Lesson Learned from Yangon to Mandalay on Wastewater Treatment Systems

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ABSTRACT

This paper presents a comparative analysis of wastewater management practices in Myanmar's major cities, Yangon and Mandalay, with a focus on drawing valuable lessons from Yangon's experiences and proposing recommendations for the improvement of Mandalay's domestic wastewater management, drawing insights from a SWOT analysis. Both cities are facing challenges due to rapid urbanization, leading to untreated discharge into the environment. The study identifies common challenges in both Yangon and Mandalay, such as limited treatment capacity, environmental concerns, and funding gaps. The decentralized-centralized strategy is a successful approach for Yangon even though the capacity is not high. Results showed that 17.5% of Decentralized Wastewater Treatment Systems (DEWATS) users were highly satisfied and 45% were somewhat satisfied. Yangon's experience with centralized systems showed that it took several years to cover the entire city for treatment, resulting in issues to cover revenue expenditures. If Mandalay adopts a similar, it will likely encounter the same issues. A recommended approach would be to implement an integrated system with DEWATS, which offers a better solution. The recommendations for sustainable wastewater management in Mandalay include active stakeholders' involvement in decision-making, promoting community participation, and providing training. Transparency and shared responsibility are crucial for success. Addressing membrane fouling, sludge disposal, and implementing monthly fees are essential for sustainable implementation. An integrated approach along with environmental and social impact assessments are necessary to develop a cost-effective and efficient wastewater treatment system while safeguarding public health and the environment. These insights offer broader implications, guiding developing countries towards more effective and environmentally responsible wastewater management practices.

1. INTRODUCTION

Poor sanitation in developing countries makes urban wastewater management (WWM) difficult. Rapid urbanization and population growth have led to harmful impacts on the environment, public health, and economy, with almost half of developing countries lacking proper sanitary disposal (Laugesen et al., 2010; WHO, 2022). Wastewater treatment systems (WWTS) aim to mitigate these issues, with centralized systems suitable for densely populated areas (Fisher, 1995; USEPA, 2005a; World Bank, 2012; ADB, 2020) and decentralized systems more appropriate for small rural or peri-urban communities, offering potential for reuse (West, 2001; Parkinson and Tayler, 2003; Seidenstat et al., 2003). Trained personnel and good operation and maintenance (O&M) can boost performance and lower costs (Tokich, 2006; Massoud et al., 2009). Population growth, urbanization, and outdated systems complicate for Myanmar (IGES, 2019). Myanmar has 77-84% urban sanitation coverage, so water- and sanitation-related diseases kill 18% of that under-5 (Kamp, 2017). Recent literature has emphasized the urgent need for modernized, cost-effective, technical support, and better environmental protection laws (WHO, 2006; YCDC, 2018; Thin, 2018; Naing et al.,

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2020). For developing countries, integrated approach between onsite treatment and centralized system was popular (Ho, 2005; Chen et al., 2011; Eales et al., 2013; Pham and Kuyama, 2013; Narayanamoorthy et al., 2022). This encourages a dynamic and multispectral approach to plans sustainable water and wastewater management based on community needs (Molinos et al., 2011; Eales et al., 2013; Capodaglio et al., 2016; Padilla et al., 2019; Mehariya et al., 2021). Sustainable integrated WWM is necessary for urban (Nagara et al., 2014; UN, 2015; Naing et al., 2020) and the proposed of integrated Decentralized Wastewater Treatment Systems (DEWATS) into the WWM chain is shown in Figure 1. Several research gaps were found in terms of comparative studies between different urban areas. Capodaglio et al. (2016) and Ho (2005) noted the absence of such comparative studies in their review of literature. This research's originality is enhanced by the incorporation of significant contributions by Laugesen et al. (2010), Nagara et al. (2014), and Gürel (2017) in the literature review. Unlike previous studies that focused solely on individual aspects of wastewater treatment, this research uniquely combines a comparative approach with SWOT analysis. The approach allows to identify the strengths, weaknesses, opportunities, and threats, providing valuable insights into the factors that influence their performance and also can help decision-making on WWM. This approach simplifies on the complex interactions between factors, providing valuable insights for sustainable WWM strategies. The analysis also can help to identify areas for improvement in sustainable construction and operations for decision-making on WWM, which can lead to reduced energy, capital, and O&M costs (Nowak et al., 2015; Akhobadze, 2018; Riaz, 2022).

The study focuses on the cities of Yangon and Mandalay to address global WWM issues in rapidly urbanizations. The objectives of this study are to assess the current situation of WWTS in Yangon and Mandalay, and to propose recommendations for implementation in Mandalay, drawing from the lessons learned in Yangon. These recommendations will not only enhance the WWM in these cities but will also serve as valuable lessons for other developing countries facing similar challenges in WWM. By analyzing WWTS, the study adds new insights to these specific challenges and opportunities. These findings are consistent with the observations made by JICA (2014), Khin and Myint (2018), and IGES (2019) in their respective studies. Using SWOT analysis brings a fresh perspective to the research, enhancing comprehension of various factors at a more profound level. This multidimensional approach is a contribution that enhances the understanding of complex urban WWM as suggested by Than (2010) and Narayanamoorthy et al. (2022) in their research on integrated approaches to urban WWM.

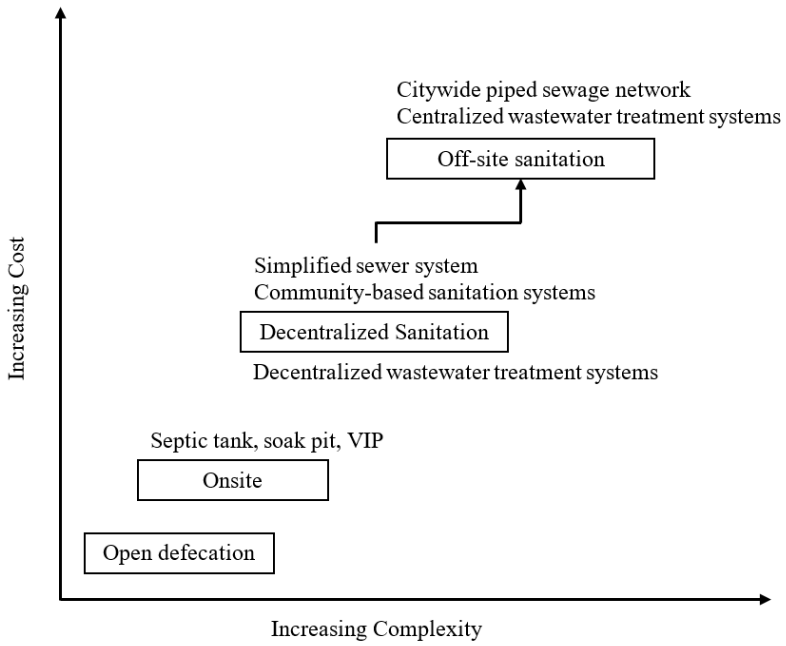

Figure 1. Proposed integrated DEWATS between onsite and offsite system (Eales et al., 2013; Pham and Kuyama, 2013)

2. METHODOLOGY

2.1 Area of studies and data collection process

Mandalay, Myanmar's third capital is the second largest city on the east bank of the Irrawaddy River. Kandawgyi Lake and the Irrawaddy River to the west. Mandalay's population was 1,360,138 (GAD, 2019; City Population, 2022). Mandalay City Development Committee (MCDC) has responsibility for 84.92% of the MCDC's 236,815 households which have upgraded sanitation facilities (Zin and Soe, 2010; Thin, 2018; Daeweaung et al., 2022). MCDC handles urban development, city planning, land administration, and taxation. The City Hall has 14 departments, including Water and Sanitation Department. The master plan for a CWTS in Amarapura township (Than, 2010; Naing et al., 2020). Field questionnaires assessed waste management, decision-making, and user opinions.

Yangon, on the east bank of the Yangon River, is a large city, 776 km south of Mandalay (Fan et al., 2022; Kohno et al., 2022). According to the 2019 GAD report, Yangon has 5.16 million people, four districts and 44 townships, with the Yangon City Development Committee (YCDC) managing 33 of them (GAD, 2019). YCDC's has 23 departments, manage waste and sanitation (Lwin et al., 2017; YCDC, 2018; MWEP, 2019). Pollution Control and Cleansing Departments (PCCD) manage domestics wastewater, 14 CWTS are planned for Greater Yangon 2040.

2.2 Factors influencing the choice of wastewater treatment systems

Selecting WWM is a challenging but necessary decision for Mandalay. Learning from Yangon's experiences and weakness, Mandalay should focus on identifying and improving major influencing factors. The key factors were examined using a review of relevant literature and selected factors in key management categories (Massoud et al., 2009; Sujaritpong and Nitivattananon, 2009; Schweitzer et al., 2014; Capodaglio et al., 2016). The factors considered are sustainability, social acceptability, public health protection, regulations, and planning. The selection process should take into account investment cost, population density, technology efficiency, and operation and maintenance. Innovative technologies and alternative financing models should be explored, especially in densely populated areas with limited land availability and skilled labor (UNESCAP, 2017; Padilla et al., 2019; Orak et al., 2021). The study has selected environmental, socioeconomic, technical, and institutional factors, along with 14 subfactors, to guide the decision-making process for WWM as shown in Table 1.

Table 1. Influencing factors on decision-makings on wastewater management

Environmental	Socioeconomics	Technical	Institutional
• Effluent quality • Resource recovery • Environmental protection	• Costs • Social acceptability • Willingness to pay • User's satisfaction • Revenue expenditure	• O&M • Skillful workers availability • Monitoring program	• Coordination • Policy and regulations • Land availability

2.3 Survey questionnaires

To evaluate the current situation of study areas, the primary sources of data were household surveys, official documents, and interviews with municipal officers were conducted. The household surveys were comprised of two parts: one with CWTS users in seven townships in downtown areas, and the other with DEWATS users in selected housing estates as illustrated in Figure 2. The Yamane formula (Yamane, 1967) was used to conduct 400 surveys, evenly distributed between DEWATS users and CWTS users. These surveys aimed to gather demographic information, assess the current state of wastewater systems in residents' homes, and examine their satisfaction levels and factors perspectives. However, one study found that the equations assumed that the population is homogenous, which may not be the case in practice which can lead to biased results if the sample does not represent the population accurately (Cochran, 1977). The systematic random sampling method was used to select 28 households in each township for centralized users and 28 households in each housing section for decentralized users, who were geographically dispersed in the Yangon study area. Demographic information, household size, types of homes, and the significance of choosing factors were gathered through the surveys. The respondents were asked about their satisfaction with the current preferences and willingness to pay system.

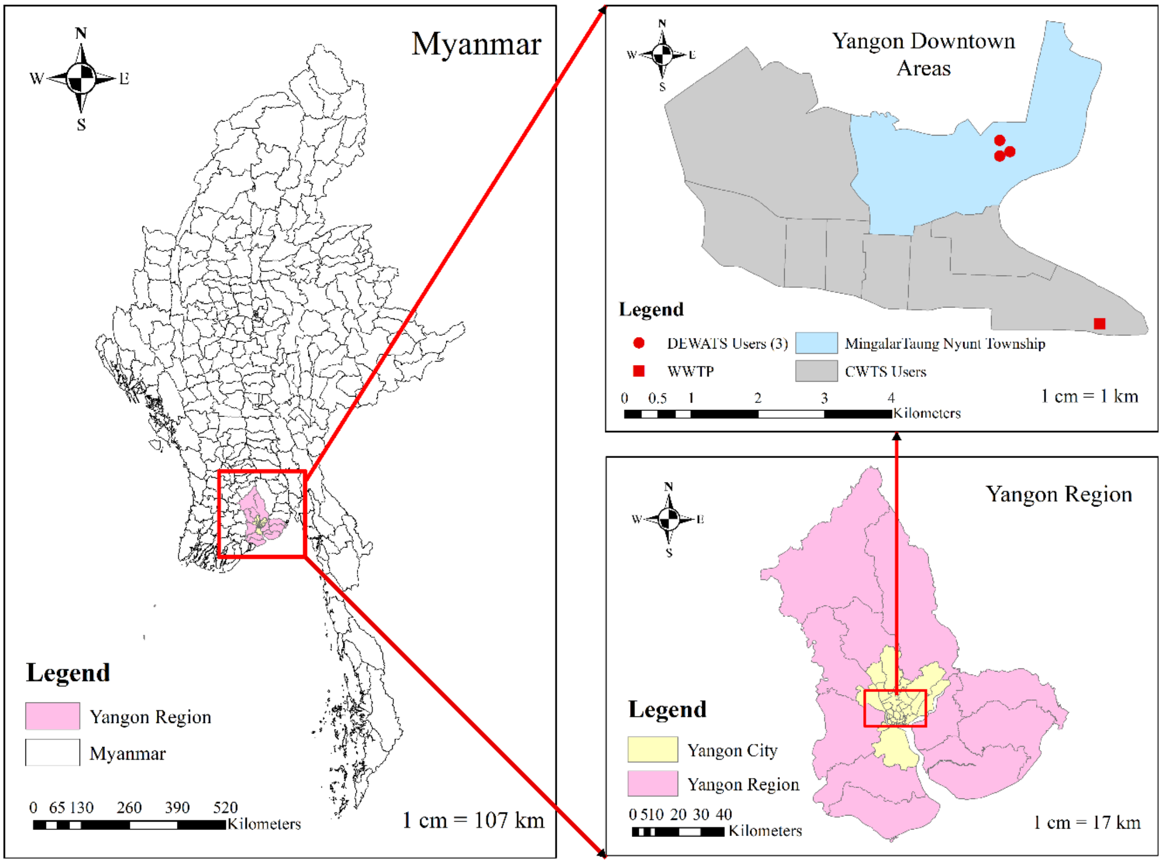

Figure 2. Map of data collection areas and points in Yangon

Data collection in Mandalay was also conducted through questionnaires to residents, official documents, and online interviews with municipal officers. Mandalay is located in the central dry zone, adjacent to the Irrawaddy River, and Kandawgyi Lake and Taung Tha Man Lake (Sanchez et al., 2019). The survey in Mandalay included 400 samples, with half of the respondents are DEWATS users and the other half utilizing onsite systems, given the absence of centralized systems in the city. The population was sampled using the systematic random sampling method, with 28 households selected in each township for onsite users and 28 households selected in each housing block for decentralized users, who were geographically across Mandalay. The survey collection points in Mandalay are illustrated in Figure 3.

2.4 SWOT analysis

The study used SWOT analysis to assess WWM lessons for Mandalay, identifying strengths, weaknesses, opportunities, and threats based on 14 selected subfactors. Data was collected through questionnaire surveys, interviews with municipal officials, and field visits, enabling factors affecting both cities' WWM. SWOT analysis proved valuable in identifying current and future factors influencing these solutions, complementing monitoring, decision-making, and management processes (Nagara et al., 2014; Akhobadze, 2018; Riaz, 2022). The study's insights can be used to inform wastewater management planning and decision-making, facilitating comparisons with practices in other cities. By using SWOT analysis, the study highlights key areas for improvement and strategic actions to enhance the effectiveness of WWM for Mandalay.

3. RESULTS AND DISCUSSION

3.1 Wastewater management situations in Yangon

In Yangon, 80% of households use onsite systems, mostly septic tanks. Using vacuum trucks, the YCDC transports sludge to CWTS and use as fertilizer (YCDC, 2018). In Botahtaung, Latha, Pabedan, Pazundaung, Kyauktada, Dagon, and Lanmadaw, a CWTS processes sewage at a rate of 14,775 m^3/day. The plant separates the sewage into 13,829 m^3/day of greywater flow and 946 m^3/day of black water. However, this capacity only serves 7% of the city's population, indicating insufficient coverage for the domestic wastewater needs of the entire city (Premakumara, 2017; Khin and Myint, 2018).

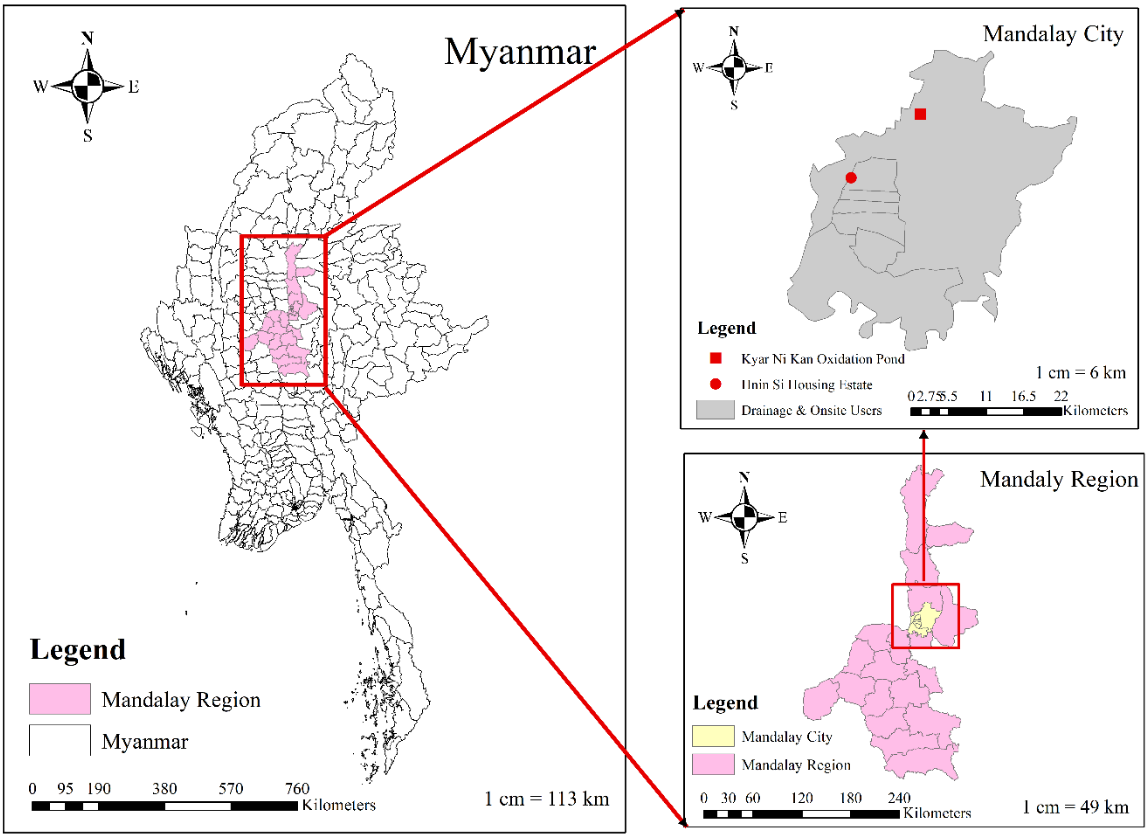

Figure 3. Map of data collection areas and points in Mandalay

There are plans to increase the percentage of the population receiving treatment to 49% by 2040 (Min, 2018). The WWTP treats 300,000 people and monitors effluent water daily to meet National Environmental Quality Emissions Guidelines (NEQEG) (JICA, 2014; ECD, 2015). Due to technological inconsistencies, some drainage directly enters the rivers. 10% of city households use membrane bio-reactor (MBR) DEWATS, before flowing drainage, wastewater is treated. Only 3% of residents use an unimproved pit latrine (Lwin et al., 2017; YCDC, 2018), as shown in Figure 4 and the survey sampling distribution details listed in Table 2. In Yangon, approximately 17.5% of DEWATS users expressed a high level of satisfaction with their system, while 45% reported being somewhat satisfied. Among centralized users, 60% stated that they felt neither satisfied nor dissatisfied, and 17.5% indicated a level of satisfaction. When asked about important factors in choosing WWTS, 36% considered all factors important, with 32% prioritizing socio-economics, 12% environmental, 11% technical, and 9% institutional considerations.

Table 2. Distribution of surveyed results in Yangon

Characteristics	DEWATS Users	CWTS Users
Number of respondents	200	200
Gender	70% female, 30% male	66% female, 34% male
Age	28% under 30 years old, 59% 31-50 years old, 13% 51 years old and above.	31% under 30 years old, 54% 31-50 years old, 15% 51 years old and above.
Education level	6% Basic Education, 8% University Level, 86% Graduates	4% Basic Education, 4% University Level, 92% Graduates
Household Size	6% below 3, 78% 4 to 6, 16% above 6 members	6% below 3, 27% 4 to 6, 67% above 6 members
Household Income	30% less than 300,000 MMK, 30% 300,001 MMK to 600,000 MMK, 40% more than 600,001 MMK	10% less than 300,000 MMK, 20% 300,001 MMK to 600,000 MMK, 70% more than 600,001 MMK

Table 2. Distribution of surveyed results in Yangon (cont.)

Characteristics	DEWATS Users	CWTS Users
Type of sanitation facility	68% Flush toilet, 32% Pour flush toilet,	45.5% Flush toilet, 50% Pour flush toilet, 4.5% Pit latrine
Willing to pay O&M (per month)	55% less than 50,000 MMK, 30% between 50,000 MMK to 100,000 MMK, 15% more than 100,000 MMK	15% less than 50,000 MMK, 36% between 50,000 MMK to 100,000 MMK, 49% more than 100,00 MMK
Users' satisfaction on current system	17.5% very satisfied, 45% Somewhat satisfied, 15% Neither satisfied nor dissatisfied, 12.5% Somewhat dissatisfied, 10% Very dissatisfied	5% very satisfied, 17.5% Somewhat satisfied, 60% Neither satisfied nor unsatisfied, 12.5% Somewhat unsatisfied, 5% Very unsatisfied

(MMK=Myanmar Kyats, 1 USD=2,095/- MMK (as of July 2023))

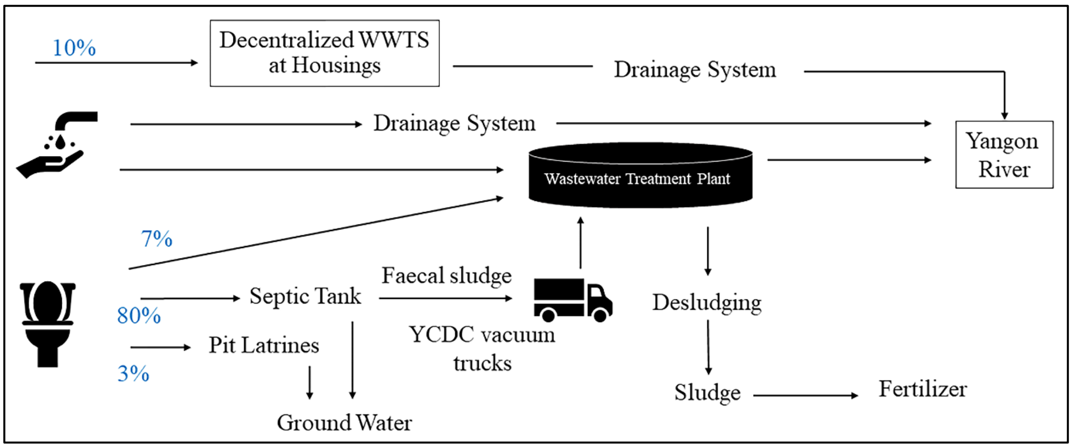

Figure 4. Sanitation flow chart of Yangon

3.2 Wastewater management situations in Mandalay

Water and Sanitation Department of Mandalay manages and administers the water supply and sanitation services for 155,880 households in the downtown area (DOP, 2015). The monthly fees for water supply service are below 1 USD, and there are no charges for domestic wastewater treatment. The city has well-planned public drainage systems, and conduct regular maintenance. Sludge is collected using vacuum trucks, and effluent monitoring is carried out monthly to comply with NEQEG (Zin and Soe, 2010; Grzybowski et al., 2019). Approximately 94% of households use onsite system, with septic tank and pit latrines. (Thin, 2018, Naing et al., 2020) Sludges are dried and used as fertilizer, and treated water is discharged near the drainage. Around 6% of households still practice open defecation, leading to contamination of underground water. Mandalay has only one DEWATS system, located in the Hnin Si Housing Estate in the Aungmyaythazan Township and others are onsite. The sanitation flowchart in Mandalay is presented in Figure 5 and the survey sampling distribution details are presented in Table 3. Based on interviews with municipal officers, Mandalay has limited domestic wastewater treatment capacity, with only 17% of the total generated being treated and the total treatment capacity of all the WWTS facilities were approximately 20,000 m^3/day as of 2017. About 39% of DEWATS users mentioned being somewhat satisfied with their current system, and 28.5% reported feeling neither satisfied nor dissatisfied. Among the onsite users in Mandalay, 31% expressed a level of satisfaction, while 30% expressed a high level of satisfaction. Regarding the selection of factors, 39% of respondents highlighted the importance of all factors, with 29% emphasizing socioeconomics as most crucial. Technical and institutional factors were considered significant by 11% of the participants, while 10% placed importance on environmental aspects.

3.3 SWOT analysis

The findings of the analysis are summarized in Tables 4 and 5 with strengths and weaknesses categorized as internal factors, while opportunities and threats were classified as external factors.

Table 3. Distribution of surveyed results in Mandalay

Characteristics	DEWATS Users	Onsite Users
Number of respondents	200	200
Gender	45% female, 55% male	41% female, 59% male
Age	23% under 30 years old, 63% 31-50 years old, 14% 51 years old and above.	22% under 30 years old, 67% 31-50 years old, 11% 51 years old and above.
Education level	25% Basic education, 11% University level, 64% Graduates	13% Basic education, 13.5% University level, 73.5% Graduates
Household size	12% below 3, 69% 4 to 6, 19% above 6 members	8% below 3, 71% 4 to 6, 21% above 6 members
Household income	27% less than 300,000 MMK, 42% 300,001 MMK to 600,000 MMK, 31% more than 600,001 MMK	15% less than 300,000 MMK, 35% 300,001 MMK to 600,000 MMK, 50% more than 600,001 MMK
Type of sanitation facility	71% Flush toilet, 29% Pour flush toilet,	63% Flush toilet, 29% Pour flush toilet, 8% Pit latrine
Willing to pay O&M (per month)	44% less than 50,000 MMK, 45.25% between 50,000 MMK to 100,000 MMK, 10.75% more than 100,000 MMK	54% less than 50,000 MMK, 32% between 50,000 MMK to 100,000 MMK, 14% more than 100,00 MMK
Users' satisfaction on current system	22.5% very satisfied, 39% Somewhat satisfied, 28.5% Neither satisfied nor dissatisfied, 6% Somewhat dissatisfied, 4% Very dissatisfied	30% very satisfied, 31% Somewhat satisfied, 20.5% Neither satisfied nor dissatisfied, 12% Somewhat dissatisfied, 6.5% Very dissatisfied

(MMK=Myanmar Kyats, 1 USD=2,095/- MMK (as of July 2023))

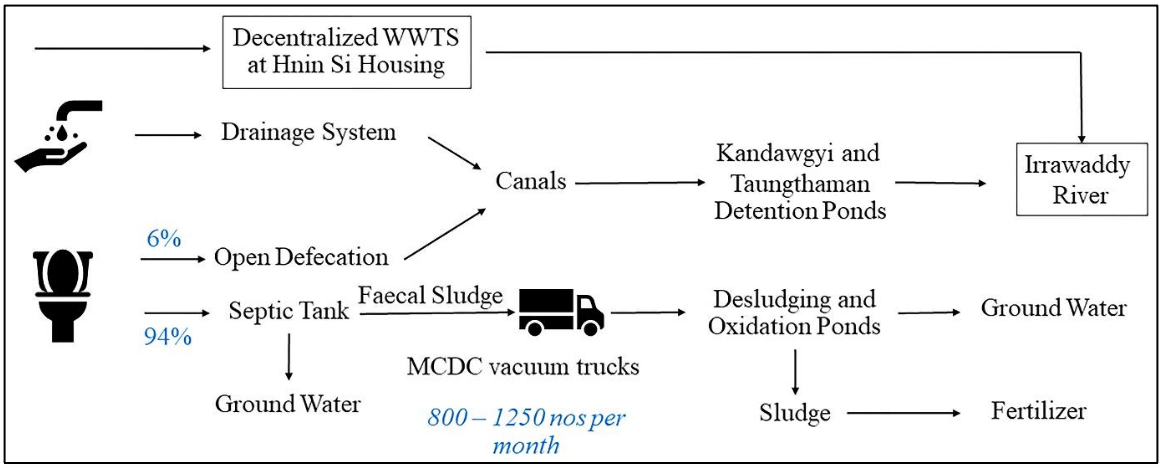

Figure 5. Sanitation flowchart of Mandalay

Table 4. SWOT analysis of CWTS in Yangon

Strengths	Weaknesses
• Improves water quality and protects the environment • Cost-effective and efficient • Ensures compliance with regulations and standards for public health • Promotes resource recovery and circular economy practices • Provides accountability and transparency	• Inconsistent effluent quality • Limited resource recovery • Construction and operation may have environmental impacts • High energy requirements • High capital and O&M expenses • Affordability and willingness to pay create financial challenges • Lack of trained personnel • Land availability major challenges • Incomplete coverage of the city and limited domestic wastewater
Opportunities	**Threats**
• Modernizing and optimizing treatment systems • Using environmentally friendly technology to improve performance	• Insufficient treatment • Limiting reuse potential • Costs and funding gaps due to development and operations

Table 4. SWOT analysis of CWTS in Yangon (cont.)

Opportunities	Threats
• Reusing wastewater to save costs • Investigating financing strategies or grants to obtain funds • Regular effluent quality monitoring • Investing in training and capacity building for operators and maintenance employees • Best practices in O&M • Fostering collaboration among local and international private sectors	• No users fee collection • Lack of experienced skillful workers and technicians • Land high price and limit availability • Residents' inability or unwillingness to pay appropriate fees • Insufficient monitoring and weak regulatory resulting in compliance issues and environmental concerns

The CWTS in Yangon has several strengths, including its positive impact on water quality, cost-effectiveness, and compliance with regulations. It also promotes resource recovery and transparency. Problems include insufficient treatment, limiting reuse potential, costs and funding gaps due to development and operations, no user fee collection, lack of experienced skilled personnel, high land prices and limited, residents' unwillingness to pay fees, insufficient monitoring, and weak regulatory compliance causing environmental concerns (MWEP, 2019; Ortega et al., 2022). Opportunities for improvement in systems, adopting environmentally friendly technology, and reusing to save costs. The system must address threats such as insufficient treatment, funding gaps, and weak regulatory monitoring to ensure effective operation and mitigate environmental concerns (Aung et al., 2020).

Table 5. SWOT analysis for DEWATS for Yangon

Strengths	Weaknesses
• High-quality effluent • Low energy consumption • Low-sludge production • Flexibility and Affordability • Odor control • Minimal capital and O&M costs • Tailored to meet local community and environmental needs • Land-Saving • Creates employment opportunities for local communities • Less O&M	• Limited capacity for large volumes • Susceptibility to fouling and membrane damage • Regularly require maintenance and replacement of membranes • Challenges in disposing of sludge • Requires skilled technicians and operators • Requires adequate land • O&M and monitoring costs • Initial investment can be a challenge, with limited funding • Revenue generated may not cover all O&M costs, leading to financial unsustainability in some cases
Opportunities	**Threats**
• Affordable for most commercial wastewater treatment needs • Complements other sustainable infrastructure projects • Ensure compliance with regulations • Job creation • O&M monitoring ensures efficient system functioning • Community payment ensures long-term sustainability • Fostering collaboration among local and international private sectors	• Lack of community acceptance due to unfamiliarity with benefits • Regulatory obstacles in acquiring authorizations and approvals • Weak or ineffective regulations and enforcement hindering adoption • Lack of skilled workers for O&M • Climate change and natural disasters • Incorrect O&M leading to negative impacts

The DEWATS in Yangon is an affordable solution to produce reusable treated water which provides flexibility, affordability, and best solutions to meet local needs while creating employment opportunities. However, it faces challenges in limited capacity for large volumes, membrane fouling and damage, and proper sludge disposal. Skilled technicians and adequate land are essential for successful operation. Weak regulations and enforcement, lack of skilled workers, and poor O&M monitoring can cause a negative impact to the system and the environment. A comprehensive plan must prioritize community engagement to address these challenges. They are sustainable solutions which aims to ensure access to clean water and sanitation for all (Nguyen et al., 2005; UN, 2021).

3.4 Lessons learned and recommendations for Mandalay

Based on the experiences and challenges faced in Yangon's CWTS and DEWATS systems by using SWOT analysis, Mandalay can draw valuable lessons to improve its wastewater treatment approach. To ensure successful implementation and sustainability, Mandalay should prioritize resource recovery and effluent quality while addressing funding gaps and enforcing strong regulatory frameworks. Mandalay can learn from Yangon's CWTS by addressing weaknesses such as insufficient treatment, funding gaps, and weak regulatory monitoring. The key points to prioritize in Mandalay include resource recovery, effluent quality improvement, modernizing systems, adopting environmentally friendly technology, and establishing effective regulatory frameworks to enforce compliance. The implementation of DEWATS in Mandalay should take into account the limited land, technical expertise and funding, as well as potential challenges such as membrane fouling and damage, sludge disposal, and O&M costs that may cause financial instability (Tchobanoglous et al., 2004; USEPA, 2005b). The development plan for Mandalay should therefore prioritize the implementation and sustainability considering their potential benefits. Prioritizing community engagement, in decision-making and implementing user fee collection, regulatory frameworks, and monitoring can improve the wastewater treatment system's performance and prevent environmental impacts (ISO, 2006; Sanchez et al., 2019). Collaboration among community is necessary for implementing and sustaining WWTS in Mandalay. Training and stronger regulations and enforcement can address the shortage of skilled trained personnel. Learning from Yangon's experience in adopting integrated approaches, Mandalay can customize and create job opportunities while producing reusable treated water. The scarcity of water in Mandalay during hot summers and frequent droughts can also be addressed by utilizing greywater reuse (Mainali et al., 2011). Table 6 compares the key aspects of each system, highlighting their strengths and weaknesses from Yangon to Mandalay.

Table 6. Comparative analysis of wastewater treatment systems in Yangon and Mandalay

Factors	Sub factors	Lessons learned from Yangon	Proposed strategies for Mandalay
Environmental	Effluent quality	Membrane fouling	Invest in advanced treatment tech for high-quality effluent
	Resource recovery	Successful resource recovery but no reuse	Implement greywater reuse to conserve water during droughts
	Environmental protection	Environmental and Social impact assessments were doing.	Need impact assessments and mitigation plans
Socioeconomics	Costs	Ongoing O&M cost challenges	Explore sustainable financing
	Social acceptability	Inadequate community engagement	Prioritize community engagement
	Willingness to pay	Inadequate user fee collection	Implement user fee collection
	User satisfaction	DEWATS received higher satisfaction levels with most users being "very satisfied" or "somewhat satisfied," while centralized had a higher proportion of users in the "neither satisfied nor dissatisfied"	DEWATS received higher satisfaction levels, with most users very satisfied or somewhat satisfied, while for onsite, satisfaction was more
	Revenue expenditure	Weak revenue generation	Improve revenue generation
Technical	O&M	Sludge disposal challenges	Develop comprehensive sludge disposal plan
	Skillful workers availability	Enough trained personnel	Invest in skilled training
	Monitoring program	Inadequate monitoring	Implement robust monitoring
Institutional	Coordination	Collaboration between stakeholders necessary	Foster collaboration for successful implementation
	Policy and regulations	Weak regulatory enforcement	Establish and enforce strong regulatory frameworks
	Land availability	Limited	Plan for adequate land for wastewater treatment plants

The recommended approach for Mandalay's wastewater treatment includes approaching an integrated strategy, promoting water conservation and reuse, considering the suitability of different systems, and ensuring transparency and stakeholder involvement. Technical training, renewable energy use, and environmental assessments are essential for sustainability. Collaboration among various stakeholders is crucial for a comprehensive and efficient wastewater management system, leading to continuous improvement and better environmental outcomes. A comparative table has been created to provide a clear overview of each recommendation's focus and potential impact as listed in Table 7.

Table 7. Recommendations for improving domestic wastewater management in Mandalay

Recommendation	Focus	Potential impact
Adopting an integrated strategy	Strategy	Improved system efficiently and resilience
Implement water conservation and reuse	Water management	Addressing water scarcity
Promoting shared responsibility and transparency	Governance	Effective and inclusive decision-making
Promoting environmental education and public health benefits	Public awareness	Increased public acceptance and support
Training and capacity building	Skill development	Efficient O&M
Reducing Environmental pollution with renewable energy	Sustainability	Lower environmental impact
Environmental and Social Impact Assessments (ESIA)	Environmental and social impact	Responsible and acceptable practices
Life cycle assessment (LCA)	Environmental assessment	Informed decision-making and planning
Involving community in decision-making	Stakeholder Engagement	Align strategies with local needs
Development user fee collection systems and enhance regulatory frameworks	Funding and compliance	Sustainable financing and adherence
Collaboration among private sectors	Stakeholder collaboration	Comprehensive and inclusive approaches
Continuous improvement based on lessons from Yangon	Learning and adaptation	Enhanced domestic wastewater management

4. CONCLUSION

Based on the obtained results, Yangon relies mainly on onsite systems. Only 7% of the city's population is served by the CWTS, creating insufficient coverage and some technological inconsistencies lead to direct drainage into rivers. In Yangon, 17.5% of DEWATS users were highly satisfied, while 45% were somewhat satisfied; among centralized users, 17.5% were satisfied and 60% expressed neither satisfied nor dissatisfied. The study revealed those factors in choosing WWTS included prioritizing socioeconomics (32%), environmental concerns (12%), technical aspects (11%), and institutional considerations (9%). Similar to Yangon, most households in Mandalay (94%) use onsite systems, primarily septic tanks and pit latrines. Only 17% of the total wastewater generated is treated due to limited capacity, leading to contamination of underground water from open defecation by 6% of households. In SWOT analysis, Yangon showed an affordable solution, but it faced challenges with limited capacity, technology, sludge disposal, and lack of skilled personnel. Mandalay can learn from Yangon's experiences to improve its approach by prioritizing water conservation, high effluent quality, reuse and customization on addressing funding gaps and regulatory enforcement. Yangon's centralized wastewater treatment system took years to treat the entire city, requiring revenue expenditure. Mandalay may face the same issue if it adopts a similar. Thus, implementing a DEWATS-integrated system is the better option. Then, in Mandalay, it is important to carefully consider implementing of monthly fee. In addition, prioritizing community engagement, training, and monitoring should be included in the intervention plan.

The study provides valuable insights for policymakers through its analysis of 14 subfactors under environmental, socioeconomic, technical, and institutional aspects of WWM, despite limitations in self-reported survey data and information gathering challenges. Nevertheless, the study offers valuable lessons from Yangon's WWTS, adaptable and implementable in Mandalay for sustainable WWM. The study's findings and recommendations contribute to a better understanding of wastewater treatment and offer valuable insights for sustainable strategies in developing countries. These may assist in developing sustainable WWM strategies for the country and other developing countries.

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