Research Paper

Understanding water demand and usage in Mandalay city, Myanmar as a basis for resetting tariffs†

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ABSTRACT

Water service providers must understand the needs and consumption patterns of their customers in order to make informed decisions on new investments. The Mandalay City Development Committee is undertaking an expansion of its water supply and sewerage infrastructure with a goal of reaching every citizen. The service provider needs to revise tariffs to cover higher provision costs. To this end, a survey conducted in 2019 in Mandalay City, Myanmar revealed that 80% of users relied on more than one water source. The selection of water source depended on intended use, quality, availability, and reliability more than it did on price. Users are heavily reliant on groundwater, which is also increasingly scarce and contaminated. The findings shed light on the challenges of meeting operational costs through tariffs when municipal supplies are not the sole source of water, water quality is poor, and non-revenue water is high.

Key words | groundwater, Myanmar, piped water supply, service delivery, tariff setting, water demand

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†This study conformed to Johns Hopkins University IRB procedures, and received the status of Exempt on March 27, 2019. The study number is HIRB00008788. Further documentation is available if necessary.

HIGHLIGHTS

- Primary data on water supply in Myanmar are relatively scant. We believe that this is the only primary data collected in Mandalay that is representative of the city's water demand and usage.
- The research provides evidence to support the hypothesis that in low-income settings, tariff setting is complicated by the presence of multiple, substitutable water sources.
- The study also presents surprising evidence that quality and reliability may matter more to a low-income urban population in their choice of drinking water solutions than does price.
- The study makes data-based short- and medium-term policy recommendations based.

INTRODUCTION

While there has been undeniable progress in access to improved sources of water, almost a third of the world's population still lacks access to a reliable source of safe water (WWAP 2019). Much of this underserved population lives in rural areas; however, rapid urbanization, particularly in middle- and low-income countries has left many governments struggling to meet urban demand. Global access to safe water is highly correlated to income, and both rural and urban-poor populations suffer disproportionately (WWAP 2019). Myanmar is no exception. Almost 70% of the country still resides in rural areas, where 22% of citizens lack access to safe water compared to 6% in urban areas (CSO 2018). Myanmar will urbanize extensively over the next decades. One third of rural residents are expected to move to cities in the next 20 years, and half of the country's population will live in urban areas by 2050

doi: 10.2166/washdev.2020.076

(UNDESA 2018). Migration and natural population growth will test urban infrastructure and present an important challenge to city managers overseeing public service provision.

Water scarcity and climate change will exacerbate the challenge of rapid urbanization. By 2040, the number of people living in settings of extreme water stress will increase by an estimated 20% around the world (UNICEF 2017) (UNICEF defines extremely high levels of 'water stress' as those that exceed a ratio of 0.8 water use to supply, indicating a very high level of competition for available water (UNICEF 2017).). The combination of climate change and economic growth means that already arid regions, such as Mandalay, will not only be drier but also have substantially higher water needs. Myanmar has ranked among the most climate-vulnerable countries for the past two decades (Eckstein *et al.* 2019). Across the country, regions have observed shorter monsoon periods, longer pre-monsoon droughts, and higher rainfall depths (Tham 2010). Other studies have identified water scarcity, infrastructure, and quality control as barriers to water security for all citizens (Pink 2016). As leaders brace for the coming decades of changing environments and demographic shifts, understanding consumption patterns and usage has become critical for governments around the world.

Little was known about public service provision in Myanmar until the early part of the 2000s. In 2011, the government undertook a series of public sector reforms including increased transparency, decentralized governance, and socio-economic development programs (Rab *et al.* 2016). The international community responded by lifting or suspending economic sanctions and by providing 'extensive international assistance for Myanmar, including for its urban development and water sector' (ADB 2017a). Among the international financial and technical assistance were projects to improve urban water supply in Mandalay City – Myanmar's second-largest city and former royal capital. In 2016, Mandalay committed to borrow $100 million from the Asia Development Bank and the French Development Agency (AFD) to improve municipal sewage and expand piped water supply (ADB 2016). Other organizations, like the Japan International Cooperation Agency (JICA), GRET, and Vides-Evides International (VEI), are also supporting development projects in Mandalay City. However, an extended humanitarian crisis in the Rakhine State has threatened the flow of foreign investment and donor financing since 2018, placing further emphasis on domestic resource mobilization (IMF 2019).

With over 1.3 million people within its jurisdiction, Mandalay City is considered an economic and cultural hub of Upper Myanmar. Mandalay's population has grown at a rate of 10% per year, faster than Myanmar's total population rate of 1.8% (DOP 2015; ADB 2017b). The Mandalay City Development Committee (MCDC) manages the city, with two departments that oversee water-related issues. One is responsible for infrastructure installation, operations, and maintenance. A second, which falls under the Revenue Department, deals solely with water revenue. Under *The City of Mandalay Development Law*, MCDC is responsible for implementing water supply works and 'determining, revising, assessing and collecting taxes and duties and rates thereof in respect of development works' (State Peace and Development Council Law No. 8/2002). Water tariffs represent one of the highest sources of revenue for the city, while water supply is also one of the highest costs. Although MCDC has improved many aspects of its piped water service, significant challenges remain. According to available estimates, MCDC piped water supply only covers about 55% of the population, tariffs do not cover the cost of limited water provision and reported non-revenue water ranges from 50 to 75% (ADB 2017b). The next section briefly looks at approaches to understanding water demand. A description of the survey methodology, findings, and short discussion follows.

URBAN WATER DEMAND

The present study looks at the intersection of urban water demand patterns and tariff setting in developing economies and contributes to the research specific to Myanmar (The present study was part of a recent International Growth Centre project conducted for the MCDC to inform policy decisions on service expansion.). Budgetary and time constraints prevented us from completing a full willingness to pay (WTP) analysis. However, the survey highlighted the main challenges MCDC faces as it considers how to finance operations and improvements to its water infrastructure and management.

There is a wealth of literature on estimating effective demand and tariff setting for water services. Arbués *et al.* (2003) and Worthington & Hoffman (2006) provide valuable insights into modeling price elasticities and variable choice considerations. Whittington & Nauges (2010) study estimation techniques in cities which face unique challenges, like the persistence of unmetered consumption, unreliable usage data, as well as the prevalence of multiple water sources. They find that modeling demand for water in these settings requires data from the alternative sources, which are often unavailable or hidden in informal markets. Other studies focus on the determinants of consumption, but they are largely clustered in rural areas (Basani *et al.* 2008; Basu *et al.* 2017; Martinez-Santos 2017; Gross and Elshiewy 2019; Wagner *et al.* 2019). In these settings, distance, perceived quality, and price influence the choice of water source.

Another section of the literature analyzes the response to changes in price or quality of water supply. In general, studies find that demand for piped water in urban areas is quite inelastic when source substitution is difficult (Nauges and Whittington 2010; Marzano *et al.* 2018). Importantly, when piped water and non-piped water are substitutes, households with access to multiple water sources (such as water venders, hand-dug, or deep wells) may be more sensitive to price changes than those relying solely on piped water, switching to cheaper sources when tariffs or prices are raised (Nauges and Whittington 2010).

WTP is positively correlated to incomes, ease of access, and reliability – especially in urban areas, and consumers will pay more for improved services (Casey *et al.* 2006, Orgill *et al.* 2013). Households tend to be more willing to pay for private water connections than public ones (North & Griffin 1993). Households without access to reliable and safe piped water engage in many 'coping behaviors'. One study finds that such coping costs can be double a monthly water bill but are still lower than WTP for improved water supply (Pattanayak *et al.* 2005). Furthermore, WTP for proposed improvements in water access declines as a household's baseline access to other water services improves (Van Houtven *et al.* 2017).

Tariff setting has been explored extensively as well. Local authorities typically hold responsibility for raising revenue sufficient to cover operational costs, ideally through a combination of local taxes (income, property, and sales tax for example), tariffs, and fees. In emerging economies, however, most utility providers are unable to cover even ongoing maintenance costs, due to large system losses from breakages and theft, poor control over investment and tariff setting decisions, and rapid urbanization (Nagpal *et al.* 2019). Recent research suggests that only 35% of utilities in developing countries are able to cover operations and maintenance costs (Lombana Cordoba *et al.* 2019).

User fees take on various forms, such as flat fees, volumetric or increasing block tariffs, and they may also reflect environmental costs and equity goals (Silva Pinto & Cunha Marques 2015). But the setting of these tariffs is often a political exercise and not based on financial, environmental, or social costs.

In many cases, the poorest households cannot connect to the piped water system despite the premise that tariffs should be kept low for social equity concerns. This challenge stems from the high upfront costs of connecting and the pervasiveness of irregular incomes in informal employment (Mitlin & Walnycki 2019). Thus, low tariffs end up being regressive as they subsidize the consumption of relatively wealthier households who can afford the connection costs and are able to pay a regular bill (van den Berg & Danilenko 2017). Under these conditions, poorer households rely on a range of sources to satisfy their household needs, using a combination of open, unimproved sources, such as ponds and lakes and safe sources, such as deep wells or purchased bottled water.

The following section briefly describes the study area and survey methodology.

METHODOLOGY

We combined in-depth interviews (IDIs) with a quantitative survey of households and micro, small, and medium enterprises (MSMEs) to draw conclusions about household and business demand and consumption patterns in the city's six townships.

Sample site: Mandalay city

Mandalay District is located in the Central Dry Zone of Myanmar and sits on the Irrawaddy River – the largest

river in the country. With over 1.3 million people within its jurisdiction, Mandalay City is considered an economic and cultural hub of Upper Myanmar. MCDC governs the jurisdiction, which comprises of seven townships. The township populations range from 197,175 citizens in Chanayetharzan to 283,781 in Chanmyatharzi. Of the seven townships, only Amarapura and Patheingyi are not fully urban, with only 34 and 5% urban population, respectively (DOP 2015). In 2018, an average household had a monthly income of 350–450,000 MMK or 245–315 USD (The figures reported in dollars use a 1 Myanmar Kyat (MMK) = 0.0007 United States Dollar (USD), which is an average of the exchange rate conversion for 2018), and comprised of 4.8 members (Ford *et al.* 2019). In the city's jurisdiction, 81% of households own or rent their dwelling (DOP 2015).

Quantitative survey

The quantitative survey was designed to investigate water demand and to capture behavioral aspects, such as perception, satisfaction, and expectations from piped water supply. The survey spanned six urban townships (including Amarapura). Due to the absence of credible data on the actual proportion of businesses per household at the township level, it was assumed to be proportional to the ratio at the city level. Therefore, as per Probability Proportional to Size sampling, the number of surveys administered followed an 80% households (HHs) to 20% businesses (MSMEs) ratio (Lavrakas 2008; Skinner 2016). Table 1 provides a comparison between the initial sampling plan and the population captured by the actual survey.

A total of 1,480 respondents were randomly selected across the 6 townships, including 1,178 (80%) households and 30 (20%) MSMEs, distributed proportionally to the actual population. Eighteen enumerators were identified based on educational qualification, sector experience, and geography. The survey tool was pretested, and enumerators were trained over an interactive four-day training workshop in Mandalay. The map of the survey sample is displayed in Figure 1.

IDIs were conducted with senior officials to understand their perceptions of current MCDC operations and costs. Survey results were shared with MCDC officials and the Mayor's office.

RESULTS

The household survey and key informant interviews found that most residents in Mandalay City use many sources of water. Households and MSMEs rely on piped water, tubewells, and bottled water. Townships vary in their access to different sources, but this is not because of income, which appears to be uniform across townships. The water source selection by users depends on intended use and availability, with quality being one of the most important factors in decision-making.

Understanding access to water: multiple sources

In the sample, most (80%) households and businesses obtain water from two or more sources. These include piped water

Table 1 | Sampling plan and survey comparison

	Sampling plan			Actual survey		
Township	**HHs**	**MSMEs**	**Total**	**HHs**	**MSMEs**	**Total**
Amarapura	193 (80%)	48 (20%)	241	193 (80%)	48 (20%)	241
Aungmyethazan	215 (80%)	54 (20%)	269	208 (78%)	60 (22%)	268
Chanayethazan	159 (80%)	40 (20%)	199	160 (80%)	40 (20%)	200
Chanmyathazi	230 (80%)	57 (20%)	287	236 (81%)	57 (19%)	293
Mahaaungmye	194 (80%)	49 (20%)	243	190 (79%)	49 (21%)	239
Pyigyitagon	193 (80%)	48 (20%)	241	191 (80%)	4 (20%)	239
Total	1,184 (80%)	296 (20%)	1,480	1,178 (80%)	302 (20%)	1,480

HH, households; MSMEs, micro, small, and medium enterprises.

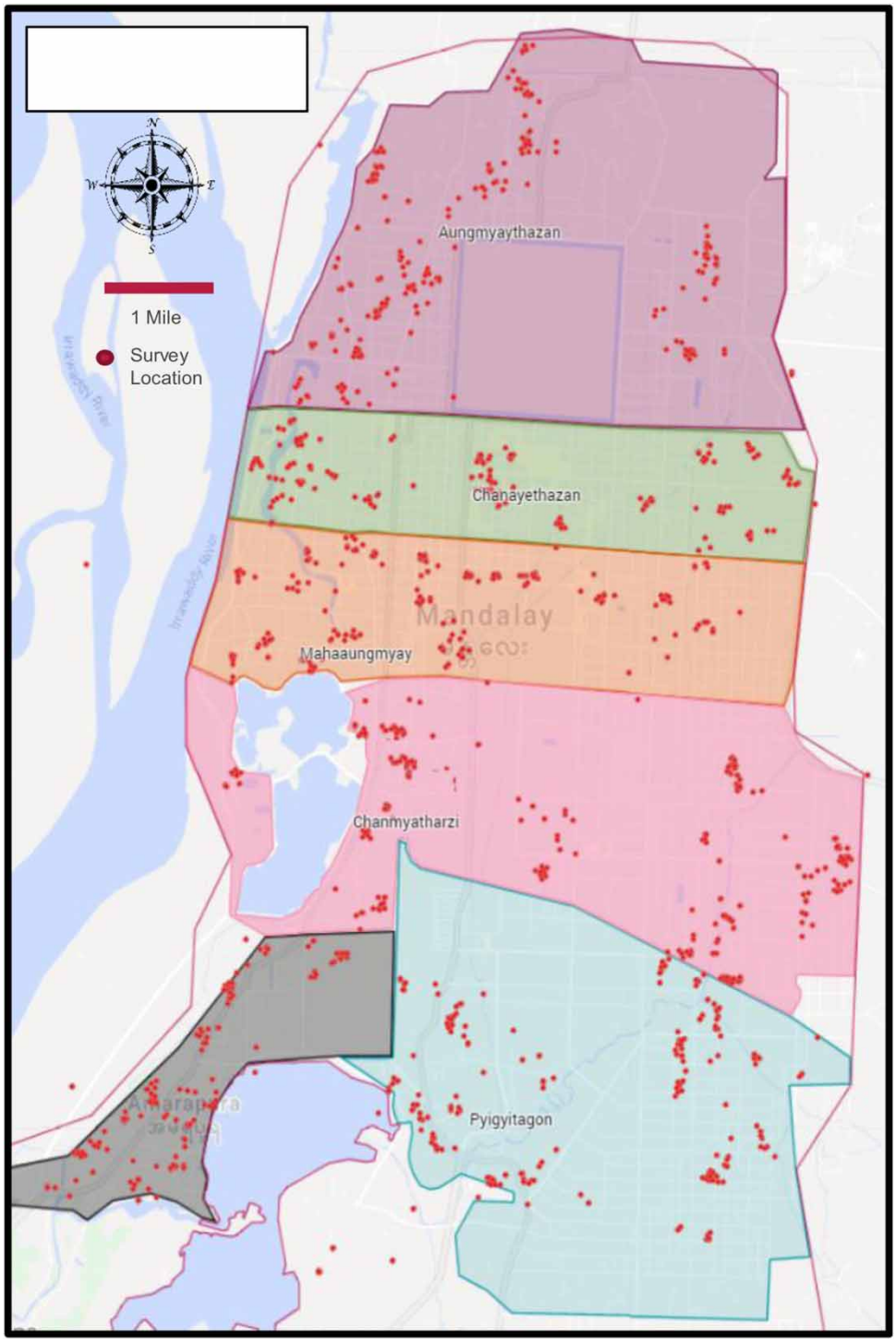

Figure 1 | Map of the survey sample. Surveys, the location of which is represented by a red dot on the map, included households and MSMEs from six townships in Mandalay. Please refer to the online version of this paper to see this figure in colour: http://dx.doi.org/10.2166/washdev.2020.076.

from MCDC, tubewells, or hand-dug wells, commercial bottled water, and other sources, including open sources. The surveyed townships all displayed similar reliance on more than one source. Moreover, water sources are used

in similar proportions between households and businesses. Overall, the most common sources of water are water bottles (71%) and tubewells (68%), while only 35% of respondents reported obtaining water through MCDC piped water systems (Figure 2(a)). MSMEs displayed little variation from households in their water sources (Figure 2(b)). A small percentage of respondents obtain their water from other sources. Almost 10% get water from public taps. Of those who collect water from public taps, 92% perform the collection daily and spend an average of 12 min per trip.

Access to water sources differed greatly across townships (Figure 3). In Amarapura, 96% of households used water from tubewells, and none reported having a piped water connection. There was an inversely proportional relationship between use of MCDC piped water and tubewells for households and the similar pattern holds for MSMEs.

Despite the variation across townships in access to different water sources, households displayed marked homogeneity in income distribution (Figure 4(a)). Most households fell between K300,000 and K500,000 a month (USD $210–$350). Nevertheless, water sources used by households do not appear contingent on the level of income (Figure 4(b)).

Understanding water usage: patterns and perceptions

The survey aimed to assess water usage and decision-making patterns. Almost all primary sources were either tubewells (48.6%) or MCDC piped water (44.7%). Households reportedly used their primary source for multiple purposes: showering (97.4%), washing dishes (98.4%), and some cooking (65.5%). Only about a third (27.2%) used their primary source – piped water or tubewells – for drinking despite 42.4% of households saying it was safe to do so.

Figure 5 summarizes the household water usage patterns across all primary, secondary, and tertiary water sources. Households clearly rely on bottled water for drinking, and MCDC water or tubewells for other water-intensive tasks, such as showering or dish washing.

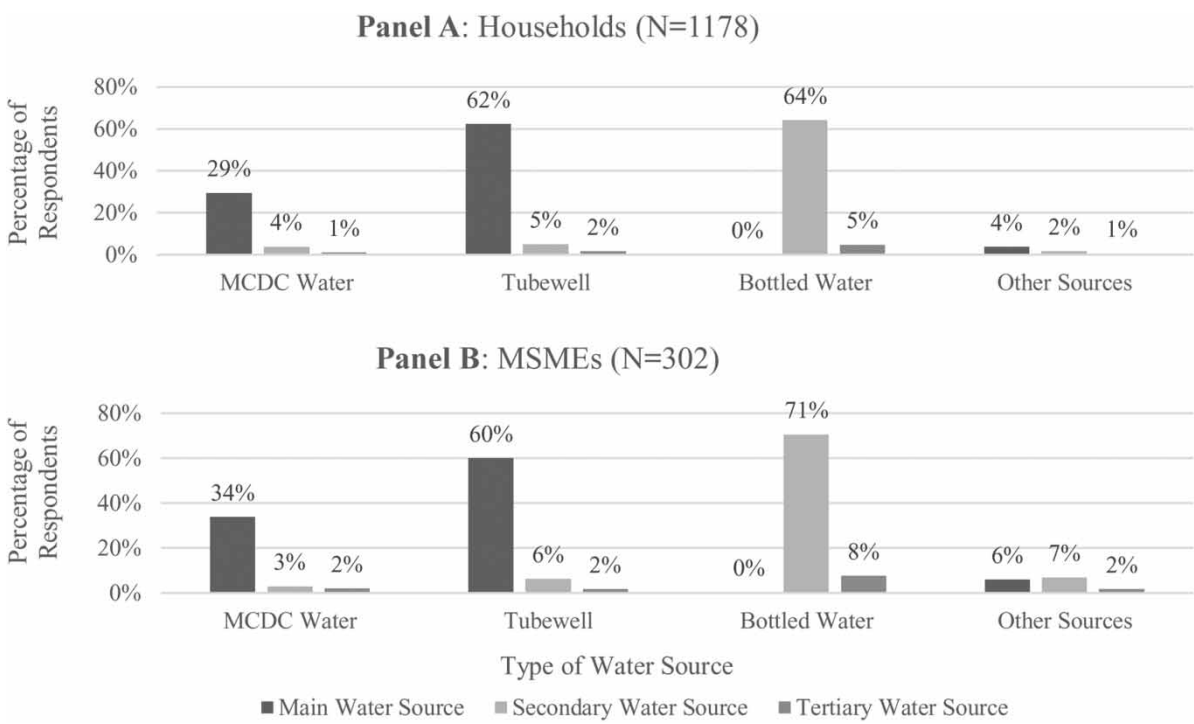

Figure 2 | Primary, secondary, and tertiary water sources used in Mandalay City. Other sources include public tap water, water sold by any other means, protected hand-dug well, protected spring/pond/rainwater/unprotected hand-dug well, unprotected spring/pond/rainwater, and river/stream/lake/dam.

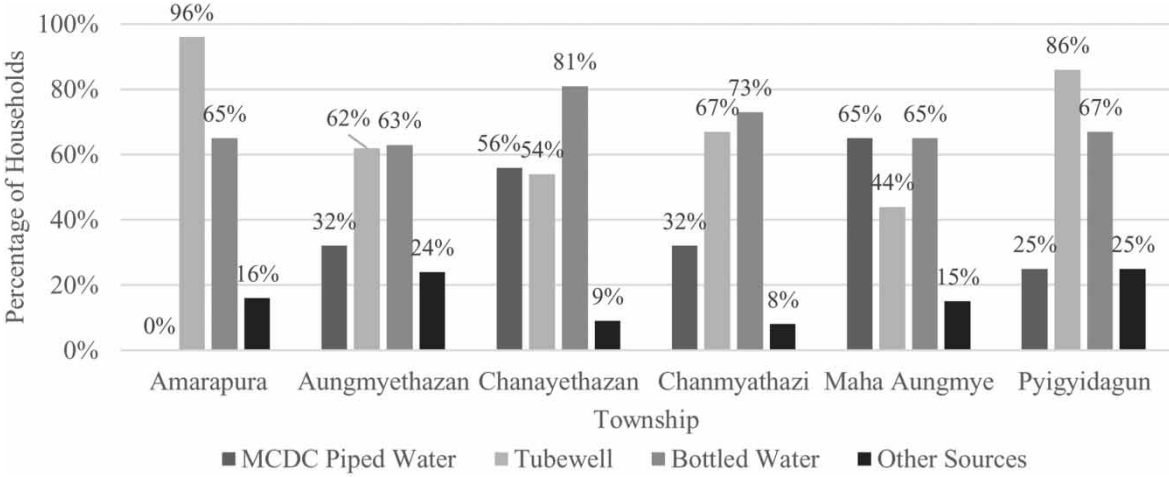

Figure 3 | Household primary, secondary, and tertiary water sources across townships ($N = 1,178$). Other sources include public tap water, water sold by any other means, protected hand-dug well, protected spring/pond/rainwater/unprotected hand-dug well, unprotected spring/pond/rainwater, and river/stream/lake/dam.

Respondents across townships highly valued water quality for consumption. Almost 80% of all households had a second water source, used primarily for drinking (91.8%). This usage was heavily supplied by commercial bottled water – more than 80%, compared to 11% by MCDC piped water and 6% by tubewells. Households used commercial bottled water regardless of whether they had access to the city's piped water or tubewells.

Mandalay citizens emphasized the quality and over half (54%) of respondents stated *quality of water* (smell, taste, etc.) as 'very important'. Only a third responded that *convenience of access* (36%), *reliability of access* (31.4%) or, interestingly, the *price of water* (20.3%), were 'very important'. In general, price and quality seldom factored into why people did not use MCDC piped water. Instead, the decision stemmed from whether MCDC service was available in their area or if they had already invested in a substitute. Based on the survey results, tubewells and MCDC piped water appear to be substitute sources dependent on access, and commercial bottled water a necessary supplement for drinking due to water quality in the city.

Understanding household billing

Among the sampled households, 95% reported a typical monthly income of less than 800,000 MMK (560 USD), and the mean income was K300,000–K500,000 ($210–$350). Only 40% of households reportedly paid for their primary source of water. On average, those who used MCDC piped water paid about 7,668.4 MMK ($5.37) for their primary water source per pay period, and most paid every 2 months (67%) or monthly (19%).

In addition to their primary source, many households (62%) also had commercial bottled water delivered to their homes (12% of households collected it themselves). Most households reported paying between 200 and 2000 MMK ($0.14–1.40) per delivery, with varying frequency of deliveries. Assuming weekly deliveries, or four times a month, a household may pay between 800 and 8,000 MMK ($0.56–5.60) a month on bottled water. Assuming a daily delivery on the other hand, or 30 times a month, bottled water could cost a household between K6,000 and K60,000 ($4.20–42.00 USD). With a monthly income of K400,000 ($280), commercial bottled water delivery could therefore comprise between 0.2 and 15% of monthly expenditure.

According to MCDC officials, the connection fee to the piped water network is about 150,000 MMK (around 105 USD). The survey revealed this connection fee, not the tariff rate, deterred users from connecting to the network. Only 11% of unconnected households and MSMEs reported that cost deterred them from using MCDC piped water. A third of those currently not using MCDC water said they did not need it. Another 71% reported that MCDC water was not available in their area; thus, one can assume that they paid little to nothing for their primary source (only 40% pay for their primary source). Households connected

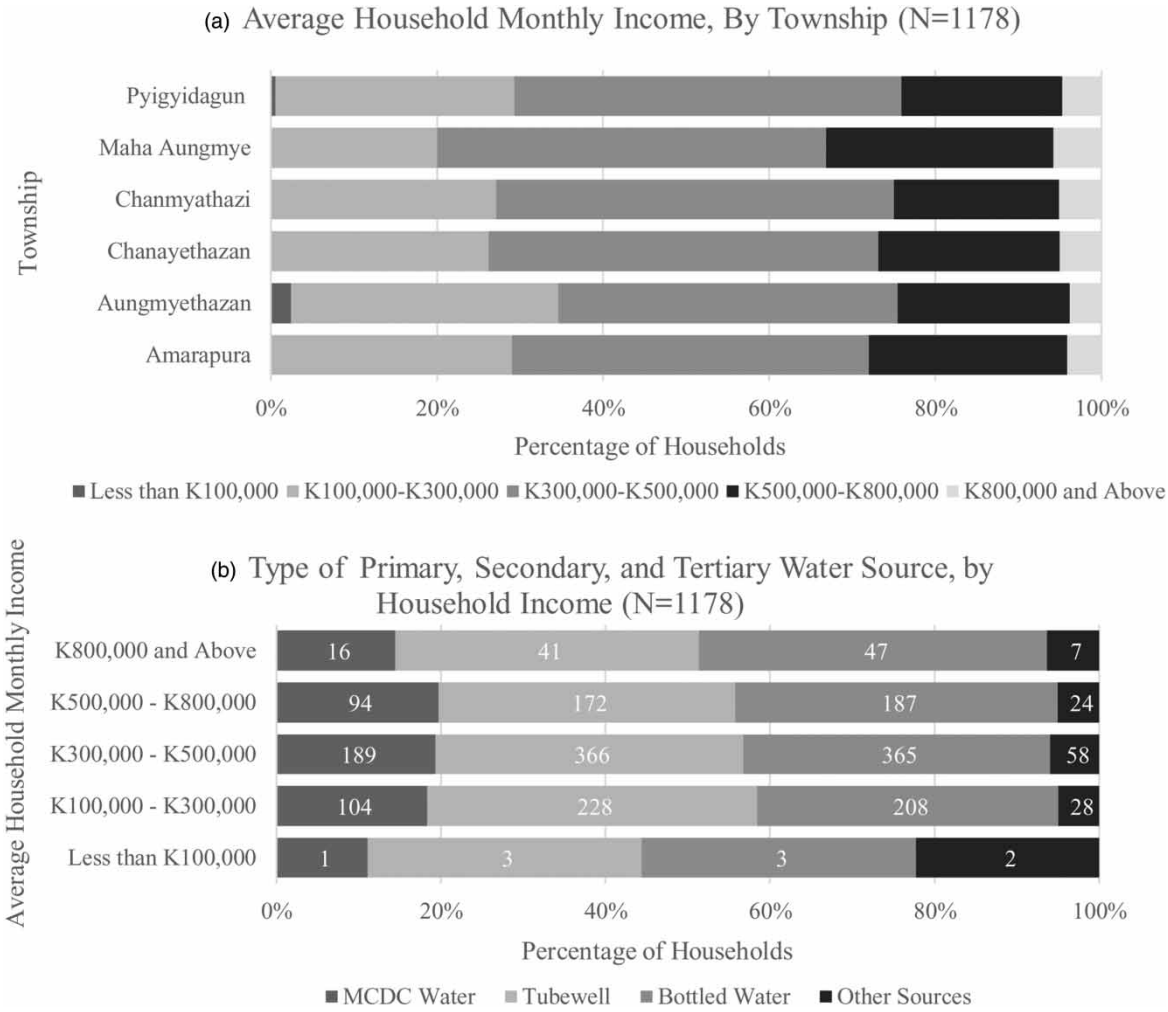

Figure 4 | Household income and water source. Other sources include public tap water, water sold by any other means, protected hand-dug well, protected spring/pond/rainwater/unprotected hand-dug well, unprotected spring/pond/rainwater, and river/stream/lake/dam. *Note:* In (b), the small number of households earning an average monthly income of less than K100,000 makes drawing conclusions about their water source patterns difficult. It should not necessarily be interpreted that this income bracket relies on other sources more than different income groups.

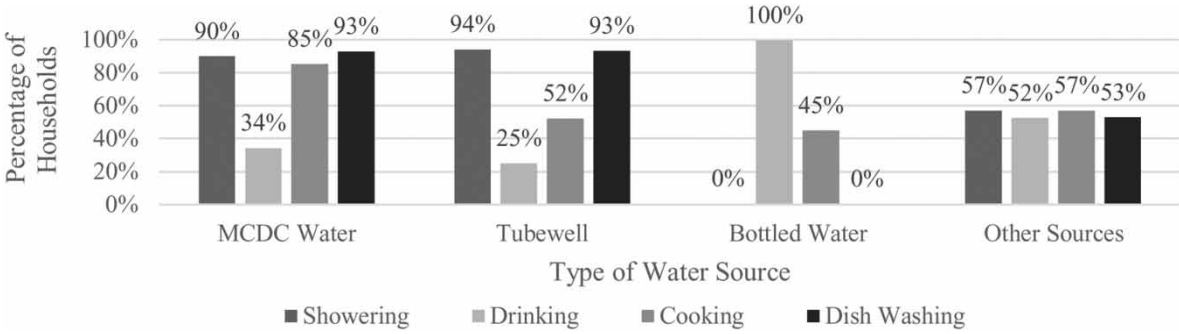

Figure 5 | Water usage, by type of water source ($N = 1,178$). Other sources include public tap water, water sold by any other means, protected hand-dug well, protected spring/pond/rainwater/unprotected hand-dug well, unprotected spring/pond/rainwater, river/stream/lake/dam.

to the MCDC network report that they were billed on a per unit basis, though some were unsure. Of all respondents, the survey found about 36% had a meter and 92% were reportedly functioning. According to MCDC officials, however, about 50% of meters are not read because they are unreadable, not working or broken. MCDC has a team of 55 m readers. If a meter is broken or unreadable, MCDC billed the household based on the average consumption over the last 3 months.

DISCUSSION

This research filled a critical data gap by producing reliable primary data on water supply and usage in Mandalay City. Such data are critical input for policymakers seeking to revise tariffs to fund service improvements. From the primary research, we conclude that users rely on either tubewells or MCDC piped water for uses other than drinking, and these sources are viewed as substitutable. Commercially bottled water is used for drinking (and sometimes cooking) irrespective of income and access to MCDC pipes. Even though some households responded that water quality of their primary source is acceptable, neither MCDC piped nor tubewell water is regarded as safe enough to drink across all income categories. It is difficult to say whether piped water is safe to drink as there is a lack of testing and reliable data on water quality. In the context of the Sustainable Development Goals, over 90% of Mandalay's population has access to improved water. However, because this water may not be 'free from contamination', it does not meet the standard of safely managed drinking water (World Bank 2017). According to one report, 'Piped water supply systems in the main cities of Mandalay and Yangon include untreated surface water from open reservoirs, thereby falling between the Joint Monitoring Program's definitions of improved water and unimproved water' (ADB 2017a). The latest investment in water supply does include plans for the purchase and installation of chlorination equipment (Based on JICA (no date) project preparation documents available online https://openjicareport.jica.go.jp/pdf/12231130_02.pdf and Myanmar Times (2018) newspaper report https://www.mmtimes.com/news/italian-firm-purify-water-mandalay.html (accessed May 29, 2020).). The high reliance of businesses and households on tubewells is also an important finding, especially since tubewells are dug without permission and may exacerbate groundwater depletion and scarcity. In Amarapura, which is urbanizing rapidly, 96% of the sample surveyed relied almost completely on tubewells. A recent study on groundwater shows that there is a high rate of contamination in wells in Amarapura (Grzybowski *et al.* 2019). Thus, as the government expands its public water supply, it will have to consider both its own use of wells and more strictly regulate drilling and extraction by households and MSME.

IDIs conducted with key MCDC officials revealed that billing data are not available for all households and all periods. However, tariffs were revised in 2015 from 55 to 85 MMK per unit (+54.5%). In 2017, the tariff was raised again to 200 MMK (+135.3%). Both tariff increases are expected to have raised MCDC revenues, but it is difficult to establish with certainty the impact that these tariff increases had on household consumption since metering is uneven, and billing records are not easy to find or comparable across time (all billing is done on paper and tariffs are collected in person). It is possible that marginal returns to further sharp tariff hikes could be very low and even negative (Balac *et al.* 2019). Furthermore, given that so many users pay a flat rate per unit (approximated either by household size or historical use), an increase in tariff would be regressive and hurt the poorest MCDC consumers. One other way to address cost recovery could be through reducing non-revenue water, which administrators estimated to be as high as 55%. About 70% of Mandalay's NRW may stem from physical losses and the rest from commercial loss – specifically broken and unreadable meters or faulty meter readings (In 2019, MCDC began the process of testing automatic meter readers, but it is unclear if large scale upgrading of meters has been completed at this time.). Schools, all government buildings, and monasteries are not metered and receive water at no charge. MCDC will need to consider these challenges as it prepares for a growing population and service expansion.

Finally, it is important to remember that piped water coverage is still quite limited; slightly more than a third (35%) of Mandalay City residents use MCDC water as a primary source of water, and only 7% as a second or third option. If MCDC must rely solely on user charges to repay its loans to development partners and to cover operational

costs, it will need to significantly expand coverage in addition to raising tariffs.

CONCLUSION

Mandalay City faces a future of population growth and climate challenges that will stress municipal water provision. Households and MSMEs in six townships currently rely on multiple water sources and largely use only bottled water for drinking. As the city administration considers tariff readjustments to finance supply expansion, it must take into account the widespread availability and use of tubewell water as a substitute to piped water, and the supplemental commercial bottled water used for drinking. While households lacking access to tubewells will have to pay the higher tariffs, those with tubewells may substitute MCDC water more often with increasingly scarce, and perhaps contaminated, tubewell water. In the short to medium term, MCDC may need to focus on raising revenues by improving the frequency and reliability of metering and better detection of leaks. Regulating groundwater abstraction may also be viewed as an immediate priority as Mandalay lies in the most arid region of Myanmar and is already facing climate change-related water scarcity.

ACKNOWLEDGEMENTS

This study was part of a recent International Growth Centre (IGC) project conducted for the Mandalay City Development Committee to inform policy decisions on service expansion. It was funded by IGC and carried out under the management of Athena Infonomics by a team from the Johns Hopkins University School of Advanced International Studies, Athena Infonomics and IGC. The authors are grateful to Nilar Win, Nan Sandi, Astrid Haas, Ian Porter (IGC), and Ankit Chatri, Akshay Natteri, Kun Zhang (Athena Infonomics) for their support.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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First received 30 March 2020; accepted in revised form 11 July 2020. Available online 6 August 2020