Integrated Science Education Journal
Vol. 6, No. 3, September 2025, pp. 224~231
ISSN: 2716-3725, DOI: 10.37251/isej.v6i3.2114

Advancing Sustainable Development Goal 6: Innovations, Challenges, and Pathways for Clean Water and Sanitation

Msafiri Mmamba Jackson[1,*], Amjd Abdallah Omer Alfaki[2]
[1]Environmental Engineering, University of Eastern Africa – Baraton, Kenya
[2]Department of Environmental Engineering, Sudan University of Science and Technology, Sudan

Article Info

Article history:

Received Jun 22, 2025
Revised Aug 15, 2025
Accepted Sep 12, 2025
OnlineFirst Sep 30, 2025

Keywords:

Clean Water
Innovation
Public Policy
Sanitation
Sustainable Development Goal 6

ABSTRACT

Purpose of the study: The aim of this research is to analyze the global state of clean water and sanitation, identify the main challenges faced, and explore innovative solutions and strategies that can contribute to the achievement of Sustainable Development Goal 6 by 2030.

Methodology: This study employed a systematic literature review and comparative analysis with secondary data from WHO, UNICEF, and the World Bank. Data collection was conducted through international databases such as Scopus, Web of Science, and Google Scholar. Data analysis was conducted using descriptive quantitative analysis and thematic qualitative analysis using a matrix-based instrument.

Main Findings: Research shows that more than 2.2 billion people still lack access to safe drinking water and 3.4 billion people lack adequate sanitation services, with the greatest disparities occurring in Sub-Saharan Africa and South Asia. Innovations such as smart water monitoring, low-cost filtration, rainwater harvesting, and community-based sanitation programs have proven to have significant impact. However, persistent barriers include limited funding, social inequality, climate change, and weak governance.

Novelty/Originality of this study: This research integrates technological innovation, public health approaches, community participation, and policy frameworks into a comprehensive analysis of clean water and sanitation. Unlike previous research that focused solely on technical or health aspects, this study expands knowledge by mapping multidimensional strategies and providing practical recommendations for policymakers and stakeholders.

Corresponding Author:
Msafiri Mmamba Jackson,
Environmental Engineering, University of Eastern Africa – Baraton,
Off Eldoret–Kapsabet Road, Baraton, Nandi County, Kenya
Email: msmamba66@gmail.com

1. INTRODUCTION

Clean water and sanitation are basic human needs that are not only related to health, but also to overall quality of life [1]-[3]. Access to clean water is a major factor in preventing infectious diseases which are still high in various developing countries [4]-[6]. Proper sanitation also contributes to the creation of a healthy, productive and dignified environment [7], [8]. However, millions of people around the world still face limitations in accessing clean water sources and adequate sanitation facilities [9]-[11]. This condition shows that the problem of clean water and sanitation remains a very crucial global issue.

The United Nations has emphasized the importance of clean water and sanitation through Sustainable Development Goal (SDG) 6 which targets "Clean Water and Sanitation for All" by 2030 [12]-[14]. Despite various efforts, global targets remain far from being achieved, especially in low-income countries. WHO and

UNICEF data show significant disparities between urban and rural areas in terms of access to clean water and sanitation [15]-[17]. This situation is exacerbated by rapid population growth and climate change, which are putting pressure on water resources. Therefore, achieving SDG 6 requires a more innovative and inclusive approach.

In recent decades, various innovations have been developed to address this issue, ranging from low-cost filtration technology, rainwater harvesting, to community-based sanitation [18], [19]. These innovations have proven effective in increasing access, but their distribution remains uneven across the globe. Furthermore, many interventions are short-term and therefore fail to ensure the sustainability of water and sanitation systems [20], [21]. Funding constraints, weak governance, and low public awareness are often factors that limit program success. This underscores the need for a more integrated strategy between technology, policy, and community participation.

The urgency of research on clean water and sanitation lies in its direct implications for public health and social development. Lack of access to clean water and sanitation contributes to high rates of stunting, diarrhea, and various environmental diseases [22], [23]. Furthermore, the greatest burden is often borne by vulnerable groups such as women and children, who must spend time searching for water. This disparity is not only a health issue, but also a social and economic justice issue. Therefore, this research seeks to highlight this issue from both a global and local perspective. The research conducted by Bain et al., [24] focused on establishing a baseline or benchmark for initial achievements in household water, sanitation, and hygiene services in the context of SDG 6, thus providing a quantitative overview of initial conditions and necessary monitoring indicators. Meanwhile, the research by Setty et al., [25] emphasized identifying global research priorities and learning challenges that need to be addressed to drive progress on SDG 6, thus providing a more strategic and conceptual approach. Both studies were limited to mapping baselines and research priorities, without an in-depth review of practical innovations, implementation strategies, and possible sustainability pathways. Therefore, the current research aims to fill this gap by highlighting current innovations, implementation challenges, and alternative pathways to achieving SDG 6 that are more applicable and oriented towards real solutions.

The novelty of this research lies in its integration of technological innovation, policy, and community practice into a single, comprehensive framework. While most previous research has focused solely on technical or health aspects, this study focuses on the multidimensional relationship between clean water, sanitation, and sustainable development. Thus, this article not only identifies problems but also maps out cross-sectoral solutions. This approach is expected to provide both theoretical and practical contributions to the development of global and local strategies. This strengthens this article's position as a study relevant to contemporary challenges. The urgency of this research is further heightened given the increasingly visible impacts of climate change on water resources. Drought, flooding, and water pollution pose new challenges that worsen sanitation and public health conditions [26], [27]. In addition, rapid urbanization creates additional pressure on water and sanitation infrastructure, particularly in developing countries [11], [28], [29]. Without well-planned interventions, the access gap will widen and hinder the achievement of the SDGs. Therefore, innovative, equitable, and sustainable solutions are urgently needed.

The main objective of this research is to analyze the global state of clean water and sanitation, identify challenges, and explore innovations that can provide sustainable solutions. This research also seeks to provide strategic recommendations that can be applied at the policy level and in practice. With an approach based on global literature analysis and case studies, this article is expected to provide a comprehensive overview. The research results will be an important contribution in strengthening the policy and practice framework towards achieving SDG 6. Thus, this article is not only academically relevant but also has practical value for policymakers and the international community.

2. RESEARCH METHOD

This research uses a descriptive qualitative approach supported by secondary quantitative data [30], [31]. The research focused on a systematic literature review combined with analysis of global data from official institutions such as the WHO, UNICEF, and the World Bank. This approach was chosen to gain a comprehensive understanding of the global state of clean water and sanitation and the innovations implemented in various countries. Furthermore, a comparative analysis across regions was used to highlight disparities in access to clean water and sanitation. The research subjects included documents, policy reports, international journal articles, and global statistical data related to clean water and sanitation. The analysis unit included developing and developed countries that represent SDG 6. Furthermore, several case studies were selected from regions with significant innovations in clean water and sanitation management, such as South Asia and Sub-Saharan Africa.

The research instruments consisted of a literature recording sheet and a data analysis matrix, which were used to summarize the study results from various sources. Data collection was conducted through a systematic

literature review with a search for articles [32], [33]. Secondary data was obtained from reports of international institutions and official government publications.

Data analysis was conducted using thematic analysis methods to identify patterns, challenges, and innovations related to clean water and sanitation. Quantitative data were analyzed descriptively to illustrate the percentage of access to clean water and adequate sanitation, as well as regional distribution. Meanwhile, qualitative analysis was conducted by grouping the literature into main themes: global conditions, technological innovation, policy challenges, and future strategies. A source triangulation approach was used to enhance the validity of the findings.

This research procedure was conducted through several systematic stages. The first stage was problem identification and formulation of research objectives, emphasizing the importance of access to clean water and sanitation as a global issue. Next, secondary data was collected through international journals, official reports from international organizations (WHO, UNICEF, and the World Bank), and relevant global databases. The collected data was then selected and filtered using inclusion criteria, namely publications within the 2015–2025 period, relevance to the theme of clean water and sanitation, and relevance to achieving SDG 6. The next stage was coding and categorizing the data to facilitate analysis, by dividing the information into main themes: global conditions, technological innovation, policy challenges, and future strategies. Following this, a quantitative descriptive analysis was conducted to interpret statistical data related to access to clean water and sanitation in various regions. Simultaneously, a thematic qualitative analysis of the literature and case studies was conducted to identify emerging patterns, challenges, and best practices.

The results of both forms of analysis were then synthesized into comprehensive research findings. This synthesis aimed to demonstrate the relationship between technical, policy, and social factors in achieving clean water and sanitation. The final stage of the research procedure is drawing conclusions and recommendations based on the key findings. These recommendations are intended for policymakers, international institutions, and the global community as a contribution to accelerating the achievement of SDG 6. This structured procedure is expected to produce valid, relevant, and applicable studies. The research procedure can be seen in the following flowchart in figure 1.

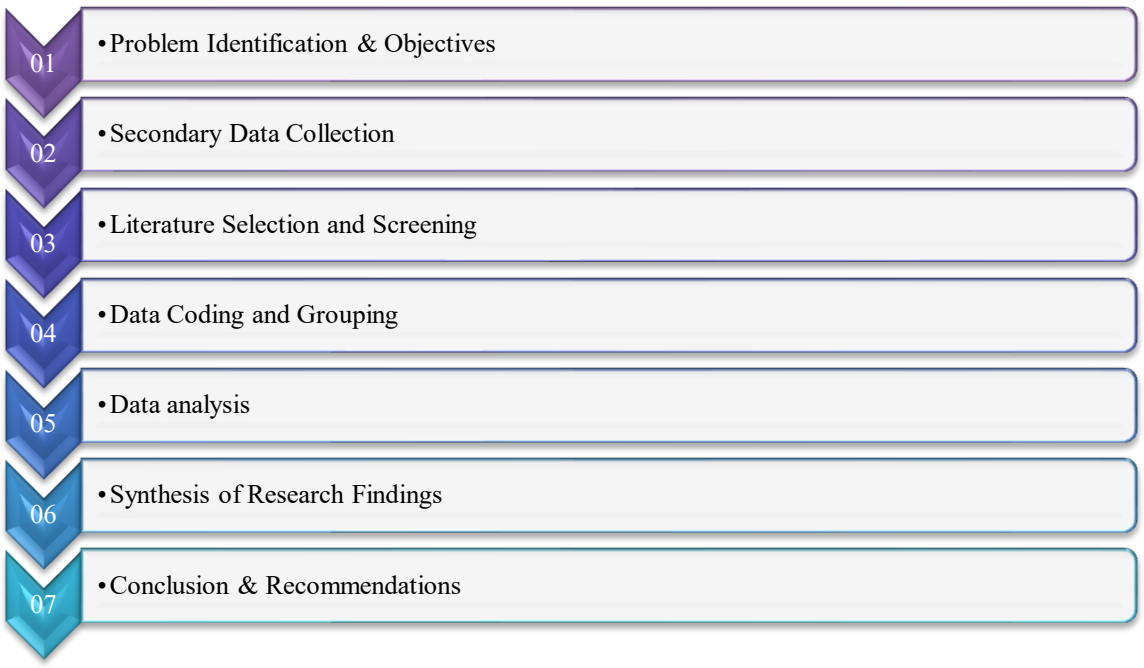

Figure 1. Research Procedure

3. RESULTS AND DISCUSSION

3.1 Global State of Clean Water and Sanitation

According to the latest report from WHO/UNICEF (JMP 2000–2024), approximately 2.1 billion people — or 1 in 4 people worldwide — still do not have access to safely managed drinking water [32]-[34]. Furthermore, 3.4 billion people still do not have access to adequate sanitation, including 354 million people who defecate in the open [35]. This shows that there is still a large global gap in access to these basic needs.

Additionally, SDG 2025 data reveals that despite increased access to WASH services since 2015, more than 2.2 billion people lack safely managed drinking water, 3.4 billion lack safely managed sanitation, and 1.7

billion lack basic hygiene services at home [37]. In Sub-Saharan Africa, research based on the DHS shows that almost 49% of households still use unimproved sanitation facilities, with variations between countries (lowest in Malawi: ≈ 16.7%, highest in Chad: ≈ 88.5%) [38]. In Ghana, UNICEF/WHO data shows stark urban-rural disparities: 88% of the urban population has basic access to water, but only 66% in rural areas; for sanitation, only 14% of the total population has basic access—19% in urban areas and 9% in rural areas.

3.2 Innovation in Water and Sanitation

Various innovative technologies have been developed to improve access to clean water, such as smart water monitoring, which allows for real-time monitoring of water quality, and low-cost water filtration, which is easily implemented in remote areas. Rainwater harvesting technology is also gaining popularity as a sustainable solution in areas with high rainfall [39], [40]. Furthermore, the concept of circular sanitation is beginning to be implemented to process liquid waste into energy or organic fertilizer. This technological innovation offers a more efficient, environmentally friendly, and affordable alternative for the community. However, its adoption remains limited to certain regions due to cost constraints and minimal infrastructure support.

In addition to technological innovation, community-based approaches have proven effective in developing sanitation systems. Community-based sanitation programs emphasize active citizen participation in the planning, implementation, and maintenance of facilities [41], [42]. This enhances ownership, sustainability, and program alignment with local needs. An example is Community-Led Total Sanitation (CLTS), which has successfully reduced open defecation practices in various Asian and African countries. This approach demonstrates the crucial role of community empowerment in addressing sanitation issues.

Integrating clean water and sanitation with public health is also a crucial innovation. Providing handwashing facilities, clean water in schools, and sanitation in health centers has been proven to reduce the number of infectious diseases. These integrated programs not only prevent the spread of water-borne diseases but also strengthen the overall health system. Several countries have successfully reduced childhood diarrhea rates by up to 30% with integrated sanitation programs. Therefore, collaboration between the health and sanitation sectors is crucial for achieving broader impact.

An example of highly affordable technological innovation comes from India, where IIIT-A scientists developed a water filtration device using hydrodynamic techniques costing only about Rs 1,000 (USD ≈ 12–13), capable of filtering bacteria and particles down to 2 nanometers without the need for replacement filters. Meanwhile, in Pakistan, the AKPBS Water and Sanitation Extension Program (WASEP) provides clean water and sanitation systems in communities with active community participation, resulting in a reduction in diarrhea by approximately 25% through inclusive implementation and hygiene education. Sanitation-related innovations also include the development of the Sato pan by Daigo Ishiyama's team in Bangladesh—a water-efficient (less than 1 liter per flush) plastic toilet that is cost-effective and easy to manufacture. This product has been used by over 68 million people in 45 countries, with UNICEF support and local training, while improving sanitation conditions and gender equality.

3.3 Challenges and Obstacles

Limited funding and infrastructure remain the biggest obstacles to providing clean water and sanitation services. Many developing countries lack sufficient financial resources to build and maintain infrastructure. This is exacerbated by high operational costs and a lack of sustainable funding mechanisms. As a result, established programs often stall midway. This situation creates a high dependence on international aid. The SDG report shows that only 57% of countries have implemented integrated water resources management (IWRM), and approximately 60% lack effective funding mechanisms, and 70% experience funding shortfalls at the subnational level.

Furthermore, social inequality also worsens access to clean water and sanitation services. Poor communities, women, and those living in rural areas are often the most impacted. Women and children, for example, must spend hours each day fetching water, reducing their opportunities for school or work. This injustice demonstrates that water and sanitation issues are closely linked to socioeconomic disparities. Therefore, solutions must not only be technical but also address aspects of gender equality and social justice. The JMP report also highlights that the most vulnerable groups—people in low-income countries, communities in fragile regions, children, and minority and indigenous groups—experience significantly disparities in access to water and sanitation compared to the general population.

Climate change is further exacerbating challenges related to clean water and sanitation. Prolonged droughts, floods, and contamination of water sources reduce the availability of clean water, especially in vulnerable areas. These impacts not only harm public health but also food security and local economies. Without appropriate adaptation, climate change will hinder the achievement of SDG 6. Therefore, the sustainability of water and sanitation systems must prioritize climate resilience. SDG 6 notes that the degradation of freshwater ecosystems and pressure on water resources (due to pollution, water stress, etc.) are serious obstacles. If current trends continue, sustainable water management will not be achieved until around 2049.

Policy barriers and weak governance are also significant issues. Many countries still face fragmentation in water and sanitation management, with overlapping authority between agencies. A lack of transparency and accountability also makes program implementation less effective. On the other hand, minimal public participation in policy-making often means that solutions are not aligned with local needs. This highlights the need for more inclusive and transparent governance reforms. Despite the availability of various policies, cross-sectoral coordination remains low: only about half of countries have formal water management coordination mechanisms in place; progress on gender integration has also stagnated, with the global score improving only slightly from 54% to 58% between 2020 and 2023.

3.4 Future Strategies and Opportunities

Strengthening inclusive-based policies is a crucial step in expanding access to clean water and sanitation. Policies that are responsive to the needs of vulnerable groups, including women, children, and rural communities, will ensure social justice. Furthermore, clear regulations and sustainable funding support can accelerate the achievement of SDG 6. Inclusivity also means involving communities in planning and decision-making processes. This approach will make programs more relevant and sustainable. Global analysis emphasizes the need for adaptive policies that are responsive to vulnerable groups, with equitable investment and an inclusive approach based on social justice and the protection of marginalized groups.

Global partnerships also play a crucial role in accelerating the achievement of universal access to clean water and sanitation. Collaboration between governments, NGOs, the private sector, and local communities allows for greater resource mobilization. Joint, cross-sectoral programs can deliver innovative solutions while strengthening local capacity. For example, global initiatives like Sanitation and Water for All (SWA) connect various actors within a single framework. Such partnerships can be a key driver of change. Acceleration efforts such as the SDG 6 Global Acceleration Framework initiated by WHO and UNICEF, as well as partnerships with WaterAid and others, demonstrate the importance of multistakeholder collaboration in addressing the global sanitation crisis (3.4 billion people without access).

Furthermore, the implementation of climate-resilient water and sanitation systems is an adaptive strategy to the challenges of climate change [43], [44]. These systems are designed to remain functional even in the face of drought, flooding, or water contamination. Examples of these systems include rainwater harvesting, sustainable wastewater treatment, and low-energy desalination technologies. By integrating climate resilience aspects, the sustainability of water and sanitation systems can be ensured. This is crucial for maintaining the availability of services for future generations. Global action urges strengthening resilience to climate change through investment in infrastructure, education, and an ecosystem approach—focused on protecting and sustainably managing water resources, and improving water use efficiency [45], [46].

Another equally important strategy is public education and raising public awareness. Clean and healthy living behaviors, wise water use, and participation in maintaining sanitation facilities are key factors in the program's success [47], [48]. Community-based health campaigns have been proven to significantly change community behavior. Furthermore, early education about the importance of clean water and sanitation can create a more environmentally conscious generation. With a combination of technology and public awareness, SDG 6 targets will be more easily achieved. Initiatives such as WASEP (Pakistan) and Satopan (Bangladesh and other countries) demonstrate that community empowerment and behavioral health education are key to successful long-term implementation.

In addition to highlighting global conditions and existing innovations, it is important to examine the findings of this study within the framework of sustainable development and environmental governance theory. The data demonstrate that disparities in access to water and sanitation are not merely technical issues but also rooted in governance and social justice. This aligns with the equity in WASH theory, which emphasizes that vulnerable groups (women, children, the poor, and rural communities) often bear the greatest burden due to limited access. Therefore, the success of technological innovation is inextricably linked to the extent to which governments and international institutions implement the principle of inclusivity in policy.

Furthermore, the findings of this study reinforce the view that achieving SDG 6 requires a multidimensional approach. Previous studies by Bain et al., [24] and Setty et al., [25] focused more on baseline indicators and research priorities, but less on actual implementation pathways on the ground. These findings demonstrate that the adoption of innovations such as community-led sanitation or low-cost filtration is not always successful without sustainable funding mechanisms and cross-sectoral coordination. In other words, the biggest challenge is not simply the availability of technology, but rather the integration between various actors—government, the private sector, civil society, and local communities.

Furthermore, this research also underscores the importance of the ecological sustainability dimension. The impacts of climate change, such as droughts and floods, demonstrate that WASH solutions must incorporate elements of climate resilience. Innovations that are not adaptive to climate dynamics will only be temporary solutions [49], [50]. Therefore, future strategies must combine environmentally friendly technologies, evidence-based policies, and public education as a whole. With this critical approach, this research not only contributes to

the academic literature but also offers a stronger practical basis for policymakers in accelerating the achievement of SDG 6 in an equitable and sustainable manner.

This research has several important implications, both academically and practically. Academically, this research expands the literature on SDG 6 by presenting an analysis that integrates aspects of technology, policy, community participation, and climate resilience within a comprehensive framework. Practically, the results of this research can serve as a reference for policymakers, international institutions, and civil society organizations in designing strategies to accelerate the achievement of more inclusive and sustainable access to clean water and sanitation. By mapping key innovations and barriers, this research is able to provide evidence-based recommendations relevant to both global and local contexts.

However, this research has several limitations that should be noted. First, this study uses only secondary data through literature reviews and international agency reports, thus excluding primary field data that could provide a more detailed picture of local dynamics. Second, the selected publication period (2015–2025) limits the scope of the references and may not fully capture long-term trends or recent changes beyond that timeframe. Third, the analysis focuses more on global conditions, so generalizations to specific country contexts require further study. Therefore, further research is recommended to combine case-based field studies with predictive analysis models, so as to provide deeper insights into the effectiveness of innovations and SDG 6 implementation strategies in various social, political, and ecological contexts.

4. CONCLUSION

Access to clean water and sanitation remains a major global challenge, despite being a key focus of the sustainable development agenda. Global statistics show that billions of people still live without adequate services, with significant disparities between regions, particularly in Sub-Saharan Africa, South Asia, and several countries in Latin America. This situation demonstrates that clean water and sanitation issues are not merely technical issues but also social, economic, and equity-based. Therefore, achieving SDG 6 requires more serious and integrated cross-sectoral attention. Various innovations, including technologies such as smart water monitoring and rainwater harvesting, as well as community-based approaches, have demonstrated positive impacts in expanding access to services. However, the sustainability of these innovations remains hampered by limited funding, weak governance, and the increasingly complex challenges of climate change. This study confirms that efforts to increase access to clean water and sanitation must be accompanied by a comprehensive strategy that combines technical aspects, policies, and community participation. This ensures that the resulting solutions are not only short-term but also sustainable.

The main recommendations of this study are the need for inclusive policies, stronger global partnerships, and the implementation of climate-resilient water and sanitation systems. Furthermore, increasing public education and awareness is a crucial foundation for the success of programs on the ground. The findings of this study provide an academic contribution by integrating analysis of innovations, challenges, and future strategies into a comprehensive framework. Practically, the results of this study are expected to serve as a reference for policymakers, international institutions, and the global community in accelerating the achievement of universal access to clean water and sanitation. With a collaborative and sustainable approach, SDG 6 targets can be more realistically achieved. Further research is recommended to conduct case-based field studies to test the effectiveness of technological innovations and community approaches in different local contexts. Furthermore, developing predictive models based on quantitative and qualitative data could provide a more accurate picture of the future path to accelerating SDG 6 achievement.

ACKNOWLEDGEMENTS

The author would like to express his deepest gratitude to all institutions and stakeholders who have contributed to the completion of this research.

REFERENCES

[1] A. N. Angelakis *et al.*, “Water quality and life expectancy: Parallel courses in time,” *Water*, vol. 13, no. 752, pp. 1–15, 2021.

[2] L. Anatolia S.M. Exposto, M. Nahak Lino, J. A.C. Quim, M. Juvi Goncalves, and H. Pereira Vicente, “Efforts to improve clean water quality to support community health,” *KESANS Int. J. Heal. Sci.*, vol. 1, no. 3, pp. 236–251, 2021, doi: 10.54543/kesans.v1i3.24.

[3] P. Bazaanah and R. A. Mothapo, *Sustainability of drinking water and sanitation delivery systems in rural communities of the Lepelle Nkumpi Local Municipality, South Africa*, vol. 26, no. 6. Springer Netherlands, 2024. doi: 10.1007/s10668-023-03190-4.

[4] G. M. Shayo, E. Elimbinzi, G. N. Shao, and C. Fabian, “Severity of waterborne diseases in developing countries and the effectiveness of ceramic filters for improving water quality,” *Bull. Natl. Res. Cent.*, vol. 47, no. 1, pp. 1–14, 2023, doi: 10.1186/s42269-023-01088-9.

[5] J. H. Ellwanger, A. Beatriz, V. D. L. Kaminski, and J. María, “Control and prevention of infectious diseases from a

One Health perspective," *Genet. Mol. Biol.*, vol. 44, no. suppl 1, pp. 1–23, 2021.
[6] R. A. Kristanti, T. Hadibarata, M. Syafrudin, M. Yılmaz, and S. Abdullah, "Microbiological contaminants in drinking water: Current status and challenges," 2022, *Springer International Publishing*. doi: 10.1007/s11270-022-05698-3.
[7] E. U. Alum, E. I. Obeagu, and O. P. C. Ugwu, "Enhancing quality water, good sanitation, and proper hygiene is the panacea to diarrhea control and the attainment of some related sustainable development goals A review," *Med. (United States)*, vol. 103, no. 38, p. e39578, 2024, doi: 10.1097/MD.0000000000039578.
[8] R. Suleiman, N. R. G. Danga, and A. Mustapha, "Enhancing environmental sanitation education and capacity building for sustainable development in a depressed economy," *Int. J. Hum. Kinet. Heal. Educ.*, vol. 9, no. 2, pp. 110–118, 2024.
[9] A. Shrestha *et al.*, "Water, sanitation, and hygiene of nepal: status, challenges, and opportunities," *ACS ES&T Water*, vol. 3, no. 6, pp. 1429–1453, Jun. 2023, doi: 10.1021/acsestwater.2c00303.
[10] D. Adugna, "Challenges of sanitation in developing counties - Evidenced from a study of fourteen towns, Ethiopia," *Heliyon*, vol. 9, no. 1, p. e12932, 2023, doi: 10.1016/j.heliyon.2023.e12932.
[11] O. J. Okesanya *et al.*, "Water, sanitation, and hygiene (WASH) practices in Africa: exploring the effects on public health and sustainable development plans," 2024, *BioMed Central*. doi: 10.1186/s41182-024-00614-3.
[12] H. Aman, Z. H. Doost, A. W. Hejran, A. D. Mehr, R. Szczepanek, and G. Gilja, "Survey on the challenges for achieving SDG 6 Clean water and sanitation: A global insight," *Knowledge-Based Eng. Sci.*, vol. 5, no. 3, pp. 21–42, 2024, doi: 10.51526/kbes.2024.5.3.21-42.
[13] C. T. Okoji, O. T. Arowolo, M. C. Okoji, and A. U. Owolabi, "Knowledge and attitude ofoffa residents on clean water and sanitation (SDG Six)," *Au J. Bus. Soc. Sci.*, vol. 5, no. 1, pp. 269–281, 2025.
[14] G. Mujtaba, M. U. H. Shah, A. Hai, M. Daud, and M. Hayat, "A holistic approach to embracing the United Nation's Sustainable Development Goal (SDG-6) towards water security in Pakistan," *J. Water Process Eng.*, vol. 57, no. November 2023, pp. 1–18, 2024, doi: 10.1016/j.jwpe.2023.104691.
[15] S. Biswas, M. Adhikary, A. Alam, N. Islam, and R. Roy, "Disparities in access to water, sanitation, and hygiene (WASH) services and the status of SDG-6 implementation across districts and states in India," *Heliyon*, vol. 10, no. 18, pp. 1–17, 2024, doi: 10.1016/j.heliyon.2024.e37646.
[16] M. S. Javed, U. Nisar, V. S. R. G, S. H. Warsi, M. M. Billah, and E. A. Karkkulainen, "Mapping the disparities between urban and rural areas in the global attainment of sustainable development goals, economic and social aspects of global rural-urban migration," *Educ. Adm. Theory Pract.*, vol. 30, no. 6, pp. 2065–2076, 2024, doi: 10.53555/kuey.v30i6.5650.
[17] H. K. Fotio and S. M. Nguea, "Access to water and sanitation in Africa: Does globalization matter?," *Int. Econ.*, vol. 170, no. March, pp. 79–91, 2022, doi: 10.1016/j.inteco.2022.02.005.
[18] R. I. Dip, Z. M. M. Hossain, A. Hossain, and I. Haque, "Domestic water filtration technologies in Bangladesh: Challenges, innovations and socio-cultural dimensions," *Barind Med. Coll. J.*, vol. 11, no. 1, pp. 93–99, 2025, doi: 10.70818/bmcj.2025.v011i01.0165.
[19] M. F. Prescott, M. F. Dobbie, and D. Ramirez-Lovering, "Green infrastructure for sanitation in settlements in the global south: A narrative review of socio-technical systems," *Sustain.*, vol. 13, no. 4, pp. 1–20, 2021, doi: 10.3390/su13042071.
[20] T. Yasmin, S. Dhesi, I. Kuznetsova, R. Cooper, S. Krause, and I. Lynch, "A system approach to water, sanitation, and hygiene resilience and sustainability in refugee communities," *Int. J. Water Resour. Dev.*, vol. 39, no. 5, pp. 691–723, 2023, doi: 10.1080/07900627.2022.2131362.
[21] N. E. Clarke, C. E. F. Dyer, S. Amaral, G. Tan, and S. V. Nery, "Improving uptake and sustainability of sanitation interventions in timor-leste: A case study," *Int. J. Environ. Res. Public Health*, vol. 18, no. 3, pp. 1–13, 2021, doi: 10.3390/ijerph18031013.
[22] N. P. Aryani and B. R. Afrida, "The relationship between environmental sanitation and stunting incidence," *J. Ilm. STIKES Yars. Mataram*, vol. 15, no. 2, pp. 137–145, 2025.
[23] W. Anwar, N. Nurjazuli, and T. Joko, "The relationship household environmental sanitation with incidence of stunting in toddlers: Literature review," *Indones. J. Heal. Promot.*, vol. 7, no. 10, pp. 2422–2429, 2024.
[24] R. Bain, R. Johnston, F. Mitis, C. Chatterley, and T. Slaymaker, "Establishing sustainable development goal baselines for household drinking water, sanitation and hygiene services," *Water (Switzerland)*, vol. 10, no. 12, pp. 1–19, 2018, doi: 10.3390/w10121711.
[25] K. Setty, A. Jiménez, J. Willetts, M. Leifels, and J. Bartram, "Global water, sanitation and hygiene research priorities and learning challenges under sustainable development goal 6," *Dev Policy Rev*, vol. 38, no. 1, pp. 64–84, 2020, doi: 10.1111/dpr.12475.Global.
[26] A. T. Aborode *et al.*, "Impact of climate change-induced flooding water related diseases and malnutrition in Borno State, Nigeria: A public health crisis," *Environ. Health Insights*, vol. 19, pp. 1–11, 2025, doi: 10.1177/11786302251321683.
[27] R. K. Mishra, "Fresh water availability and it's global challenge," *J. Mar. Sci. Res.*, vol. 2, no. 1, pp. 01–03, 2023, doi: 10.58489/2836-5933/004.
[28] R. El-Bouayady and H. Radoine, "Urbanization and sustainable urban infrastructure development in Africa," *Environ. Ecol. Res.*, vol. 11, no. 2, pp. 385–391, 2023, doi: 10.13189/eer.2023.110212.
[29] M. A. Rahaman, A. Kalam, and M. Al-Mamun, "Unplanned urbanization and health risks of Dhaka City in Bangladesh: uncovering the associations between urban environment and public health," *Front. Public Heal.*, vol. 11, pp. 1–18, 2023, doi: 10.3389/fpubh.2023.1269362.
[30] H. I. Cheong, A. Lyons, R. Houghton, and A. Majumdar, "Secondary qualitative research methodology using online data within the context of social sciences," *Int. J. Qual. Methods*, vol. 22, pp. 1–19, 2023, doi: 10.1177/16094069231180160.
[31] T. K. Haynes-Brown and M. D. Fetters, "Using joint display as an analytic process: An illustration using bar graphs

joint displays from a mixed methods study of how beliefs shape secondary school teachers' use of technology," *Int. J. Qual. Methods*, vol. 20, pp. 1–14, 2021, doi: 10.1177/1609406921993286.
[32] T. Justesen, J. Freyberg, and A. N. Ø. Schultz, "Database selection and data gathering methods in systematic reviews of qualitative research regarding diabetes mellitus-an explorative study," *BMC Med. Res. Methodol.*, vol. 21, no. 1, pp. 1–12, 2021, doi: 10.1186/s12874-021-01281-2.
[33] S. Almasi, K. Bahaadinbeigy, H. Ahmadi, S. Sohrabei, and R. Rabiei, "Usability evaluation of dashboards: A systematic literature review of tools," *Biomed Res. Int.*, vol. 2023, 2023, doi: 10.1155/2023/9990933.
[34] D. Baye, "Sustainable development goals (SDG) target 6.2 in Ethiopia: Challenges and opportunities," *Open Access Libr. J.*, vol. 08, no. 05, pp. 1–28, 2021, doi: 10.4236/oalib.1107458.
[35] WHO and UNICEF, "1 in 4 people globally still lack access to safe drinking water – WHO/UNICEF Joint Monitoring Programme (JMP) report," UNICEF. [Online]. Available: https://www.unicef.org/press-releases/fast-facts-1-4-people-globally-still-lack-access-safe-drinking-water-who-unicef
[36] W. H. Organization, "1 in 4 people globally still lack access to safe drinking water," WHO. [Online]. Available: https://www.who.int/philippines/news/detail-global/26-08-2025-1-in-4-people-globally-still-lack-access-to-safe-drinking-water---who--unicef?
[37] U. Nations, "Ensure availability and sustainable management of water and sanitation for all (SDG 6)." [Online]. Available: https://unstats.un.org/sdgs/report/2025/Goal-06/
[38] L. Demoze *et al.*, "Determinants and geographic distribution of unimproved sanitation facilities in sub-Saharan Africa, spatial and multilevel analysis using demographic and health survey (DHS) data," *BMC Public Health*, vol. 25, no. 1, pp. 1–16, 2025, doi: 10.1186/s12889-025-24184-z.
[39] G. Ssekyanzi, M. J. Ahmad, and K. S. Choi, "Sustainable solutions for mitigating water scarcity in developing countries: A comprehensive review of innovative rainwater storage systems," *Water (Switzerland)*, vol. 16, no. 17, pp. 1–21, 2024, doi: 10.3390/w16172394.
[40] Z. H. Doost, M. Alsuwaiyan, and Z. M. Yaseen, "Runoff management based water harvesting for better water resources sustainability: A comprehensive review," *Knowledge-Based Eng. Sci.*, vol. 5, no. 1, pp. 1–45, 2024, doi: 10.51526/kbes.2024.5.1.1-45.
[41] T. T. Praja, D. W. S. Rengganis, D. A. Iryani, and L. Hakim, "Evaluation of community participation in community-based water supply and sanitation programs in Kampung Rantau Jaya Ilir, Central Lampung Regency," *Int. J. Islam. Educ. Res. Multiclturalism*, vol. 5, no. 3, pp. 673–690, 2023.
[42] A. Mustika and I. Kustiani, "Community participation and management performance on the quality of service provision of community-based drinking water and sanitation facilities in Kelawi …," *Lampung Int. J. …*, vol. 1, no. 1, pp. 22–27, 2022, [Online]. Available: http://lije.eng.unila.ac.id/index.php/ojs/article/view/5
[43] G. Howard *et al.*, "The how tough is WASH framework for assessing the climate resilience of water and sanitation," *npj Clean Water*, vol. 4, no. 1, pp. 1–10, 2021, doi: 10.1038/s41545-021-00130-5.
[44] A. Wriege-Bechtold, M. Barjenbruch, C. Sieker, A. Peter-Fröhlich, B. Heinzmann, and B. Lengemann, "Production of energy by co-fermentation with contents from fat separators," *J. Water Clim. Chang.*, vol. 1, no. 4, pp. 251–257, 2010, doi: 10.2166/wcc.2010.105.
[45] M. Falkenmark and J. Rockström, "Building water resilience in the face of global change: From a blue-only to a green-blue water approach to land-water management," *J. Water Resour. Plan. Manag.*, vol. 136, no. 6, pp. 606–610, 2010, doi: 10.1061/(asce)wr.1943-5452.0000118.
[46] D. Butler *et al.*, "Reliable, resilient and sustainable water management: The Safe & SuRe approach," *Glob. Challenges*, vol. 1, no. 1, pp. 63–77, 2017, doi: 10.1002/gch2.1010.
[47] S. Nelson, D. Drabarek, A. Jenkins, J. Negin, and S. Abimbola, "How community participation in water and sanitation interventions impacts human health, WASH infrastructure and service longevity in low-income and middle-income countries: A realist review," *BMJ Open*, vol. 11, no. 12, pp. 1–18, 2021, doi: 10.1136/bmjopen-2021-053320.
[48] F. R. Nasution and C. Nuraini, "Study on the preparation of regional policy and strategy for drinking water supply system (JAKSTRADA SPAM) Batu Bara Regency," *Int. Conferance Digit. Sci. Eng. Technol.* , vol. 1, no. 1, pp. 229–239, 2024, [Online]. Available: https://proceeding.pancabudi.ac.id/index.php/ICDSET/article/view/181
[49] M. Egerer *et al.*, "Urban change as an untapped opportunity for climate adaptation," *npj Urban Sustain.*, vol. 1, no. 1, pp. 1–9, 2021, doi: 10.1038/s42949-021-00024-y.
[50] X. Yuan *et al.*, "Impacts of global climate change on agricultural production: A comprehensive review," *Agronomy*, vol. 14, no. 7, pp. 1–19, 2024, doi: 10.3390/agronomy14071360.