as a basis for integrated and sustainable clean water services in the province of Bali. The results of this study are the value of the water usage index for each Regency/City in Bali as a basis for developing clean water services. The method in this study is quantitative analysis. The results of the study will be published in the international journal IRJEIS.

Corresponding author:
I Gusti Lanang Made Parwita,
Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia
Kampus Politeknik Negeri Bali, Bukit Jimbaran, Kuta Selatan Badung, Bali, Indonesia
Email address: gstlanangmadeparwita@pnb.ac.id

[a] Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia
[b] Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia
[c] Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia
[d] Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia
[e] Civil Engineering, Politeknik Negeri Bali, Badung, Indonesia

1 Introduction

Bali is one of the main tourist destinations in Indonesia that attracts various tourists from various regions in Indonesia and various regions in the corners of the world. In addition to the arrival of tourists, Bali is also experiencing an increase in population due to births and migration of people coming to the Bali region. The increase in population and the increase in the number of tourists require sufficient water availability in terms of quantity, quality and quantity. The clean water provision program has been carried out sustainably throughout Bali by looking at the potential of the region and the distribution of water potential that can be developed (Varol, 2020; Vieira et al., 2017). Preliminary research shows that the South Bali region which includes Badung Regency, Denpasar City, Gianyar Regency, Klungkung Regency, the eastern part of Tabanan Regency and the western part of Karangasem Regency is the region with the greatest water potential. This is related to the position of Lake Beratan and Lake Batur which are the sources of rivers and springs in Bali above this region. Several rivers in this region flow throughout the year with good water quality. Some of these rivers include: the Unda, Bubuh, Melangit, Jinah, Pakerisan, Petanu, Oos, Ayung, Badung, Mati, Yeh Empas and Balian rivers. Outside the southern Bali region, there are areas with limited water potential. The rivers in this area do not flow all year round or flow with very minimal discharge during the dry season. This condition has the consequence of uneven distribution of water potential and use throughout the region.

The uneven distribution of water potential and availability is faced with the development of coastal areas throughout the Province which requires greater water availability due to the development of tourism. Until now, there has never been an analysis of the comparison between needs and availability that produces a water use index that can produce a map of water use conditions in several criteria, namely non-critical, light critical, moderate critical and heavy critical (Andayani et al., 2023). Therefore, this study will be one of the references in mapping water use conditions so that it can be one of the bases for developing an integrated and sustainable clean water supply program in Bali Province.

State of the art

There have been many studies related to clean water problems, namely: Koop & van Leeuwen (2015) analyzed the sustainability of clean water management with several case studies in several cities experiencing water shortages but has not yet reported the clean water usage index. Cole (2012) and Yamamoto et al. (2021), conducted an analysis of the influence of tourism on the increasing need for clean water in Bali but did not link it to water use for the entire population in Bali so that no clean water usage index was found. Corona-Nakamura et al. (2008), conducted an analysis of the classification of clean water consumption using the Anfis method and did not report the clean water usage index. Elimelech (2006), conducted an analysis of global challenges in meeting clean water needs and how to secure sustainable water resources but also did not report the water usage index. Astani et al. (2022), conducted an analysis only analyzing domestic and non-domestic water needs, Cain & Gleick (2005), analyzed the global water crisis throughout the world, Carrard et al. (2019), conducted a study on the contribution of groundwater in meeting clean water needs in the world. Of the studies conducted, none have presented a clean water usage index that produces a very important category in the clean water supply system in Bali.

Literature Review

Water scarcity

Population growth has caused an increase in the amount of water, both in quantity and quality. In a condition where water sources are not evenly distributed, it has caused water scarcity to increase. Water has become an economic commodity that influences the development of a country. In 2020, most of the world's population enjoys sufficient water services except in Africa and a few in Asia that experience water shortages. In 2050, it is estimated that most African countries and several countries in Asia will experience problems related to clean water (Macedonio et al., 2012; Tortajada & Biswas, 2018; Teo et al., 2022). In 2050, water use in Africa and Asia experienced a decrease in water consumption between 1000 and 2000 m3/person/year, even in some areas with water consumption below 100 m3/person/year. The water shortage that occurs in Asia and Africa is caused by the increasing population and is not balanced by adequate clean water supply infrastructure. The water shortage in this region has an impact on the welfare of the population which is not so good in this region. The map of water scarcity conditions in the world is shown in Figure 1 (Xie, 2006).

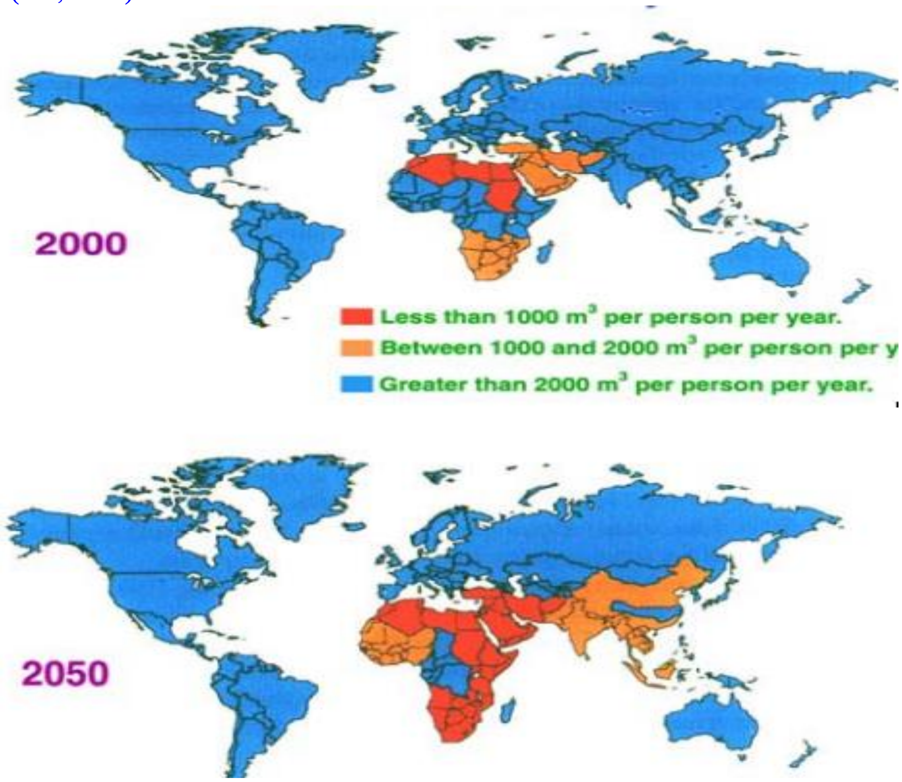

Figure 1. Distribution of Water Resource Scarcity
Source: Xie (2006), modified

Water scarcity in various parts of the world increases efforts to meet the needs of integrated cross-sectoral needs. Integration was initially aimed purely at meeting water needs, but in its development then involved other sectors supported by adequate water availability.

Integrated water management concept

Integrated water resources management is a process aimed at improving and developing the management of water resources, land and related resources in a coordinated manner by considering the characteristics of the region to achieve community welfare (Pusat Pendidikan Dan Pelatihan Sumber Daya Air Dan Konstruksi, 2017). Integration that is carried out considers various interests coupled with the ability and carrying capacity of the environment wisely and can ultimately improve community welfare (Sangkawati & Hadihardaja, 2005; Merla et al., 2005; GWP, 2009)

The availability of water in the earth's hemisphere is not always evenly distributed in every place and at every time as expected, causing people with various interests in water to try to fulfil it in various ways from the various competencies they have and with various ways of legitimacy and participation in an integrated manner (Werkneh & Gebru, 2023; Miller, 2006; Kusworo et al., 2018). The approach to water resources management in the past has not been adequate to face the challenges of global water management. The management approach is mostly sectoral, each sector (household use, agriculture, industry, environmental protection, and others) is managed separately with limited coordination between sectors. This approach causes the development of water resources to be fragmented and uncoordinated. Many water uses have spillover effects on other uses and sometimes have unintended social and environmental consequences. This is especially true for watersheds where upstream water and land practices directly impact the quantity and quality of water downstream. As water becomes more scarce, it becomes increasingly

 ISSN: 2454-2261

inefficient to manage water without recognizing the interdependencies between institutions, sectors and geographic regions (Fuzil et al., 2021; Kumar et al., 2022).

Clean Water Needs

a. Clean Water Usage Patterns
The use of clean water is influenced by several factors including climate, city size, type of industry, water tariffs, public welfare, type of industry, public understanding of efficient water use and others. Some areas that have a hotter climate will require more water compared to cold areas. Likewise, the larger the city, the larger the population with different variations of work and activities requiring different per capita water needs between one city and another (Direktorat Jenderal Cipta Karya Kementerian Pekerjaan Umum Dan Penataan Ruang, 1996; Vollmer et al., 2016)

b. Classification of Clean Water Needs
Clean water needs can be divided into two groups, namely domestic water needs and non-domestic water needs. Domestic water needs are water needs for daily life such as cooking, washing, bathing and others related to households. While non-domestic water needs are water needs that are intended for purposes other than households, such as water needs for social facilities (markets, places of worship), offices, schools and others (PUPR, 1996; Rahmi, 2017; Direktorat Jenderal Cipta Karya Kementerian Pekerjaan Umum Dan Penataan Ruang, 1996)

c. Population Projection
Population projections are carried out to estimate the number of people in the future about the use of water that needs to be provided. In the analysis of population projections, several methods are used according to population characteristics such as arithmetic, geometric or exponential methods (Boretti & Rosa, 2019; Budi et al., 2021; Vanella et al., 2020; Mekonnen, 2018). The selection of these three methods is based on the results of the smallest deviation from the actual population.

d. Water Needs
Water needs are calculated based on domestic and non-domestic needs. Domestic and non-domestic needs are calculated according to the criteria in Table 1.

Table 1
Household water usage levels according to city category

No	City Category	Total population	Water Usage Rate (mm/day)
1	Metropolitan	> 1,000,000	190
2	Big City	5,000.000 – 1,000.000	170
3	Medium City	100,000 – 500,000	150
4	Small City	20,000 – 10,000	130
5	Sub-district City	< 20,000	100
6	Growth Center City	< DPP Standard	30

Source: SK-SNI Clean Water, 1997

e. Clean Water Usage Index
The clean water usage index is a comparison between water needs and water availability (Waluyo, 2012). The water usage index table can be seen in Table 2.

Table 2
Water Use Index in Indonesia

Water Use Index	Classification
< 25%	Not critical
25 -50%	Mild Critical
More than 50% to 100%	Critical Moderate
➢ 100%	Critical Severe

Source: Water Resources Research and Development Center, 2021

2 Materials and Methods

Research Design

The research steps are arranged in stages and continuously so that all existing problems can be resolved. In general, the method in this research is carried out as follows:

a. Secondary data collection
Secondary data collection includes population data from BPS Regency and City throughout Bali, water production data from PDAM, data on public perception and tourism world towards clean water usage and data on PDAM clean water development system throughout Bali

b. Primary data collection
Primary data collection includes direct measurement of water sources to determine the capacity of water taken as a source, interview data and observations with residents related to clean water services

c. Analysis
1) Analysis of the population and its projections using arithmetic, geometric and exponential methods
2) Analysis of community water usage using random sampling checking method from data available at PDAM
3) Analysis of clean water development using the method of conducting audiences with PDAM and PUPR Regency/City Offices
4) Analysis of water needs
5) Analysis of water availability
6) Analysis of water usage index

Survey and data collection

1. Conduct a field survey to find out the following things:
   a) PDAM water production
   b) PDAM Engineering report data
   c) Population size
   d) Sample of water usage by residents
   e) Comparison of water needs and water availability (water usage index)

2. Analysis Stages
The analysis is carried out in stages by considering the needs and availability of data which includes the following analysis:
   a) Population analysis
   b) This analysis refers more to the records from BPS related to the current population
   c) Population projection analysis
   d) This analysis is carried out using several formulas such as arithmetic, geometric and exponential
   e) Clean water development system analysis

f) This analysis is carried out to find the direction and system of clean water development in the future
g) Analysis of non-domestic and non-domestic water needs
h) This analysis is carried out to find out the non-domestic water needs of the tourism sector, which can be used as a reference in developing tourism in other areas.
i) Water use index analysis

3 Results and Discussions

3.1 Clean water needs

Clean water needs are calculated based on domestic water needs and non-domestic water needs. Domestic water needs are the water needs used by residents for daily life. Data on domestic water use by residents is adjusted to the size of the city, namely metropolitan cities, large cities, medium cities, small cities and rural areas. Meanwhile, non-domestic water needs are the water needs for various purposes outside of daily life such as for educational institutions, businesses, government offices, places of worship, hospitals and others. Total water needs are domestic water needs plus non-domestic water needs and the amount of loss is estimated at 20% of water needs (domestic and non-domestic). Variations in water needs are influenced by several other things such as temperature, level of community welfare, number of industries and other facilities related to the use of clean water. The calculation of clean water needs per capita in each household is calculated based on monthly usage divided by the number of families in the family. The more family members, the greater the potential for water use. Likewise, the presence of more complete washing machines and sanitation equipment and the completeness of gardens in the household environment have the potential to increase the need for clean water.

3.2 Availability of clean water

The availability of clean water is calculated based on the current availability of water plus the availability of water from several new infrastructures built by the Government, namely from the Titab dam increasing the raw water supply by 350 liters/second, the Tamblang dam increasing the raw water supply by 510 liters/second and from the Sidan dam increasing the raw water supply by 750 liters/second.

3.3 Clean water balance

Clean water balance is a comparison between the availability of clean water compared to the need for clean water. In this analysis, additional clean water has been taken into account from several new building infrastructures built by the Government such as the Tamblang Dam, Titab Dam, Sidan Dam, Unda Estuary Reservoir and Yeh Empas River long storage. This balance shows that several areas such as Karangasem Regency in the east and Jembrana Regency in the west are areas whose balance conditions are very vulnerable. This is because the potential and water sources in eastern Karangasem and Jembrana are very limited. The results of the clean water balance analysis after adding additional water from the Tamblang, Titab and Sidan dams can be seen in Table 3 and Table 4.

Table 3
Clean Water Balance of Bali Province in 2025

No.	Regency	Water Availability (liter/second)	Water Need (liter/second)	Difference (liter/second)
1	Badung	1,807.69	1,819.41	-11.72
2	Bangli	333.45	305.43	28.02
3	Buleleng	1,544.50	1,458.44	86.06
4	Gianyar	1,099.28	1,154.76	-55.48
5	Jembrana	340.75	437.54	-96.79
6	Karangasem	454.54	577.25	-122.71
7	Klungkung	1,158.40	361.65	796.75
8	Kota Denpasar	1,969.24	1,331.00	638.24

No.	Regency	Water Availability (liter/second)	Water Need (liter/second)	Difference (liter/second)
9	Tabanan	1,102.19	986,52	115.67
	Amount	9,810.04	8,431.99	1,378.04

Source: analysis results

Table 3
Clean Water Balance of Bali Province in 2050

No.	Regency	Water Availability (liter/second)	Water Needs (liter/second)	Difference (liter/second)
1	Badung	1,807.69	2,855.96	-1,048.27
2	Bangli	333.45	568.33	-234.88
3	Buleleng	1,544.50	1,830.13	-285.63
4	Gianyar	1,099.28	1,617.17	-517.89
5	Jembrana	340.75	619.25	-278.50
6	Karangasem	454.54	987.41	-532.87
7	Klungkung	1,158/40	461.22	697.18
8	Kota Denpasar	1,969.24	2,557.79	-588.55
9	Tabanan	1,102.19	1,282.18	-179.99
	Amount	9,810.04	12,779.44	-2,969.40

Source: analysis results

The calculation of the clean water balance is done by taking into account the availability of water and the existing infrastructure. The addition of the amount of water available by including additional water from new infrastructure that has been built at this time. Some new infrastructure that increases the availability of water in Bali is the Titab, Tamblang and Sidan dams, in addition to several water intakes in the downstream rivers such as the Yeh Empas River long storage and others. The complete water balance analysis can be seen in Table 5.

Table 5
Recapitulation of clean water balance of Bali Province

Description	Year						
	2022	2025	2030	2035	2040	2045	2050
Water Availability (liter/Second)	6,000.04	9,810.04	9,810.04	9,810.04	9,810.04	9,810.04	9,810.04
Water Needs (liter/second)	8,075.60	8,431.99	8,924.94	9,662.35	10,495.80	11,804.71	12,779.44

Source: analysis results

3.4 Clean Water Usage Index

The clean water usage index is a comparison between water needs and water availability. Based on the data, the amount of water usage index for each Regency and the total for Bali Province is calculated as in Table 6 to Table 14

ISSN: 2454-2261

Table 6
Clean water usage index in Badung Regency

Badung Regency	2025 (liter/second)	2050 (liter/second)
Water Needs	1,819.41	2,855.96
Water Availability	1,807.69	1,807.69
Index	100.65	157.99
Category	Critical Severe	Critical Severe

Source: analysis results

Table 7
Clean water usage index in Bangli Regency

Bangli Regency	2025 (liter/second)	2050 (liter/second)
Water Needs	300.43	489.43
Water Availability	333.45	333.45
Index	90.10	146.78
Category	Critical Moderate	Critical Severe

Source: analysis results

Table 8
Clean water usage index in Buleleng Regency

Buleleng Regency	2025 (liter/second)	2050 (liter/second)
Water Needs	1,424.37	1,719.90
Water Availability	734.50	1.544.50
Index	193.92	111.36
Category	Critical Severe	Critical Severe

Source: analysis results

Table 9
Clean water usage index in Gianyar Regency

Gianyar Regency	2025 (liter/second)	2050 (liter/second)
Water Needs	1,123.57	1,543.48
Water Availability	799.28	1,099.28
Index	140.57	140.41
Category	Critical Moderate	Critical Severe

Source: analysis results

Table 10
Clean water usage index in Jembrana Regency

Jembrana Regency	2025 (liter/second)	2050 (liter/second)
Water Needs	429.84	603.42
Water Availability	290.75	340.75
Index	147.84	177.08
Category	Critical Severe	Critical Severe

Source: analysis results

Table 11
Clean water usage index in Karangasem Regency

Karangasem Regency	2025 (liter/second)	2050 (liter/second)
Water Needs	568.03	900.70
Water Availability	454.54	454.54
Index	124.97	198.16
Category	Critical Severe	Critical Severe

Source: analysis results

Table 12
Clean water usage index in Klungkung Regency

Klungkung Regency	2025 (liter/second)	2050 (liter/second)
Water Needs	354.63	448.38
Water Availability	158.40	1,158.40
Index	223.88	38.71
Category	Critical Severe	Mild Critical

Source: analysis results

Table 13
Clean water usage index in Denpasar City

Denpasar City	2025 (liter/second)	2050 (liter/second)
Water Needs	1,255.41	2,181.42
Water Availability	1,169.24	1,969.24
Index	107.37	110.77
Category	Critical Severe	Critical Severe

Source: analysis results

Table 14
Clean water usage index in Tabanan Regency

Tabanan Regency	2025 (liter/second)	2050 (liter/second)
Water Needs	968.82	1,241.69
Water Availability	752.19	1,102.19
Index	128.80	112.66
Category	Critical Severe	Critical Severe

Source: analysis results

4 Conclusion

Based on the results of the analysis, several things can be concluded related to the water usage index in Bali Province as follows:

1) Water availability in Bali Province in 2023 is 6,000.04 liters/second based on the availability of water that can be provided by PDAM and rural PAM. This figure does not take into account areas or regions that independently provide water for their areas using wells. Several areas in the Denpasar area use water from drilled wells made by the community independently, such as the Sanur area, Padangsambian and several other areas.

2) The need for water in 2023 in Bali Province is 8,900.22 liters/second, this shows a water deficit of 2,900.18 liters/second.
3) The development of infrastructure that serves the supply of clean water to several areas can reduce the critical conditions of an area, however, in areas with little infrastructure development, the water usage index will certainly increase every year. The clean water usage index will be better if viewed from each Regency/City because the availability and need for water varies greatly and will not be the same as the Provincial index. The index for each Regency/City provides more real figures based on the conditions of each region. The conditions of the water usage index in each Regency/City are as follows:
   a) Badung Regency
   Badung Regency has a clean water usage index in severe conditions from 2025 to 2050 with an average index of 127.34. The smallest index in 2025 with an index of 100.65 and the largest index in 2050 with an index of 157.99.
   b) Bangli Regency
   Bangli Regency has a clean water usage index from 2025 to 2040 in moderate critical conditions and from 2045 to 2050 in severe conditions, with an average index of 108.80. The smallest index in 2025 with an index of 90.10 and the largest index in 2050 with an index of 146.78.
   c) Buleleng Regency
   Buleleng Regency has a clean water usage index from 2025 and 2050 in severe critical conditions, while from 2030 to 2045 in moderate critical conditions, with an average index of 108.80. The smallest index in 2035 with an index of 94.43 and the largest index in 2025 was 193.92, with an average index of 115.07. The change in index occurred because starting in 2030, the Titab Dam and Tamblang Dam have been operating with full water supply.
   d) Gianyar Regency
   Gianyar Regency has a clean water usage index from 2025 to 2040 in moderate critical conditions and from 2045 to 2050 in severe conditions, with an average index of 124.24. The smallest index in 2030 with an index of 105.05 and the largest index in 2050 with an index of 140.41.
   e) Jembrana Regency
   Jembrana Regency has a clean water usage index in severe conditions from 2025 to 2050 with an average index of 146.73. The smallest index in 2025 with an index of 147.84 and the largest index in 2050 with an index of 177.08.
   f) Karangasem Regency
   Karangasem Regency has a clean water usage index from 2025 to 2040 in moderate critical conditions and from 2045 to 2050 in severe conditions, with an average index of 149.64. The smallest index in 2025 with an index of 124.97 and the largest index in 2050 with an index of 198.16.
   g) Klungkung Regency
   Klungkung Regency has a clean water usage index in 2025 with a severe critical condition. However, if the construction of the Unda estuary reservoir with a capacity of 1000 liters/second can be realized, then from 2035 to 2050 this area will be in a mild critical condition with an index below 100.
   h) Denpasar City
   Denpasar City has a clean water usage index from 2025 to 2040 in a moderate critical condition and from 2045 to 2050 in a severe condition, with an average index of 91.47. The smallest index in 2030 with an index of 67.59 and the largest index in 2050 with an index of 110.77.
   i) Tabanan Regency
   Tabanan Regency has a clean water usage index in a severe critical condition in 2025 with an index of 128.80. Moderate and 2030 to 2050 in moderate critical condition. Average index 104.48. The smallest index in 2030 with an index of 89.51 and the largest index in 2025 with an index of 128.80.

Conflict of interest statement
The authors declared that they have no competing interests.

Statement of authorship
The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

Acknowledgements
We are grateful to two anonymous reviewers for their valuable comments on the earlier version of this paper.

ISSN: 2454-2261

References

Andayani, K. W., Winaya, I. N. A. P., Triadi, I. N. S., & Wardana, I. G. N. K. M. A. (2023). The study of clean water supply system managed by the community to ensure reliability of the clean water supply system in Tabanan District. *International Research Journal of Engineering, IT and Scientific Research*, *9*(2), 65–75. https://doi.org/10.21744/irjeis.v9n2.2289

Astani, L. P., Supraba, I., & Jayadi, R. (2022). Analisis kebutuhan air domestik dan non domestik Di kabupaten kulon progo, daerah istimewa yogyakarta. *Teknologi Sipil: Jurnal Ilmu Pengetahuan Dan Teknologi*, *5*(2), 34-41.

Boretti, A., & Rosa, L. (2019). Reassessing the projections of the world water development report. *NPJ Clean Water*, *2*(1), 15.

Budi, N. M. N., Sudiajeng, L., & Tapayasa, I. M. (2021, November). Perspective of Population Growth and Clean Water Supply in Denpasar, Bali-Indonesia. In *International Conference on Innovation in Science and Technology (ICIST 2020)* (pp. 411-417). Atlantis Press.

Cain, N. L., & Gleick, P. H. (2005). The global water crisis. *Issues in Science and Technology*, *21*(4), 79-82.

Carrard, N., Foster, T., & Willetts, J. (2019). Groundwater as a source of drinking water in southeast Asia and the Pacific: A multi-country review of current reliance and resource concerns. *Water*, *11*(8), 1605.

Cole, S. (2012). A political ecology of water equity and tourism: A case study from Bali. *Annals of tourism Research*, *39*(2), 1221-1241. https://doi.org/10.1016/j.annals.2012.01.003

Corona-Nakamura, M. A., Ruelas, R., Ojeda-Magana, B., & Andina, D. (2008). Classification of domestic water consumption using an ANFIS model. In *2008 World Automation Congress* (pp. 1-9). IEEE.

Direktorat Jenderal Cipta Karya Kementerian Pekerjaan Umum Dan Penataan Ruang. (1996). *Kriteria Perencanaan Air Bersih Di Indonesia*, 1st Ed. Kementerian Pekerjaan Umum, Jakarta.

Elimelech, M. (2006). The global challenge for adequate and safe water. *Journal of Water Supply: Research and Technology—AQUA*, *55*(1), 3-10.

Fuzil, N. S., Othman, N. H., Alias, N. H., Marpani, F., Othman, M. H. D., Ismail, A. F., ... & Shirazi, M. M. A. (2021). A review on photothermal material and its usage in the development of photothermal membrane for sustainable clean water production. *Desalination*, *517*, 115259. https://doi.org/10.1016/j.desal.2021.115259

GWP, I. (2009). A handbook for integrated water resources management in basins. *Global Water Partnership (GWP) and the International Network of Basin Organizations (INBO)*.

Koop, S. H., & van Leeuwen, C. J. (2015). Assessment of the sustainability of water resources management: a critical review of the city blueprint approach. *Water Resources Management*, *29*, 5649-5670.

Kumar, R., Pandey, A. K., Samykano, M., Aljafari, B., Ma, Z., Bhattacharyya, S., ... & Tyagi, V. V. (2022). Phase change materials integrated solar desalination system: An innovative approach for sustainable and clean water production and storage. *Renewable and Sustainable Energy Reviews*, *165*, 112611. https://doi.org/10.1016/j.rser.2022.112611

Kusworo, T. D., Aryanti, N., & Utomo, D. P. (2018). Oilfield produced water treatment to clean water using integrated activated carbon-bentonite adsorbent and double stages membrane process. *Chemical Engineering Journal*, *347*, 462-471. https://doi.org/10.1016/j.cej.2018.04.136

Macedonio, F., Drioli, E., Gusev, A. A., Bardow, A., Semiat, R., & Kurihara, M. J. C. E. (2012). Efficient technologies for worldwide clean water supply. *Chemical Engineering and Processing: Process Intensification*, *51*, 2-17. https://doi.org/10.1016/j.cep.2011.09.011

Mekonnen, Y. A. (2018). Population forecasting for design of water supply system in Injibara Town, Amhara Region, Ethiopia. *Population*, *10*(10), 54-65.

Merla, A., Duda, A., Van Der Beck, I., Vaughan, T. S., & Rucks, J. (2005). *Implementation Of Integrated River Basin Management Practices In The Pantanal And Upper Paraguay River Basin Ana/Gef/Unep/Oas Strategic Action Program For The Integrated Management Of The Pantanal And The Upper Paraguay River Basin*.

Miller, G. W. (2006). Integrated concepts in water reuse: managing global water needs. *Desalination*, *187*(1-3), 65-75. https://doi.org/10.1016/j.desal.2005.04.068

PUPR, K. (1996). Modul Proyeksi Kebutuhan Air Dan Identifikasi Pola Fluktuasi Pemakaian Air. *Perenc. Jar. Pipa Transm. Dan Distrib. Air Minum*, 1-16.

Pusat Pendidikan Dan Pelatihan Sumber Daya Air Dan Konstruksi. (2017). *Modul Pengelolaan Sumber Daya Air Terpadu*, 32.

Rahmi, L. (2017). Analisis proyeksi pertumbuhan penduduk terhadap kondisi ketenagakerjaan di Kota Sawahlunto Sumatera Barat. *Jurnal Geografflesia: Analisis Proyeksi Pertumbuhan Penduduk Terhadap Kondisi Ketenagakerjaan di Kota Sawahlunto Sumatera Barat*, *2*(1).

Sangkawati, S., & Hadihardaja, J. (2005). Pemberdayaan Sumber Daya Air untuk Berbagai Kepentingan Secara Berkelanjutan. *Media Komunikasi Teknik Sipil*, *13*(3), 117-127.

Teo, S. H., Ng, C. H., Islam, A., Abdulkareem-Alsultan, G., Joseph, C. G., Janaun, J., ... & Awual, M. R. (2022). Sustainable toxic dyes removal with advanced materials for clean water production: A comprehensive review. *Journal of Cleaner Production*, *332*, 130039. https://doi.org/10.1016/j.jclepro.2021.130039

Tortajada, C., & Biswas, A. K. (2018). Achieving universal access to clean water and sanitation in an era of water scarcity: strengthening contributions from academia. *Current opinion in environmental sustainability*, *34*, 21-25. https://doi.org/10.1016/j.cosust.2018.08.001

Vanella, P., Deschermeier, P., & Wilke, C. B. (2020). An overview of population projections—methodological concepts, international data availability, and use cases. *Forecasting*, *2*(3), 346-363.

Varol, M. (2020). Use of water quality index and multivariate statistical methods for the evaluation of water quality of a stream affected by multiple stressors: A case study. *Environmental Pollution*, *266*, 115417. https://doi.org/10.1016/j.envpol.2020.115417

Vieira, P., Jorge, C., & Covas, D. (2017). Assessment of household water use efficiency using performance indices. *Resources, Conservation and Recycling*, *116*, 94-106. https://doi.org/10.1016/j.resconrec.2016.09.007

Vollmer, D., Regan, H. M., & Andelman, S. J. (2016). Assessing the sustainability of freshwater systems: A critical review of composite indicators. *Ambio*, *45*, 765-780.

Waluyo, H. (2012). Neraca Ketersediaan Dan Kebutuhan Air, Pp. 1–23.

Werkneh, A. A., & Gebru, S. B. (2023). Development of ecological sanitation approaches for integrated recovery of biogas, nutrients and clean water from domestic wastewater. *Resources, Environment and Sustainability*, *11*, 100095. https://doi.org/10.1016/j.resenv.2022.100095

Xie, M. (2006). Integrated water resources management (IWRM)–introduction to principles and practices. *World Bank Institute*, 1-15.

Yamamoto, E. M. S., Sayama, T., & Takara, K. (2021). Impact of Rapid Tourism Growth on Water Scarcity in Bali, Indonesia. *Indonesian Journal of Limnology*, *2*(1), 1-16.