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Predominant Drinking Water Treatment Technologies in Urban Areas of Myanmar: Challenges and Solutions. A Review

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Abstract:

Access to clean drinking water is essential for public health and socioeconomic development in Myanmar, where rapid urbanization has heightened the need for effective water treatment solutions. Adequate water treatment in urban areas is crucial for reducing waterborne diseases, such as cholera, dysentery, and typhoid, thus lowering infant mortality rates due to severe diarrhea and dehydration. Economically, a healthier population results in a more productive workforce and can attract tourism, boosting local economies. Environmentally, proper water treatment prevents pollutants from contaminating rivers and lakes, protecting ecosystems and biodiversity, and ensuring industrial and residential waste does not harm the environment. As urban populations expand, the need for clean water rises, necessitating efficient water treatment for sustainable development and attracting investments in essential infrastructures like sanitation and healthcare. Effective water treatment systems are vital for managing flood impacts, providing safe drinking water during floods, and recycling water during droughts.

However, Myanmar faces challenges such as aging infrastructure, limited financial and technical resources, and the need for strict enforcement of water quality standards. Investing in modern water treatment technologies and capacity building for local technicians and engineers is essential for improving efficiency and effectiveness. Raising community awareness and involving local communities in water management practices can also enhance the sustainability of water treatment efforts. Therefore, improving water treatment infrastructure and governance is a critical step for Myanmar's urban areas to ensure public health, support economic growth, protect the environment, foster sustainable development, and build resilience against climate change. This review examines the predominant drinking water treatment technologies in urban Myanmar, identifies the challenges faced, and proposes potential solutions.

Keywords: *Urban Water Treatment, Public Health, Sustainability, Technological Innovations and Myanmar Water Challenge.*

Introduction

Access to clean drinking water is essential for public health and socioeconomic development in Myanmar, where rapid urbanization has heightened the need for effective water treatment solutions (Win et al., 2023). Adequate water treatment in urban areas is crucial for reducing waterborne diseases, such as cholera, dysentery, and typhoid, thus lowering infant mortality rates due to severe diarrhea and dehydration. Economically, a healthier population results in a more productive workforce and can attract tourism, boosting local economies. Environmentally, proper water treatment prevents pollutants from contaminating rivers and lakes, protecting ecosystems and biodiversity, and ensuring industrial and residential waste does not harm the environment (Saravanan et al., 2021). As urban populations expand, the need for clean water rises, necessitating efficient water treatment for sustainable development and attracting investments in essential infrastructures like sanitation and healthcare (Alshehri et al., 2021). Effective water treatment systems are vital for managing flood impacts, providing safe drinking water during floods, and recycling water during droughts (Ferreira et al., 2022). However, Myanmar faces challenges such as aging infrastructure, limited financial and technical resources, and the need for strict enforcement of water quality standards (Ko & Sakai, 2021b). Investing in modern water treatment technologies and capacity building for local technicians and engineers is essential for improving efficiency and effectiveness. Raising community awareness and involving local communities in water management practices can also enhance the sustainability of water treatment efforts. Therefore, improving water treatment infrastructure and governance is a critical step for Myanmar's urban areas to ensure public health, support economic growth, protect the environment, foster sustainable development, and build resilience against climate change (Ferreira et al., 2022). This review examines the predominant drinking water treatment technologies in urban Myanmar, identifies the challenges faced, and proposes potential solutions.

Overview of Predominant Drinking Water Treatment Technologies in Urban Myanmar

Traditional Methods of Drinking Water Treatment in Myanmar's Urban Areas

Sand Filtration

Sand filtration, commonly used in smaller urban areas, involves passing water through sand layers to remove suspended solids and particulate matter. While effective for sediment removal, it does not address microbial contamination adequately. Sand filtration removes suspended solids, microorganisms, and impurities from water, commonly used in water treatment plants and private systems. The two main types are slow sand filters and rapid sand filters, each with unique characteristics and applications. Slow sand filters, consisting of sand beds supported by gravel, rely on biological activity in the upper layer to break down organic matter. They are simple to operate, require periodic scraping, and are effective for low-turbidity surface water in small communities, though they need large land areas and are unsuitable for highly turbid water (Huisman & Wood, 1974). Rapid sand filters, enclosed in concrete or steel tanks, require pre-treatment and regular backwashing. They are efficient for large volumes in municipal plants, effective for both surface and groundwater, but involve more complex operation, maintenance, and higher costs (Adelman Michael et al., 2012). Sand filtration works through mechanical straining, sedimentation, adsorption, and biological action.

Boiling

Boiling water is a traditional household method to kill pathogens such as bacteria, viruses, and protozoa by heating water to 100°C. This simple and effective practice is especially useful in emergencies or when treated water is unavailable, requiring at least 1-3 minutes of boiling to ensure safety, with longer times needed at higher altitudes. While boiling doesn't involve chemicals and is accessible with a heat source, it is energy-intensive, time-consuming, and ineffective against chemical contaminants. Despite its drawbacks, it's recommended by the WHO and EPA for microbiological safety, particularly in emergencies, rural areas, and outdoor activities (Cohen et al., 2017; Nicole).

Modern Technologies for Drinking Water Treatment in Myanmar's Urban Areas

Chlorination

Chlorination, the most widely used method for disinfecting drinking water in urban treatment plants, effectively kills bacteria, viruses, and protozoa, ensuring safe drinking water. Chlorine, added in liquid or solid forms, remains in the water for a specific time to ensure thorough disinfection, and a residual amount continues to protect against microbial contamination in the distribution system. Despite its effectiveness and cost-efficiency, chlorination requires careful management to prevent harmful by-products and may alter water taste and odor. It is endorsed by the EPA and WHO for its efficacy in pathogen control and is utilized in municipal, private, and emergency water systems (Drogui & Daghrir, 2015).

UV Treatment

Ultraviolet (UV) treatment is one of the drinking water treatment methods used in urban areas of Myanmar. This UV light is used to inactivate and eliminate microorganisms in the water (Sakai et al., 2013). Research has shown that Ultraviolet (UV) light is one of the most cost-effective and efficient methods for homeowners to eliminate a wide range of biological contaminants from their water supply. This technology is advantageous because it introduces no chemicals, produces no by-products, and does not alter the water's taste, pH, or other properties. Extensive studies have compared the effectiveness of chlorine and UV sterilization lamps in removing microbiological contaminants from domestic water supplies (Adegbola et al., 2019).

Membrane Filtration

Membrane filtration methods, such as microfiltration, ultrafiltration, and reverse osmosis, are utilized for drinking water treatment in Myanmar to remove particulate matter, microorganisms, and various dissolved pollutants. These advanced techniques are highly effective, though expensive and maintenance-intensive. Each method employs membranes with specific pore sizes, surface charges, and hydrophobic properties. The widespread adoption of membrane filtration in water treatment is due to its superior treatment quality, straightforward process management, efficient solid-liquid separation, small footprint, and adaptability to existing facilities, all while maintaining low energy consumption (Le & Nunes, 2016). The effectiveness of contaminant removal relies on both the membrane's characteristics and the contaminant's properties (Snyder et al., 2007). However, the primary drawback of this technology is the cost of the membrane, which can be mitigated or eliminated with proper handling of the filtration process (Gupta & Ali, 2013; Razali et al., 2023).

Conventional Drinking Water Treatment Process General Description

In urban areas of Myanmar, including cities like Nay Pyi Taw and Yangon, conventional drinking water treatment processes are the most predominant for centralized treatment plants and ensures safe consumption through a series of standard steps. First, coagulation and flocculation involve adding chemicals such as alum (aluminum sulfate) to the water, causing small particles to clump into larger flocs (Saritha et al., 2017). The water and flocs then flow into a sedimentation basin, where the heavier flocs settle at the bottom, removing a significant amount of suspended solids.

The water is filtered through sand, gravel, and charcoal to remove smaller particles, bacteria, and other contaminants not removed during sedimentation (M. A et al., 2018). It is then disinfected with chlorine or other agents to eliminate remaining pathogens, making it safe for drinking (Collivignarelli et al., 2017). Finally, the treated water is stored in reservoirs or tanks before being distributed to consumers.

Occasionally, additional steps like aeration and fluoridation are used. Aeration removes dissolved gases and oxidizes dissolved metals such as iron and manganese, while fluoridation, though less common, is sometimes used for dental health benefits (Gaid, 2023). Conventional methods are well-established, cost-effective, and suitable for the infrastructure and resources available in most urban and rural areas as compared to advanced methods thereby making them predominant. This structured approach effectively provides safe drinking water, addressing both chemical and microbiological contaminants to ensure public health in Myanmar's urban areas (Organization, 2017). Figure 1 shows the process flow sheet of conventional drinking water treatment.

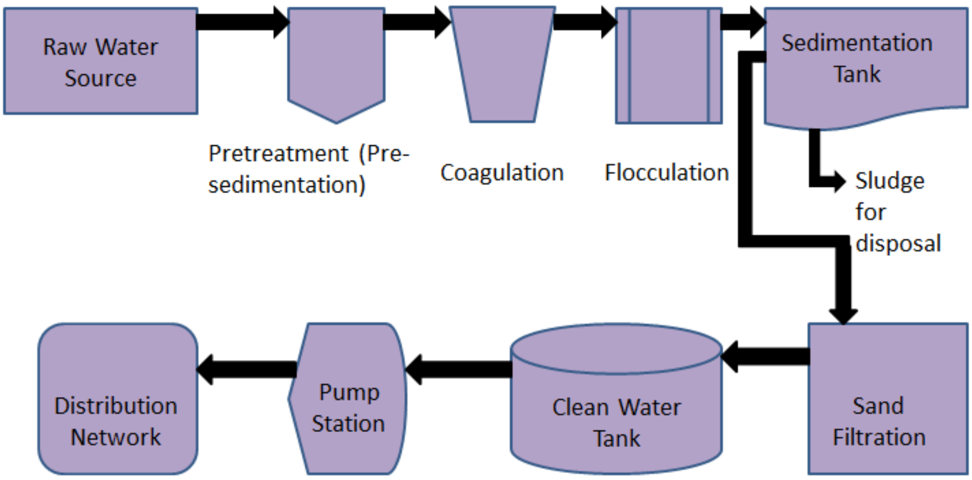

Figure 1. Schematic Conventional drinking water treatment process
Source: Pacific, 2017

Evaluation of Water Treatment Technologies Applied in Urban Cities of Myanmar

Evaluating water treatment technologies for urban cities in Myanmar requires considering their effectiveness, cost, accessibility, and sustainability. Sand filtration is effective for removing particulate matter and some pathogens, with low initial and operational costs, easy implementation using local materials, and high sustainability due to minimal energy use and low environmental impact (Mac Mahon, 2022). Boiling is highly effective in killing pathogens, but its cost varies based on the energy source, and it relies on a consistent fuel supply, making its sustainability moderate to low due to fuel consumption and emissions (WHO, 2017). Chlorination offers excellent pathogen removal and residual disinfection at low to moderate costs, is widely accessible, but requires regular chemical supply, impacting its sustainability moderately (Clasen et al., 2015; WHO, 2012). UV treatment is very effective against pathogens but not for turbid water, with moderate to high initial costs and low operational costs, requiring electricity and maintenance, but offering high sustainability with low energy use and no chemical residues (Sommer et al., 2008). Membrane filtration is highly effective for a broad range of contaminants, but comes with high initial and maintenance costs, requires technical expertise and reliable infrastructure, and is moderately sustainable due to energy intensity and membrane replacement (Kennedy et al., 2008; Kumano & Fujiwara, 2008; Uemura & Henmi, 2008).

Challenges in Water Treatment in Urban Myanmar

Urban Myanmar struggles with water treatment due to outdated infrastructure, financial limitations, regulatory challenges, and environmental issues. Many urban areas depend on inadequate facilities unable to meet the increasing demand from urbanization ((ADB), 2020; Larsen et al., 2016). Additionally, the absence of advanced technologies and skilled personnel further impedes effective water treatment efforts.

Financial constraints further complicate the situation. There is often insufficient funding for upgrading and maintaining water treatment infrastructure, and these financial limitations restrict investments in new technologies and the expansion of services to underserved areas ((ADB), 2020). The high cost of advanced water treatment technologies can be prohibitive for a developing country like Myanmar, leading to reliance on less effective and outdated methods.

Regulatory and governance issues also pose significant barriers. Myanmar lacks comprehensive water management policies and regulatory frameworks, resulting in fragmented efforts and inefficiencies in water treatment and distribution. Even where regulations exist, weak enforcement leads to non-compliance and substandard water treatment practices.

Environmental factors like industrial discharge, agricultural runoff, and untreated sewage complicate water treatment. Climate change worsens these issues by causing irregular rainfall and more frequent extreme weather, impacting water availability and quality (Ong et al., 2023).

Social and accessibility issues also contribute to the complexity of water treatment in urban Myanmar. There is a general lack of public awareness about water conservation and the importance of safe drinking water, leading to inefficient water use and higher pollution levels. Ensuring equitable access to clean water remains a significant challenge, with marginalized communities often having the least access to treated water. Addressing these multifaceted challenges requires a coordinated effort involving technological upgrades, financial investments, robust regulatory frameworks, environmental protection measures, and public education initiatives

Case Studies on Drinking Water Treatment

Nay Pyi Taw's Water Treatment Status

Nay Pyi Taw, Myanmar's administrative capital, provides an insightful case study for drinking water treatment. The city sources its water from reservoirs and rivers, including the Pyinmana and Upper Paunglaung Rivers, as well as groundwater wells with varying quality. It has about ten water treatment plants employing sedimentation, filtration, and disinfection processes. However, challenges persist in maintaining and modernizing infrastructure to ensure consistent treatment and address contamination issues. Regular water quality testing for turbidity, microbial contamination, and pollutants is essential, with efforts to meet both national and international standards. The distribution network's aging infrastructure affects water availability and quality, highlighting the need for improvements. Increasing population and climate change further strain water resources. As of 2017, Nay Pyi Taw had about 10 drinking water treatment plants catering for an urban population of 375189 people living in an area of 7118.89 sq km. The treatment plants are indicated in the table below.

Nay Pyi Taw has several initiatives to ensure the provision of clean drinking water. The Nay Pyi Taw Water Extension Plan (Paunglaung) aims to provide adequate piped water supply to all eight townships by 2030, ensuring 100% water coverage for the urban population. This project involves identifying site locations, treatment types, and pipe alignments. Additionally, the Nay Pyi Taw Development Committee's Engineering Department oversees water supply and sanitation, including the maintenance of extensive water and sewer network (https://www.projectbank.gov.mm).

Table 1. Water Treatment Plants of Nay Pyi Taw City as of 2017

Purification Plant	Plant Capacity (Million gallons per day)	Treatment Method
SSTP No. 1	7.5	Slow Sand Filtration Method
SSTP No. 2	5.0	Slow Sand Filtration Method
SSTP No. 3	2.5	Slow Sand Filtration Method
Yan Aung Myin	1.25	Slow Sand Filtration Method
Paddauk	0.75	Slow Sand Filtration Method
Shwe Kyar Pin	1.5	Slow Sand Filtration Method
Zabuthiri Hospital	0.25	Slow Sand Filtration Method
Guest House 1	0.125	Slow Sand Filtration Method
Kyauk Myat	0.75	Slow Sand Filtration Method
Nyaung Pin Gyisu	0.25	Slow Sand Filtration Method
Total	19.8	Slow Sand Filtration Method

Yangon Water Treatment Status

Yangon, Myanmar's largest city, faces severe water treatment challenges. This case study evaluates the current technologies, their effectiveness, and the specific issues encountered. Only 38% of Yangon's population has access to municipal water, with many relying on alternative sources. The study, conducted in Insein township using household surveys and key informant interviews, highlighted several problems, including seasonal shortages in wards like Gyo Gone (East), Hpawt Kan, and Taung Thu Gone. Water quality issues stem from aging pipelines and inadequate treatment, while improper water tariffs hinder revenue collection and supply efficiency.

Recommendations for improving Yangon's water supply include enhancing water quality, rehabilitating pipelines, and addressing ward-specific issues with immediate actions like installing pumping systems. Upgrading the water tariff collection system and establishing a comprehensive tariff policy to cover provision costs are also crucial for sustainability (Yay Chan, 2018).

Despite being an early adopter of tap water systems, Yangon now struggles due to decades of political instability. A brief democratic period saw the installation of disinfection facilities and the enactment of the Myanmar National Drinking Water Quality Standard (MNDWQS). However, the safety of tap water remains uncertain. A study showed 95% of tap water in the central business district was contaminated with E. coli or coliform bacteria, and only 14% of bottled water was free of contaminants. Household treatment devices, such as ceramic purifiers (CPs) and reverse osmosis (RO) systems, proved over 99% effective in eliminating E. coli, with RO systems also reducing dissolved organic carbon more effectively than CPs. Immediate regulatory actions are needed to ensure compliance with MNDWQS, including regular monitoring and enforcement against unlicensed water sales. Until the Yangon City Development Committee (YCDC) upgrades the tap water system, household treatment devices remain essential for safe drinking water (Ko & Sakai, 2021a).

The Nyaungnapin Water Treatment Plant, essential for Yangon's drinking water, processes surface water from four main reservoirs and some groundwater wells. Serving 5.8 million residents, it provides 340 MLD out of the required 600 MLD. Originally built with a 170 MLD capacity, the plant's expansion in 2014 doubled this capacity. Treatment includes pre-sedimentation, flocculation, sedimentation, rapid sand filtration, and storage. Recent improvements focus on better chemical storage, hourly water quality monitoring, and enhanced sludge disposal. Investments of $19 million for a new pump station and pipeline, and $610,000 for non-revenue water reduction, are aimed at boosting efficiency and water quality management (Ms. Su Su Myat, 2017b).

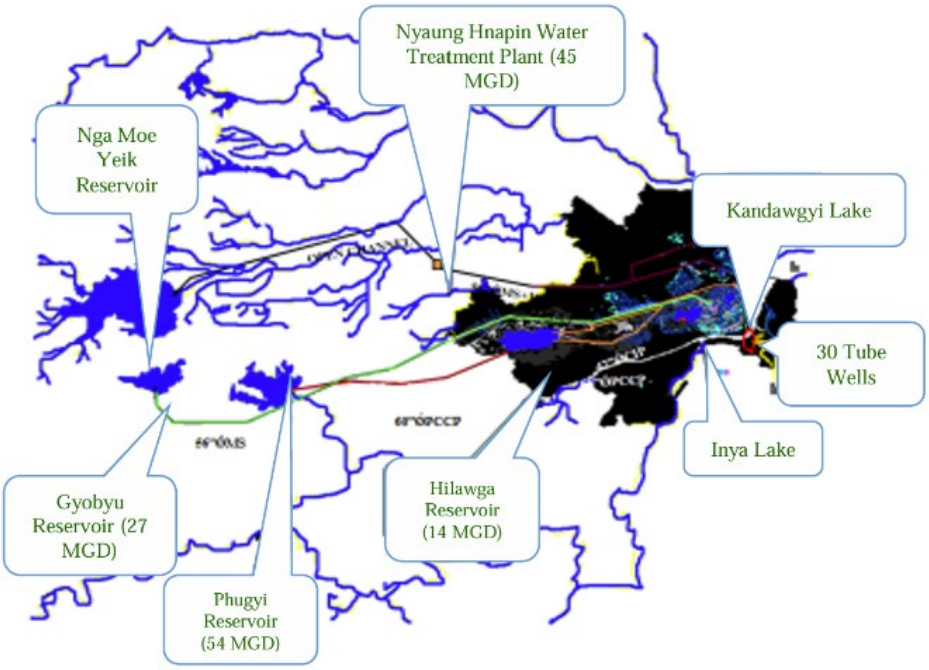

Figure 2. Location of the sources of raw water for Nyaungnapin WTP
Source: Ms. Su Su Myat, 2017a

Mandalay Water Treatment Status

Mandalay exemplifies effective drinking water treatment in Myanmar through its robust and evolving infrastructure (Nagpal et al., 2020). Managed by the Mandalay City Water Supply Department (MCWSD), the city's treatment system utilizes standard processes like coagulation, sedimentation, filtration, and disinfection to ensure safe water from local sources. The Mandalay Water Supply Project (MWSP) highlights the city's commitment to modernization, featuring upgrades with advanced technologies such as membrane filtration and real-time monitoring, alongside network expansion to meet increasing demand (*https://opecfund.org/operations/list/mandalay-water-supply-project*). Despite challenges like maintaining water quality and managing aging infrastructure, Mandalay's efforts in regular maintenance and sustainable practices address these issues effectively. The Nyaungpinlay Water Treatment Plant and other facilities work together within an integrated system, ensuring reliable water supply. Mandalay's approach, blending traditional methods with modern advancements, offers valuable insights for enhancing water treatment across Myanmar. A number of challenges are however encountered in the water production and supply system. These include Water quality (sediments, not drinkable), interruptions of service (only Intermittent supply, not 24/7), Low pressure, Free of Charge Water consumer and pipe Leakages (Committee, 2018).

Solutions and Recommendations

Technological Innovations

Technological advancements are crucial for improving drinking water treatment in

Myanmar's urban areas. Implementing advanced methods like UV disinfection provides a chemical-free solution to eliminate pathogens, enhancing water safety. Reverse osmosis systems effectively remove various contaminants, including heavy metals and dissolved salts, ensuring high-quality drinking water. (Van der Bruggen, 2021). Membrane filtration techniques such as ultrafiltration and nanofiltration effectively eliminate particles and reduce turbidity, resulting in clearer water. Advanced oxidation processes (AOPs) simultaneously degrade organic pollutants and disinfect water, providing a comprehensive solution for complex treatment needs (Aziz et al., 2024). Real-time monitoring and control systems with sensors and automation enhance treatment efficiency by optimizing processes and enabling early contaminant detection (Sun & Chu, 2021). Utilizing renewable energy sources like solar power increases sustainability and reduces costs. Adopting these innovations can greatly improve Myanmar's urban water treatment infrastructure, ensuring a reliable supply of safe drinking water for its expanding urban population (Foundation, 2024; Ko & Sakai, 2020; Naing et al., 2020).

Community Involvement

Community involvement is crucial for enhancing the effectiveness of drinking water treatment in Myanmar's urban areas. Engaging local communities in water management initiatives can foster greater public awareness and responsibility regarding water conservation and pollution prevention. Community-based programs that educate residents about the importance of protecting water sources, proper waste disposal, and water-saving practices can significantly reduce contamination and demand on treatment facilities. Establishing local water committees or advisory boards can facilitate more direct communication between water authorities and residents, allowing for better feedback and tailored solutions to local water issues. Additionally, involving communities in the monitoring and reporting of water quality issues can help identify problems early and ensure swift action. Encouraging volunteer participation in water-related activities, such as clean-up drives and water conservation campaigns, can further strengthen community engagement. By actively involving the community, Myanmar can improve water management practices, enhance the effectiveness of treatment technologies, and ensure a sustainable and reliable supply of safe drinking water (Ananga et al., 2021; Pavisorn et al., 2024).

Collaboration Between Interested Institutions

Institutional collaboration is crucial for improving drinking water treatment technologies in Myanmar’s urban areas(Richard & Catherine, 2015). Partnering with global organizations, development agencies, and foreign governments can bring in advanced technologies, technical expertise, and financial resources. International bodies can provide support through grants, loans, and technical assistance, enabling the modernization of water treatment infrastructure and the implementation of innovative solutions like UV disinfection, reverse osmosis, and real-time monitoring systems. Collaborating with international experts can enhance the skills of local water professionals through knowledge exchange, training programs, and capacity-building efforts. Participation in global water networks and forums keeps Myanmar informed about best practices, emerging technologies, and successful case studies from other countries. By leveraging these international partnerships and resources, Myanmar can significantly improve its water treatment systems, ensuring safe and reliable drinking water for urban populations and addressing the challenges of rapid urbanization and environmental degradation (EUROPE, 2018).

Sustainable Practices

Sustainable practices are crucial for addressing the challenges of drinking water treatment in Myanmar's urban areas. Implementing water-saving technologies and promoting efficient water use can reduce the strain on treatment facilities and conserve valuable resources. Integrating energy-efficient solutions, such as solar-powered water treatment systems, can enhance sustainability by lowering operational costs and reducing the environmental impact (Zakariazadeh et al., 2024). Encouraging the reuse and recycling of water, through systems like greywater recycling, can further decrease the demand on primary water sources (Habibullah et al., 2023). Additionally, adopting green infrastructure practices, such as rain gardens and permeable pavements, can improve water management by reducing runoff and enhancing natural filtration. Community-based water conservation initiatives and education programs can raise awareness about sustainable practices and promote responsible water use. By incorporating these sustainable practices, Myanmar can not only address immediate water treatment challenges but also ensure long-term environmental protection and resource efficiency (Win et al., 2023).

Long-term Strategies

Addressing the persistent challenges of drinking water treatment in Myanmar's urban areas requires long-term strategies. This involves modernizing and expanding infrastructure to meet growing demands, and enforcing regulations to protect water sources from pollution. Promoting advanced technologies like smart water management systems and energy-efficient methods will improve efficiency and sustainability. Strengthening institutional capacity and technical expertise through continuous training is crucial. Public engagement and community-based management can enhance accountability and support conservation efforts. Integrating climate resilience into planning will help adapt to environmental changes, ensuring a reliable water supply. Implementing these strategies will create a resilient and sustainable water treatment system for Myanmar's urban populations ((NWRC), 2014).

Policy Recommendations

Addressing drinking water treatment in Myanmar necessitates a comprehensive strategy to guarantee clean and safe water access for all. Key policy recommendations include strengthening the regulatory framework by aligning with WHO guidelines and developing a national water policy. Significant investments are needed in modern water treatment infrastructure, particularly in urban areas, alongside decentralized systems for rural regions. Promoting sustainable technologies such as biosand filters and solar disinfection is crucial, as is incentivizing research and development. Capacity building through training and public awareness campaigns is essential, while fostering partnerships with international organizations and involving local communities ensures sustainability. Robust monitoring and evaluation frameworks must be established to track progress and enhance initiatives. Collaborative efforts among government, private sector, civil society, and international partners are vital for successful implementation, ultimately improving Myanmar's water treatment and public health.

Conclusion

In conclusion, addressing the drinking water treatment challenges in urban Myanmar is critical for ensuring public health, economic development, and environmental sustainability. Traditional methods like sand filtration and boiling, while effective for small-scale use, are insufficient for the growing urban population's needs. Modern technologies such as chlorination, UV treatment, and membrane filtration offer more robust solutions but require significant investment and expertise. Evaluating these technologies based on effectiveness, cost, accessibility, and sustainability highlights the need for a multifaceted approach. Challenges such as aging infrastructure, financial constraints, and regulatory issues must be overcome through coordinated efforts involving technological innovations, community involvement, institutional collaboration, and sustainable practices. Long-term strategies and policy recommendations focus on strengthening regulatory frameworks, modernizing infrastructure, promoting advanced technologies, and fostering partnerships to build a resilient and sustainable water treatment system. Through these measures, Myanmar can ensure a reliable supply of safe drinking water, supporting urban growth and resilience against climate change.

References

(ADB), A. D. B. (2020). *Sector Assessment Summary: Water and other Urban Infrastracrure and Services 1;* (Yangon City Water Resilience Project: Report and Recommendation of the President, Issue. https://www.adb.org

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Adegbola, A., Ayodele, & Olaoye, R. (2019). Investigating the Effectiveness of Ultraviolet (UV) Water Purification as Replacement of Chlorine Disinfection in Domestic Water Supply.

Adelman Michael, J., Weber-Shirk Monroe, L., Cordero Anderson, N., Coffey Sara, L., Maher William, J., Guelig, D., Will Jeffrey, C., Stodter Sarah, C., Hurst Matthew, W., & Lion Leonard, W. (2012). Stacked Filters: Novel Approach to Rapid Sand Filtration. *Journal of Environmental Engineering*, *138*(10), 999-1008. https://doi.org/10.1061/(ASCE)EE.1943-7870.0000562

Alshehri, M., Bhardwaj, A., Kumar, M., Mishra, S., & Gyani, J. (2021). Cloud and IoT based smart architecture for desalination water treatment. *Environmental Research*, *195*, 110812. https://doi.org/https://doi.org/10.1016/j.envres.2021.110812

Ananga, E. O., Naiga, R., Agong', S. G., Njoh, A. J., & Vickers, H. P. (2021). Examining the contribution of community participation in water resource production and management: perspectives from developing countries. *SN Social Sciences*, *1*(1). https://doi.org/10.1007/s43545-020-00050-0

Aziz, S., Mazhar, A. R., Ubaid, A., Shah, S. M. H., Riaz, Y., Talha, T., & Jung, D.-W. (2024). A comprehensive review of membrane-based water filtration techniques. *Applied Water Science*, *14*(8). https://doi.org/10.1007/s13201-024-02226-y

Clasen, T. F., Alexander, K. T., Sinclair, D., Boisson, S., Peletz, R., Chang, H. H., Majorin, F., & Cairncross, S. (2015). Interventions to improve water quality for preventing diarrhoea. *Cochrane database of systematic reviews*(10).

Cohen, A., Zhang, Q., Luo, Q., Tao, Y., Colford, J. M., Jr., & Ray, I. (2017). Predictors of Drinking Water Boiling and Bottled Water Consumption in Rural China: A Hierarchical Modeling Approach. *Environmental Science & Technology*, *51*(12), 6945-6956. https://doi.org/10.1021/acs.est.7b01006

Collivignarelli, M., Abbà, A., Benigna, I., Sorlini, S., & Torretta, V. (2017). Overview of the Main Disinfection Processes for Wastewater and Drinking Water Treatment Plants. *Sustainability*, *10*, 86. https://doi.org/10.3390/su10010086

Drogui, P., & Daghrir, R. (2015). Chlorine for Water Disinfection: Properties, Applications and Health Effects. In E. Lichtfouse, J. Schwarzbauer, & D. Robert (Eds.), *CO2 Sequestration, Biofuels and Depollution* (pp. 1-32). Springer International Publishing. https://doi.org/10.1007/978-3-319-11906-9_1

EUROPE, U.N.E.C.F. (2018). *The water convention: responding to global water challenges.* https://unece.org/

Ferreira, C. S. S., Potočki, K., Kapović-Solomun, M., & Kalantari, Z. (2022). Nature-Based Solutions for Flood Mitigation and Resilience in Urban Areas. In C. S. S. Ferreira, Z. Kalantari, T. Hartmann, & P. Pereira (Eds.), *Nature-Based Solutions for Flood Mitigation: Environmental and Socio-Economic Aspects* (pp. 59-78). Springer International Publishing. https://doi.org/10.1007/698_2021_758

Foundation, T. W. R. (2024). *Advanced-Treatment.* www.waterrf.org

Gaid, K. (2023). *Drinking Water Treatment 1: Water Quality and Clarification.* Wiley Online Library.

Gupta, V. K., & Ali, I. (2013). Water Treatment by Membrane Filtration Techniques.

Habibullah, N., Sahrir, S., & Ponrahono, Z. (2023). Integrating Rainwater Harvesting And Greywater Recycling To Increase Water

Efficiency In Office Buildings. *Planning Malaysia*, *21*. https://doi.org/10.21837/pm.v21i29.1369

Kennedy, M. D., Kamanyi, J., Rodríguez, S. G. S., Lee, N. H., Schippers, J. C., & Amy, G. (2008). Water Treatment by Microfiltration and Ultrafiltration. In *Advanced Membrane Technology and Applications* (pp. 131-170). https://doi.org/https://doi.org/10.1002/9780470276280.ch6

Ko, S. H., & Sakai, H. (2020). Water treatment practices in rural Myanmar and residents' perceptions of technologies from donor countries. *Desalination and Water Treatment*, *208*, 337-344. https://doi.org/10.5004/dwt.2020.26483

Ko, S. H., & Sakai, H. (2021a). Evaluation of Yangon city tap water quality and the efficacy of household treatment. *Water Quality Research Journal*, *56*(3), 155-166. https://doi.org/10.2166/wqrj.2021.006

Ko, S. H., & Sakai, H. (2021b). Evaluation of Yangon city tap water quality and the efficacy of household treatment. *Water Quality Research Journal*. https://doi.org/10.2166/wqrj.2021.006

Kumano, A., & Fujiwara, N. (2008). Cellulose Triacetate Membranes for Reverse Osmosis. In *Advanced Membrane Technology and Applications* (pp. 21-46). https://doi.org/https://doi.org/10.1002/9780470276280.ch2

Larsen, T. A., Hoffmann, S., Lüthi, C., Truffer, B., & Maurer, M. (2016). Emerging solutions to the water challenges of an urbanizing world. *Science*, *352*(6288), 928-933. https://doi.org/10.1126/science.aad8641

Le, N. L., & Nunes, S. P. (2016). Materials and membrane technologies for water and energy sustainability. *Sustainable Materials and Technologies*, *7*, 1-28. https://doi.org/https://doi.org/10.1016/j.susmat.2016.02.001

M. A, S., Anas, P., & Shifa, S. (2018). *Treatment of Water Using Various Filtration Techniques: Review Study*.

Mac Mahon, J. (2022). Chapter 7 - Water purity and sustainable water treatment systems for developing countries. In T. M. Letcher (Ed.), *Water and Climate Change* (pp. 115-144). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-323-99875-8.00021-5

Ms. Su Su Myat, M. P. M. O., and Ms. June Khaing Wint Tun. (2017a). *Nyaungnapin Water Treatment Plant Yangon, Myanmar*

Ms. Su Su Myat, M. P. M. O., and Ms. June Khaing Wint Tun. (2017b). *Nyaungnapin Water Treatment Plant Yangon, Myanmar*.

Nagpal, T., Rawlings, H., & Balac, M. (2020). Understanding water demand and usage in Mandalay city, Myanmar as a basis for resetting tariffs†. *Journal of Water, Sanitation and Hygiene for Development*, *10*(4), 680-690. https://doi.org/10.2166/washdev.2020.076

Naing, K., Yun, C., Qi'en, C., Teh, G., & Pung, X. (2020). *Evaluation of Technological Solutions to Water Related Problems in Mandalay*.

Nicole, W. A Better Way to Boil: Comparing Methods of Purifying Water at Home. *Environmental Health Perspectives*, *129*(4), 044001. https://doi.org/10.1289/EHP8921

Ong, C., Tortajada, C., & Arora, O. (2023). Key Challenges to Urban Water Management in ASEAN. In *Urban Water Demand Management* (pp. 3-14). https://doi.org/10.1007/978-981-19-8677-2_2

Organization, W. H. (2017). Guidelines for drinking-water quality: fourth edition incorporating the first addendum.

Pacific, N. o. w. T. i. A. a. (2017). *Nyaungnapin Water Treatment Plant Yangon, Myanmar*.

Pavisorn, C., Chitchanuwat, M., Chaiyraweepat, T., & Anurak, S. (2024). Community participation and effective water management: A study on water user organizations (WUOs) in Thailand. *World Development Perspectives*, *34*, 100589. https://doi.org/https://doi.org/10.1016/j.wdp.2024.100589

Razali, M. C., Wahab, N. A., Sunar, N., & Shamsudin, N. H. (2023). Existing Filtration Treatment on Drinking Water Process and

Concerns Issues. *Membranes*, *13*(3). https://doi.org/10.3390/membranes13030285

Richard, D. M., & Catherine, J. R. (2015). Collaborative partnerships and the challenges for sustainable water management. *Current Opinion in Environmental Sustainability*, *12*, 53-58. https://doi.org/https://doi.org/10.1016/j.cosust.2014.09.003

Sakai, H., Kataoka, Y., & Fukushi, K. (2013). Quality of source water and drinking water in urban areas of Myanmar. *ScientificWorldJournal*, *2013*, 854261. https://doi.org/10.1155/2013/854261

Saravanan, A., Senthil Kumar, P., Jeevanantham, S., Karishma, S., Tajsabreen, B., Yaashikaa, P. R., & Reshma, B. (2021). Effective water/wastewater treatment methodologies for toxic pollutants removal: Processes and applications towards sustainable development. *Chemosphere*, *280*, 130595. https://doi.org/https://doi.org/10.1016/j.chemosphere.2021.130595

Saritha, V., Srinivas, N., & Srikanth Vuppala, N. V. (2017). Analysis and optimization of coagulation and flocculation process. *Applied Water Science*, *7*(1), 451-460. https://doi.org/10.1007/s13201-014-0262-y

Snyder, S. A., Adham, S., Redding, A. M., Cannon, F. S., DeCarolis, J., Oppenheimer, J., Wert, E. C., & Yoon, Y. (2007). Role of membranes and activated carbon in the removal of endocrine disruptors and pharmaceuticals. *Desalination*, *202*(1), 156-181. https://doi.org/https://doi.org/10.1016/j.desal.2005.12.052

Sommer, R., Cabaj, A., Hirschmann, G., & Haider, T. (2008). Disinfection of Drinking Water by UV Irradiation: Basic Principles - Specific Requirements - International Implementations. *Ozone-science & Engineering - OZONE-SCI ENG*, *30*, 43-48. https://doi.org/10.1080/01919510701759181

Sun, W., & Chu, W. (2021). Editorial: Advanced Treatment Technologies for Drinking Water. *AQUA - Water Infrastructure, Ecosystems and Society*, *70*(8), iii-iv. https://doi.org/10.2166/aqua.2021.102

Uemura, T., & Henmi, M. (2008). Thin-Film Composite Membranes for Reverse Osmosis. In *Advanced Membrane Technology and Applications* (pp. 1-19). https://doi.org/https://doi.org/10.1002/9780470276280.ch1

Van der Bruggen, B. (2021). Sustainable implementation of innovative technologies for water purification. *Nature Reviews Chemistry*, *5*(4), 217-218. https://doi.org/10.1038/s41570-021-00264-7

WHO, W. H. O. (2012). *A toolkit for monitoring and evaluating household water treatment and safe storage programmes* (9241504625). https://www.who.int/publications

WHO, W. H. O. (2017). *Guidelines for drinking water quality: fourth edition incorporating the first addendum*. https://creativecommons.org/licenses/by-nc-sa/3.0/igo

Win, C. Z., Jawjit, W., Thongdara, R., Gheewala, S. H., & Prapaspongsa, T. (2023). Towards more sustainable Water, Sanitation and Hygiene (WASH) projects in Magway Region, Myanmar. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-023-03727-7

Yay Chan, S. M. G. H., Wai Hlyan Paing (2018). *Report on Access to Clean and Safe Water in Yangon.*

Zakariazadeh, A., Ahshan, R., Al Abri, R., & Al-Abri, M. (2024). Renewable energy integration in sustainable water systems: A review. *Cleaner Engineering and Technology*, *18*, 100722. https://doi.org/https://doi.org/10.1016/j.clet.2024.100722