



SUSTAINABLE WATER MANAGEMENT: GREYWATER REUSE AND SMART IRRIGATION AT PUSGIWA UI

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KEYWORDS	ABSTRACT
environmental health, greywater reuse, sustainable wastewater management, urban wastewater.	The increasing demand for water in urban areas, coupled with challenges related to water scarcity and environmental concerns, underscores the need for effective fresh water management practices. This study explores the potential for greywater reuse and smart systems to meet domestic water needs at Pusgiwa UI. The methodology involves quantifying water consumption across different areas of the building to identify potential sources of reusable greywater for non-potable applications such as flushing toilets and landscape irrigation. Through water balance analysis, it was found that greywater from <i>ablution (wudu)</i> activities can be directly repurposed for irrigation, while greywater containing soap and grease requires treatment before being reused for flushing. The findings indicate that implementing greywater reuse can save approximately 45.5% of fresh water consumption. This study provides practical solutions for sustainable water management, demonstrating significant reductions in fresh water usage and offering a replicable model for other urban buildings aiming to optimize water resources efficiently.

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INTRODUCTION

Water is one of the most fundamental resources for sustaining life, economic growth, and environmental stability (Ahmadov, 2020; Ishaque et al., 2023; Li & Wu, 2024; Mugagga & Nabaasa, 2016; Zhang et al., 2023). Despite its critical role, a significant portion of the global population continues to struggle with access to clean water. While approximately 71% of the Earth's surface is covered by water, only 2.5% is freshwater, making it the primary source for drinking, agriculture, and domestic use (Khilchevskiy & Karamushka, 2021). However, much of this freshwater is locked in glaciers and permanent snow cover, rendering it inaccessible (Birkhold, 2023). As urban populations expand and industrial activities accelerate, the gap between water availability and consumption widens, leading to growing concerns regarding resource depletion and sustainability (Chartres & Noble, 2015).

The increasing global demand for freshwater, compounded by inefficient usage and climate change, has intensified water scarcity concerns (Shemer et al., 2023). Cities and buildings play a crucial role in this issue, as their operations require substantial amounts of water for sanitation, cooling, irrigation, and daily consumption (Pimentel-Rodrigues & Silva-Afonso, 2019). Poor water management not only contributes to environmental degradation but also strains existing water supplies, making conservation efforts imperative (Jain et al., 2024). Implementing efficient water-saving measures within buildings can address these challenges by reducing overall consumption and promoting sustainable resource utilization (Gil-ozoudeh et al., 2023). With institutional buildings serving as hubs for learning,

governance, and innovation, incorporating sustainable water management strategies in their operations can set an example for broader adoption (Ramísio et al., 2019).

The US Green Building Council (USGBC) identifies several core principles that can enhance water efficiency within the built environment. These include reducing indoor water consumption through advanced technologies, lowering overall water use to decrease energy demand, and adopting sustainable practices that minimize resource wastage (Moghadam, 2010). Each of these concepts contributes to reducing the environmental footprint of buildings and fostering long-term resilience in water-scarce regions. A combination of emerging technologies and policy-driven approaches can pave the way for more effective water conservation initiatives, particularly through the integration of alternative water sources such as *greywater* reuse and smart irrigation systems (Menegaki, 2024).

Greywater reuse presents a viable solution for optimizing water usage by repurposing wastewater from sinks, showers, and *ablution* areas for non-potable applications (Agnihotri et al., 2025). Instead of allowing this water to go to waste, it can be treated and redirected toward landscape irrigation and toilet flushing, reducing dependency on fresh water sources (Allen, 2010; Oteng-Pepurah et al., 2018). Additionally, smart irrigation systems enable data-driven water distribution, ensuring that green spaces receive only the necessary amount of water based on soil moisture levels and weather patterns (Ahmed et al., 2023). These innovations demonstrate how technology can be leveraged to improve water efficiency while simultaneously reducing costs and conserving resources (Egbumokei et al., 2024).

Various specific uses for wastewater are categorized under urban applications, landscape irrigation, and support for wildlife habitats and recreational areas (Committee on the Beneficial Use of *Greywater* and Stormwater: An Assessment of Risks, Costs, and Benefits et al., 2016). *Ablution* water generally has a neutral pH between 6.92 and 7.10, with chemical oxygen demand (COD) ranging from 50 to 70 mg/L, biological oxygen demand (BOD) between 20 and 40 mg/L, and total suspended solids (TSS) varying from 5 to 146 mg/L (Alharbi et al., 2019; Radin Mohamed et al., 2016). Due to its relatively low contamination levels, *ablution greywater* can be treated with simple methods and reused for non-potable purposes such as irrigation, toilet flushing, and vehicle washing (Suratkon et al., 2014). Examining the potential use of wastewater in Pusgiwa UI reveals significant opportunities, particularly in crucial areas such as toilet and urinal flushing, lawn irrigation, and supporting wetlands. The demand for water in Pusgiwa UI, especially for irrigation, is substantial. Therefore, it becomes important to consider the reuse of wastewater for such purposes instead of relying solely on clean freshwater sources. This proactive approach aligns with sustainable water management practices, ensuring a more efficient and responsible utilization of this valuable resource within the university premises.

This study aims to provide concrete, data-driven solutions that enhance water sustainability within institutional buildings, using Pusgiwa UI as a case study. By exploring the integration of *greywater* reuse and smart irrigation, the research aims to demonstrate the feasibility and impact of these strategies in reducing freshwater consumption while maintaining operational efficiency. Through a holistic approach, this paper offers valuable insights into the practical adoption of water conservation technologies, serving as a potential model for similar institutions striving to minimize their environmental footprint and optimize resource management.

METHOD

Case study: Pusgiwa UI

The methodology involves quantifying water consumption across different areas of the building to identify potential sources of reusable *greywater* for non-potable applications such as flushing toilets and landscape irrigation. Through water balance analysis, it was found that *greywater* from *ablution* (*wudu*) activities can be directly repurposed for irrigation, while *greywater* containing soap and grease

requires treatment before being reused for flushing. The multi-purpose building located at Universitas Indonesia in Depok City, West Java, Indonesia (6°21'55"S 106°49'27"E), constructed in 2017, spans a total floor area of 19,499.92 m² over eight floors, as seen in Figure 1. The building serves diverse purposes and is designed to accommodate a substantial number of users, with an estimated maximum capacity of 10,454 people. Regarding water sources, the building relies on the public water supply system (PAM) and utilises dug wells. This combination of water sources reflects a strategic approach to ensure a reliable and sustainable water supply for the varied needs of the multipurpose building at Universitas Indonesia.



Figure 1. Pusgiwa UI

The wastewater system at Pusgiwa UI is divided into two sections (see Figure 2). Blackwater from urinals and closets will be collected towards the Sewage Treatment Plant (STP) for further processing. In contrast, the greywater that comes from sinks, showers, and washbasins does not undergo treatment through the STP. Instead, it follows a direct discharge flowing directly into a lake nearby named Mahoni Lake. The direct discharge of untreated greywater into Mahoni Lake raises questions about its potential impact on the lake's water quality, ecosystem, and surrounding environment.

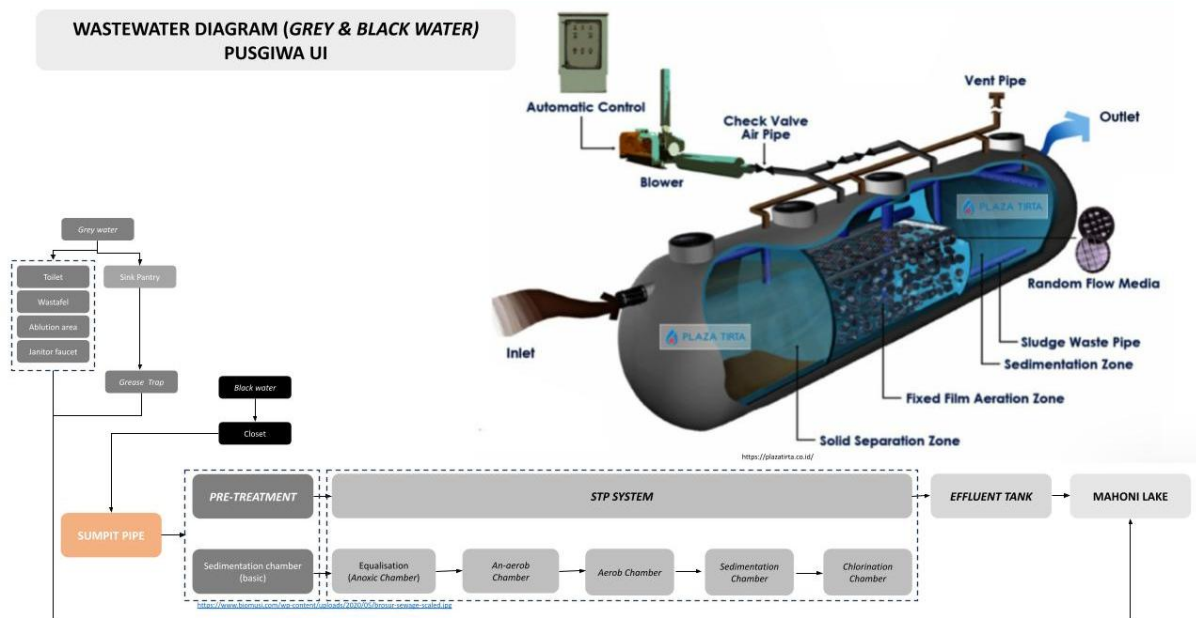


Figure 2. Wastewater system diagram at Pusgiwa UI (grey & black water)

Data Analysis

The analysis in this study was conducted by calculating wastewater volumes generated from activities in sinks, washbasins, urinals, toilets, and ablution areas, as shown in Table 1. The objective is to determine the potential volume of greywater that is available in the Pusgiwa UI, which will be subsequently reused to fulfil the domestic water needs in Pusgiwa UI. The results indicate that the top three activities consuming the most water are ablution (wudu), landscape irrigation, and tap usage (see Figure 3). The greywater from the ablution area, which does not contain oil and grease, holds potential to be used in landscape irrigation, given its comparable volume to other activities. This finding underscores the feasibility of reusing greywater from ablution areas to meet the specific water demands for landscape irrigation.

Table 1. Water consumption per month in Pusgiwa UI

Fixtures	Occupants	Factors	Debit (liter/minute)	Water consumption/ day (liter)	Water consumption/ week (liter)	Water consumption / month (liter)
WC uses male	50%	0,3	4,5	55,8	334,8	1339,2
WC uses female	50%	0,3	4,5	55,8	334,8	1339,2
Urinal uses	50%	2	2,5	206,7	1240	4960
Hand washing duration	100%	0,15	5	62,0	372	1488
Duration of shower	5%	5	12	246,0	1476	5904
Tap usage	100%	1	5	410	2460	9840
Ablution (wudu) usage	100%	0,5	12	492,0	2952	11808
Janitor uses	100%	1	12	320,0	1920	7680
Landscape usage	-	1	6	810,0	2784,3	11137
Sink Pantry	100%	1	8	32	192	2304
Total consumption/ day (liter)				2.658,3	13.876,9	55.495,4

Source: Author,

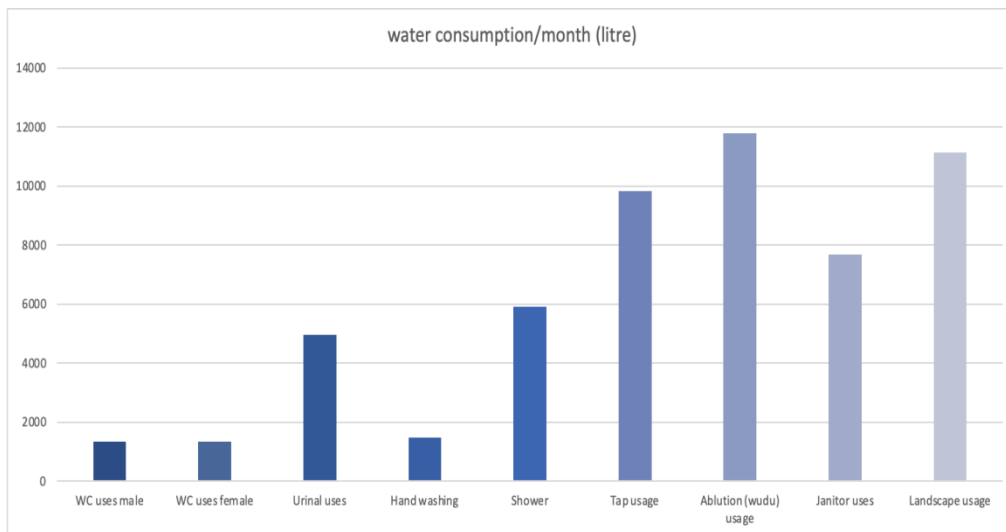


Figure 3. Water consumption per month in Pusgiwa UI

Irrigation Water Needs Calculation

The provided data offers insights into the water management practices for an area spanning approximately 4,500 m². The primary water source is derived from PAM, and the watering routine involves a duration of three hours per day, occurring five times a week. The specific water consumption for sanitary fixtures is noted at 4.5 liters per minute, contributing to a daily water consumption of 810 liters and a monthly total of 11,137 liters. The area hosts diverse vegetation, including trees, grass, bushes, and decorative plants. The operational aspect involves the dedicated effort of one person managing the watering regimen. This comprehensive overview sheds light on the water utilisation patterns, emphasising the need for efficient management strategies to ensure sustainability and optimal resource utilisation in landscaping activities.



Figure 4. Landscape at Pusgiwa UI

RESULT AND DISCUSSION

Water Balance in Pusgiwa UI

From the existing 100% reliance on fresh water sourced from Pusgiwa, the analysis using a water balance reveals significant potential for water reuse. The findings indicate that: (a) approximately 21.2% of greywater from ablution (wudu) can be effectively utilised for landscape irrigation and janitorial purposes, (b) about 10.6% of greywater from showers can be repurposed for janitorial activities, (c) a portion of 13.7% from janitorial activities can be reused for flushing toilets and urinals.

Table 2. Water balance

Water Usage	Volume (liter)	Water Source				Total
		Recycled (shower)	Recycled (janitor)	Recycled (wudu)	PDAM	
		5.904	7.680	11.808		
1 WC flushing	2.678,4		2.678,4		0	2.678,4
2 Urinal	4.960		4.960		0	4.960
3 Sink faucet	1.488				1.488	11.328
4 Wudu faucet	11.808				11.808	11.808
5 Shower	5.904				5.904	5.904
6 Landscape	11.137			11.137	0	11.137
7 Janitor	7.680	5.904		671	1.105	7.680
8 Tap usage	9.840					
	55.495,4	5.904	7.638,4	11.808	20.305	55.495,4
	percentage	10,6%	13,7%	21,2%	36,5%	

Cross-Subsidization of Grey Water Reuse

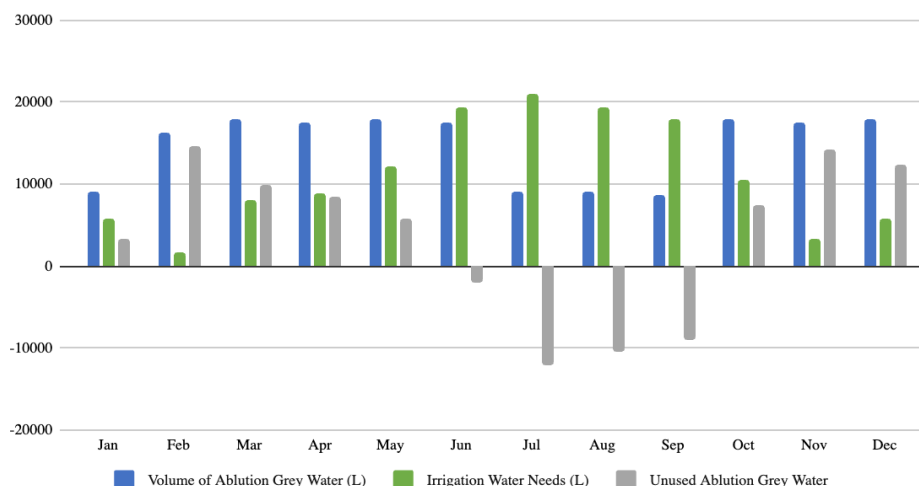


Figure 5. Stocks of ablution greywater in a year

During the months of June, July, August, and September, a noticeable shortage in stock arises, primarily attributed to lower-than-average rainfall during these dry months. However, to counteract the impact of this seasonal scarcity, a strategic approach is adopted. The surplus stock accumulated from the preceding months, spanning from February to May, serves as a valuable reserve. This proactive

measure ensures a steady supply during the dry months, mitigating the challenges posed by the decreased rainfall and guaranteeing continued operational stability.

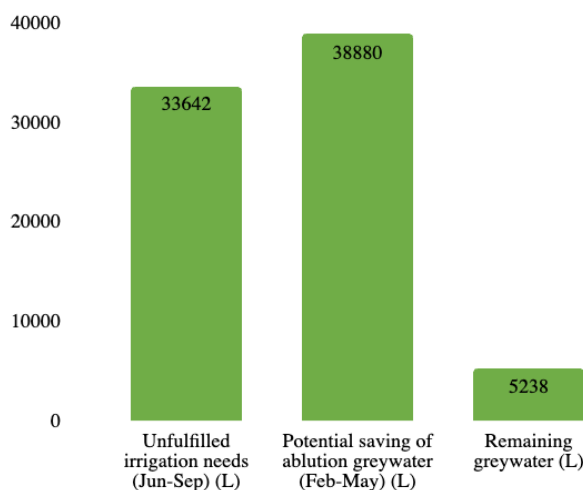


Figure 6. Remaining greywater from irrigation water needs annually

The provided dataset represents the residual greywater quantities retained within the greywater storage tank, originating from abluion activities over the course of multiple years. This reservoir of greywater holds significant potential for utilisation across various purposes beyond its initial source, offering an opportunity for sustainable and resource-efficient practices. As we delve into the exploration of these greywater volumes, there arises a potential avenue for their repurposing to meet diverse needs, aligning with eco-friendly initiatives and contributing to the optimization of water resources in a multifaceted manner.

Table 3. Potential water & cost saving

Month	Number of Rainy Days	Number of Irrigation Days	Volume of Ablution Grey Water (L)	Irrigation Water Needs (L)	PAM fee/month (IDR)	Unused Ablution Grey Water
Jan	24	7	8997,75	5670	IDR17.010.000	3327,75
Feb	26	2	16254	1620	IDR4.860.000	14634
Mar	21	10	17995,5	8100	IDR24.300.000	9895,5
Apr	19	11	17415	8910	IDR26.730.000	8505
May	16	15	17995,5	12150	IDR36.450.000	5845,5
Jun	6	24	17415	19440	IDR58.320.000	-2025
Jul	5	26	8997,75	21060	IDR63.180.000	-12062,25
Aug	6	24	8997,75	19440	IDR58.320.000	-10442,25
Sep	8	22	8707,5	17820	IDR53.460.000	-9112,5
Oct	18	13	17995,5	10530	IDR31.590.000	7465,5
Nov	26	4	17415	3240	IDR9.720.000	14175
Dec	24	7	17995,5	5670	IDR17.010.000	12325,5
Total in a year	199	165	176181,75	133650	IDR400.950.000	42531,75
Average (monthly)	16,58	13,75	14681,81	11137,50	IDR33.412.500	3544,31

Source: Author

Utilising grey water only derived from abluion activities without undergoing any treatment not only contributes to environmental sustainability but also results in substantial cost savings. The amount

of 133,650 litres saved annually translates into a significant reduction in water consumption expenses, amounting to IDR 400,950,000 per year (Table 6). This approach not only exemplifies resource efficiency but also underscores the economic benefits of adopting environmentally friendly practices. By repurposing untreated grey water, the system proves to be a practical and cost-effective solution, aligning with the principles of sustainable water management. The considerable financial savings further highlight the potential for widespread adoption of such practices in promoting both environmental and economic sustainability.

Grey Water System Intervention in Pusgiwa

A comprehensive intervention has been implemented at Pusgiwa UI, focusing on efficient water management and reuse. The interventions include: (a) greywater storage and distribution: greywater from ablution (wudu) activities is stored and subsequently distributed through a sprinkler system to meet the irrigation needs of the landscape. (b) Treatment of contaminated greywater: greywater containing oil and soap residues from janitorial activities, showers, washbasins, and sinks is temporarily collected in a greywater tank. The greywater undergoes a multi-stage treatment process, starting with pollutant neutralisation in a disk filter. Oxygen is introduced to reduce bacterial buildup, followed by ultrafiltration for disinfection. The treated water undergoes chlorine level verification to ensure it meets safety standards. (c) Reuse for Flushing Toilets and Urinals: Once the treated water meets safety standards, it is stored in tanks and subsequently directed to flushing toilets and urinals for reuse.



Figure 7. Recommendation for the wastewater recycling system in Pusgiwa UI

By implementing these interventions, Pusgiwa UI has established a closed-loop system that maximises the reuse of greywater for non-potable purposes. The careful treatment process ensures that the recycled water meets stringent safety standards, contributing to both water conservation and sustainable water management practices within the building.

CONCLUSION

The greywater reuse system at Pusgiwa UI serves as an innovative and scalable model for sustainable urban water management by repurposing *greywater* from *ablution* activities, showers, and

janitorial processes, resulting in a 45.5% reduction in fresh water consumption and notable financial savings. Seasonal shortages during dry months are effectively addressed through strategic stock reserves, ensuring continuous operations, while multi-stage treatment processes enhance water safety for reuse in toilet flushing and landscape irrigation. This integrated approach not only optimizes resources and delivers environmental and economic benefits but also demonstrates the feasibility of broader adoption in other urban buildings. For future research, it is recommended to evaluate the long-term performance and user acceptance of *greywater* systems, as well as to explore the integration of real-time monitoring technologies for improved efficiency and safety.

REFERENCES

- Ahmadov, E. (2020). Water resources management to achieve sustainable development in Azerbaijan. *Sustainable Futures*, 2, 100030. <https://doi.org/10.1016/j.sfr.2020.100030>
- Ahmed, Z., Gui, D., Murtaza, G., Yunfei, L., & Ali, S. (2023). An overview of smart irrigation management for improving water productivity under climate change in drylands. *Agronomy*, 13(8), 2113. <https://doi.org/10.3390/agronomy13082113>
- Agnihotri, V., Chandola, D., & Thathola, P. (2025). Grey water treatment and circular economy. *Chemosphere*, 284, 144433. <https://doi.org/10.1016/j.chemosphere.2025.144433>
- Alharbi, S. K., Shafiquzzaman, M., Haider, H., AlSaleem, S. S., & Ghumman, A. R. (2019). Treatment of ablution greywater for recycling by alum coagulation and activated carbon adsorption. *Arabian Journal for Science and Engineering*, 44, 8389–8399. <https://doi.org/10.1007/s13369-019-03834-6>
- Allen, L. (2010). *Overview of greywater reuse*. Pacific Institute.
- Birkhold, M. H. (2023). *Chasing icebergs: How frozen freshwater can save the planet* (First Pegasus Books edition). Pegasus Books.
- Chartres, C. J., & Noble, A. (2015). Sustainable intensification: Overcoming land and water constraints on food production. *Food Security*, 7(2), 235–245. <https://doi.org/10.1007/s12571-015-0425-1>
- Committee on the Beneficial Use of Graywater and Stormwater: An Assessment of Risks, Costs, and Benefits, Water Science and Technology Board, Division on Earth and Life Studies, & National Academies of Sciences, Engineering, and Medicine. (2016). *Using graywater and stormwater to enhance local water supplies: An assessment of risks, costs, and benefits* (p. 21866). National Academies Press. <https://doi.org/10.17226/21866>
- Egbumokei, P. I., Dienagha, I. N., Digitemie, W. N., Onukwulu, E. C., & Oladipo, O. T. (2024). Sustainability in reservoir management: A conceptual approach to integrating green technologies with data-driven modeling. *International Journal of Multidisciplinary Research and Growth Evaluation*, 5(5), 1003–1013. <https://doi.org/10.54660/IJMRGE.2024.5.5.1003-1013>
- Gil-Ozoudeh, I., Iwuanyanwu, O., Okwandu, A. C., & Ike, C. S. (n.d.). Water conservation strategies in green buildings: Innovations and best practices. *Engineering Science & Technology Journal*, 4(6), 651–671. <https://doi.org/10.51594/estj.v4i6.1525>
- Ishaque, W., Mukhtar, M., & Tanvir, R. (2023). Pakistan's water resource management: Ensuring water security for sustainable development. *Frontiers in Environmental Science*, 11. <https://doi.org/10.3389/fenvs.2023.1096747>
- Jain, S., Srivastava, A., Khadke, L., Chatterjee, U., & Elbeltagi, A. (2024). Global-scale water security and desertification management amidst climate change. *Environmental Science and Pollution Research*, 31(49), 58720–58744. <https://doi.org/10.1007/s11356-024-34916-0>
-

- Khilchevskiy, V., & Karamushka, V. (2021). Global water resources: Distribution and demand. In W. Leal Filho, A. M. Azul, L. Brandli, A. L. Salvia, & T. Wall (Eds.), *Clean water and sanitation* (pp. 1–11). Springer International Publishing. https://doi.org/10.1007/978-3-319-70061-8_101-1
- Li, P., & Wu, J. (2024). Water resources and sustainable development. *Water (Switzerland)*, *16*(1), 134. <https://doi.org/10.3390/w16010134>
- Menegaki, A. N. (2024). Powering down hospitality through a policy-driven, case-based and scenario approach. *Business, Economics and Management*. <https://doi.org/10.20944/preprints202412.2482.v1>
- Moghadam, B. Z. (2010). A route to a resourceful water efficiency exploration: Residential water usage of Water Efficiency section of USGBC, LEED Program. *2010 Spring ASEE Middle Atlantic Section Conference*. <https://doi.org/10.18260/1-2-1153-50058>
- Mugagga, F., & Nabaasa, B. B. (2016). The centrality of water resources to the realization of Sustainable Development Goals (SDG): A review of potentials and constraints on the African continent. *International Soil and Water Conservation Research*, *4*(3), 215–223. <https://doi.org/10.1016/j.iswcr.2016.05.004>
- Oteng-Peprah, M., Acheampong, M. A., & deVries, N. K. (2018). Greywater characteristics, treatment systems, reuse strategies and user perception—A review. *Water, Air, & Soil Pollution*, *229*(8), 255. <https://doi.org/10.1007/s11270-018-3909-8>
- Pimentel-Rodrigues, C., & Silva-Afonso, A. (2019). Contributions of water-related building installations to urban strategies for mitigation and adaptation to face climate change. *Applied Sciences*, *9*(17), 3575. <https://doi.org/10.3390/app9173575>
- Radin Mohamed, R. M. S., Nazmi, A., Arief, M., & Mohd Kassim, A. H. (2016). Conventional water filter (sand and gravel) for ablution water treatment, reuse potential, and its water savings. *Journal of Sustainable Development*, *9*(1), 35. <https://doi.org/10.5539/jsd.v9n1p35>
- Ramísio, P. J., Pinto, L. M. C., Gouveia, N., Costa, H., & Arezes, D. (2019). Sustainability strategy in higher education institutions: Lessons learned from a nine-year case study. *Journal of Cleaner Production*, *222*, 300–309. <https://doi.org/10.1016/j.jclepro.2019.02.257>
- Shemer, H., Wald, S., & Semiat, R. (2023). Challenges and solutions for global water scarcity. *Membranes*, *13*(6), 612. <https://doi.org/10.3390/membranes13060612>
- Suratkon, A., Ming, C., & Tuan, A. (2014). SmartWUDHU’: Recycling ablution water for sustainable living in Malaysia. *Journal of Sustainable Development*, *7*(6), 150. <https://doi.org/10.5539/jsd.v7n6p150>
- Zhang, S., Wu, Y., & Xu, B. (2023). Rational utilization of water resources to promote sustainable development of rural ecotourism. *Water Supply*, *23*(9), 3855–3869. <https://doi.org/10.2166/ws.2023.229>



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