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Household-scale water metabolism assisting the management of intermittent water supply systems: case studies in the Brazilian semi-arid region

Metabolismo da água em escala domiciliar auxiliando a gestão de sistemas intermitentes de abastecimento de água: estudos de casos no semi-árido brasileiro

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ABSTRACT

Urban water management faces the challenge of balancing supply and demand. Management and operations of urban water supply systems are usually driven by aggregated data on demands over sectors or city scales. This approach does not consider the impacts of the operations on the end-user, at the household. This study aims to provide a more detailed understanding of household-level water demands and demonstrate how this information can support intermittent urban water supply management. The social metabolism methodology and Maslow's hierarchy of needs were Applied. The research draws on both secondary and primary data, with questionnaires administered to 123 households in 47 cities located in the semi-arid region of Brazil. The findings reveal distinct consumption patterns, with rigid demand, which represent the most urgent needs, being prioritized by households and recommended for prioritization by water managers. Higher-order demands tend to increase water consumption, underscoring the need for awareness and water-efficiency policies tailored to different population segments.

Keywords: Uses of water; Domestic scale; Social metabolism; Hierarchy of demands.

RESUMO

A gestão de águas urbanas enfrenta o desafio de equilibrar oferta e demanda. A gestão e as operações de sistemas de abastecimento de água urbanos são geralmente conduzidas por dados agregados sobre demandas em setores ou escalas de cidades. Essa abordagem não considera os impactos das operações no usuário final, no domicílio. Este estudo visa fornecer uma compreensão mais detalhada das demandas de água em nível domiciliar e demonstrar como essas informações podem dar suporte à gestão urbana de sistemas intermitentes de abastecimento de água. Foram aplicadas a metodologia do metabolismo social e a hierarquia de necessidades de Maslow. A pesquisa se baseia em dados secundários e primários, com questionários aplicados em 123 domicílios em 47 cidades localizadas na região semiárida do Brasil. As descobertas revelam padrões de consumo distintos, com demanda rígida, que representam as necessidades mais urgentes, sendo priorizadas pelas famílias e recomendadas para priorização pelos gestores de água. Demandas em níveis mais elevados tendem a aumentar o consumo de água, ressaltando a necessidade de conscientização e políticas de eficiência hídrica adaptadas a diferentes segmentos populacionais.

Palavras-chave: Usos da água; Escala doméstica; Metabolismo social; Hierarquia das demandas.

INTRODUCTION

In recent years, rapid urbanization and population growth have increased water consumption and intensified stress on water resources (Schewe et al., 2014), creating a challenge for urban water management. Sustainable water management is essential to meet the growing demands of urban populations worldwide. To ensure the sustainability of urban water systems and meet the increasing water demands of the urban population, it is crucial to understand the water consumption characteristics of households residing in urban areas and to identify the factors influencing their usage patterns (Cominola et al., 2015; Kumar et al., 2021; Cominola et al., 2023).

Urban planners and governments strive to supply their populations using a classical economic model of supply and demand (Adler, 2011). Traditionally, managers focus on expanding and optimizing water sources, predominantly adopting a supply management strategy. Supply management actions generally seek to obtain new water supplies, which incurs high financial costs. Initially, governments prioritized the most cost-effective water sources and turned to alternative sources when deemed suitable (Adler, 2011). Historically, in developing countries, governments prioritize large-scale and high-cost infrastructure projects to expand water supply (Ramsey et al., 2017). However, demand management has gained prominence as a complementary or alternative approach, aiming to reduce consumption and increase efficiency in water use (Braga & Ribeiro, 2006; Brooks, 2006; Butler & Memon, 2006; Lemos et al., 2010; Balado-Naves et al., 2025). Demand management strategies have not yet been adequately implemented, resulting in the overexploitation of available water resources (Kumar et al., 2024).

Developing efficient strategies for sustainable water management requires a comprehensive understanding of the different water consumption behaviors of urban residents (Beal et al., 2013; Luo et al., 2020). Traditional approaches to analyzing water consumption often rely on aggregated data, which can obscure the heterogeneity in usage patterns among households (Cardell-Oliver et al., 2016; Porse et al., 2018). Various factors shape water consumption behaviors, including household characteristics, socio-economic aspects, cultural norms, and environmental conditions (Jorgensen et al., 2009; Rathnayaka et al., 2014). Water consumption patterns vary substantially among different types of households and regions (Willis et al., 2011). Research has also investigated the relationship between household characteristics and water consumption, identifying factors such as the presence of a garden, the number of bedrooms, family size, income, and the use of water-efficient appliances as significant drivers (Fox et al., 2009; Jorgensen et al., 2009).

Studies on domestic water consumption represent the most robust and accurate approach to understanding water demand and the domestic generation of greywater. These studies provide data and insights into the factors influencing per capita variations in water use and consumption (Beal et al., 2013). They also help to understand how water is used quantitatively and qualitatively in a household (Chen et al., 2013; Makki et al., 2015; Otaki et al., 2017a). Accurate data covering a variety of socio-demographic factors, household attitudes, and behaviors are essential for implementing more effective models of urban water management (Makki et al., 2015; Roshan & Kumar, 2020). For example, in a study of 600 households in Lyari, Karachi, Khan et al. (2023) identified that water use varies by gender, season, and economic level; the study also concluded that wealthier families can 'buy' water security and sustain higher water use, even in situations of extreme scarcity.

Water demand projections have historically been overestimated (Fan et al., 2014), particularly in low- to middle-income regions (Shaban & Sharma, 2007). The predictability of domestic water demand is unclear for all users, given the many factors that affect their needs (Zhi-Guo et al., 2010). Climate also influences demand, generating seasonal variations in water use. Increasing heat periods intensify urban water demand (Syvrud et al., 2021). Water consumption is highly dynamic across various temporal scales (Price et al., 2019; Di Mauro et al., 2020). Overestimated demand projections can lead to inefficient investments in water supply expansion (Fletcher et al., 2019). These projections often construct narratives of acute scarcity, diverting attention from more urgent water challenges and serving as a convenient justification for water utilities in the face of poor water resource management (Khan & Arshad, 2022).

Higher estimates may arise from misconceptions that water consumption will undoubtedly increase with socio-economic development, that growing industries will significantly elevate water use, and that urbanization will substantially increase urban consumption (Yuan et al., 2014). These errors stem from an inadequate understanding of the factors causing the increase in water demand due to socio-economic development, owing to the inability to clearly define the mechanisms and norms that regulate water demand, as well as the failure to analyze actual water demand from the consumers' perspective (Steenbergen et al., 2013). Relatively low water consumption values may indicate that actual water demand is not fully met, resulting in prolonged user scarcity (Pawlowski et al., 2010).

Data on domestic water use is increasingly utilized to develop potential solutions and aid in the formulation of tailored strategies and policies (Khan et al., 2023; Wang et al., 2024). In urban water management, ignoring demand variability can lead to inefficient system operations and unequal access to water. Aggregated urban-scale data may obscure localized variations, such as those between informal/semi-regularized and formal neighborhoods (Mutono et al., 2022), and differences in household consumption (Khan et al., 2023). Despite this gap, relatively few studies investigate intra-urban variations in domestic water consumption (Adams, 2018; Cominola et al., 2023).

Therefore, this work aims to contribute to a more detailed understanding of demands at the household scale and how this information can support urban water management. Based on the previous discussions, the gaps this work intends to fill are related to a better understanding of how water moves within households, detailing how water is received and used, associating demands with human needs, and identifying how water use is prioritized. Thus, the work contributes to the discussion of factors that influence domestic water demand, providing information that can be used for its determination and analysis, assisting managers in urban water management.

METHODOLOGY

This study adopts a qualitative-quantitative approach. Quantitative data generate inquiries that can be analyzed qualitatively, and qualitative data can be evaluated quantitatively, allowing for a more significant interpretive potential of the object of study. Regarding the procedures, the study is classified as a case study, with data collection through the application of questionnaires and a literature review.

The methodology has the following stages: gathering secondary data through a literature review, obtaining primary data through the application of a questionnaire, processing the collected data, categorizing domestic demand, constructing the structure of water circulation within the residence, and analyzing and discussing the results (Figure 1).

We collected primary data through a structured questionnaire, designed to understand the factors influencing domestic water consumption in the context of water scarcity. The selection of collected data was based on previous studies, such as the one by Sousa & Fouto (2024), who analyzed 55 articles and identified that, to understand the consumption behavior of households, it is necessary to consider a set of factors, which include: psychological factors, available technologies, awareness, sociodemographic and economic characteristics, water availability context, and applied policies. The authors emphasize that these factors should be analyzed together, establishing their relationships rather than separately.

The questionnaire has 17 open and closed questions, divided into socio-demographic data (location, income, and number of residents) and data related to access to water, describing the types of supply, usage patterns, and disposal of effluents (see Supplementary Material – Table S1). The questionnaire was available to potential respondents from March to July 2024 and was shared on social media platforms such as WhatsApp groups and Instagram. Participants were encouraged to share the questionnaire with others whenever possible.

The data collection was conducted using non-probabilistic convenience sampling, in which the cities were not preselected but defined based on the respondents. This type of sampling is particularly used in qualitative and exploratory research (Fonseca & Martins, 2012). The choice of this technique was due to time and cost constraints in accessing the entire population. However, since the study is exploratory and aims to gather initial data on how water is metabolized in households, this approach is suitable for achieving its objectives.

Content analysis was used to examine the responses to open-ended questions. According to Espírito Santo (2010), this technique organizes information through coding, categorization, and inference processes, enabling an analytical approach with a quantitative and/or inferential nature, depending on the objectives and methods adopted. The analysis occurs in three phases: pre-analysis, material exploration, and result processing with interpretation (Bardin, 2016).

The respondents comprised 123 households across 47 cities, including 36 small towns with populations ranging from 2,338 to 38,984 inhabitants and 11 medium-sized towns with populations ranging from 56,496 to 419,379 inhabitants, all located in the semi-arid region of Brazil in the states of Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí, and Rio Grande do Norte (Figure 2). This region is characterized by prolonged droughts and low availability of water resources (Srinivasan et al., 2021).

To characterize the demands, this study followed the Maslow's Hierarchy of Needs. This theory is widely used in social sciences research (Hutchins et al., 2019; Hale et al., 2020; Linwei et al., 2021). However, its application in the field of water resources is still in the exploratory phase (Russo et al., 2014; Pan et al., 2018; Sadeghi et al., 2020; Xue et al., 2020; Crouch et al., 2021; Niu et al., 2022). Here, we utilized the methodology employed by Pan et al. (2018), which, based on Maslow's Hierarchy of Needs, structured water demands into three primary levels: the demand for survival, the demand for hygiene and health maintenance, and the demand for leisure and recreation.

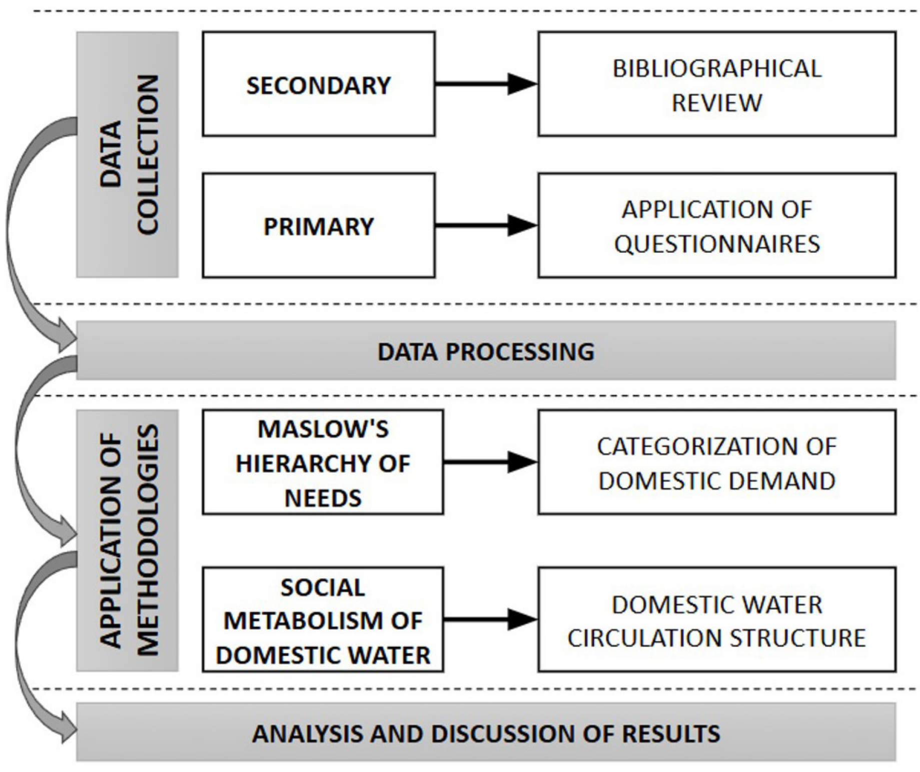

Figure 1. Flowchart of the methodological design.

CITY/STATE	POPULATION	CITY/STATE	POPULATION	CITY/STATE	POPULATION
Taboleiro Grande/RN	2.338	Betânia/PE	11.232	Esperança/PB	31.231
Várzea/PB	2.668	Salgado de São Felix/PB	11.505	Monteiro/PB	32.277
Ouro Velho/PB	2.918	Barra de Santa Rosa/PB	12.904	Oeiras/PI	38.161
Vila Nova do Piauí/PI	2.935	Serra Branca/PB	13.614	Várzea Alegre/CE	38.984
Gurjão/PB	3.242	Coremas/PB	14.683	Açu/RN	56.496
Agricolândia/PI	4.940	Batalha/AL	16.448	Caicó/RN	61.146
Damião/PB	4.982	Pocinhos/PB	17.469	Cajazeiras/PB	63.239
Padre Marcos/PI	6.382	Boqueirão/PB	17.598	Palmeira dos Índios/AL	71.574
Serra Redonda/PB	6.828	Pio IX/PI	17.613	Macaíba/RN	82.249
Pedra Lavrada/PB	6.859	Ingá/PB	17.692	Picos/PI	83.090
Livramento/PB	6.877	Remígio/PB	17.885	Paulo Afonso/BA	112.870
São Mamede/PB	7.470	Picuí/PB	18.333	Parnaíba/PI	162.159
Marcelino Vieira/RN	7.896	Barro/CE	19.381	Sobral/CE	203.023
Cruzeta/RN	8.005	Quixeré/CE	20.874	Mossoró/RN	264.577
Umarizal/RN	10.078	Alagoa Grande/PB	26.062	Campina Grande/PB	419.379
São Sebastião de Lagoa de Roça/PB	11.040	Lavras da Mangabeira/CE	30.802		

Figure 2. Map of the location of the case studies and data on the population of municipalities.

This hierarchy related to water demand develops the formation of the domestic water cycle, which in this work will be addressed through the metabolism of domestic water. We classified the demands in this study following the same approach as the previously cited study. From this classification, it is possible to understand how and which demands can be altered, supporting managers in prioritizing the allocation of water resources.

The construction of the water circulation structure within the residence was based on the structure of social metabolism proposed by González de Molina & Toledo (2014). Social metabolism involves three flows: input flows, internal flows, and output flows. This concept is approached from multiple perspectives, framing itself along at least three axes: the spatial dimension, represented by the global territory, the temporal dimension, and the dimension of the analyzed metabolic processes.

In the spatial dimension, we used the household scale to understand how water moves within the home and how users experience access. In the temporal dimension, we processed the data to reflect the most recent reality, collecting it between March and July 2024. In the dimension of metabolic processes, the study by González de Molina & Toledo (2014) identifies five processes: appropriation, transformation, circulation, consumption, and effluents.

Based on the definition of each process and considering the context of this work, we understand appropriation as how water enters the household. We added the storage process, as it is a component in intermittent water supply systems (Galaitsi et al., 2016), which are prevalent in developing countries (Abu-Madi & Trifunovic, 2013; Kumpel et al., 2017; Belmeziti et al., 2025). Storage occurs through devices used to supply periods without water supplied by the regular distribution system. Transformation comprises the treatment techniques applied before use. Consumption includes the use of water, characterized in this work by domestic water demands. Effluents are characterized by their forms of disposal, while circulation refers to the movement of water within the home, encompassing all previous processes.

Thus, we renamed the metabolic processes as input, storage, transformation, circulation, demand, and effluents. These processes were categorized based on their occurrence in the collected data. Circulation does not have a categorization, as it represents the water path between the processes. Table 1 presents this subdivision.

RESULTS AND DISCUSSION

Socio-demographic data

We organized the data and presented it based on the frequency of occurrence for the three categories identified in this

Table 1. Categories for each metabolic process identified from the data collected.

INDEX	INPUT	INDEX	STORAGE
1	Water Company	1	Fixed Storage[2]
2	Water Company, Bottled Water	2	Mobile Storage[3]
3	Water Company, Alternative Source[1]	3	Fixed Storage[2] and Mobile Storage[3]
4	Water Company, Bottled Water, Alternative Source[1]	4	No Water Storage
INDEX	**TRANSFORMATION**	**INDEX**	**DEMAND**
1	Disinfection	1	Rigid Demand
2	Filtration	2	Flexible Demand I
3	Filtration, Disinfection	3	Flexible Demand II
4	No transformation		-
INDEX	**EFFLUENT**		
1	Septic Tank		-
2	Sewage System		-
3	Septic Tank, Water Reuse		-
4	Sewage System, Water Reuse		-

Note: [1]Rainwater harvesting, well, drinking water truck, non-drinking water truck; [2]Water tank, cistern; [3]Buckets, barrels, bottles.

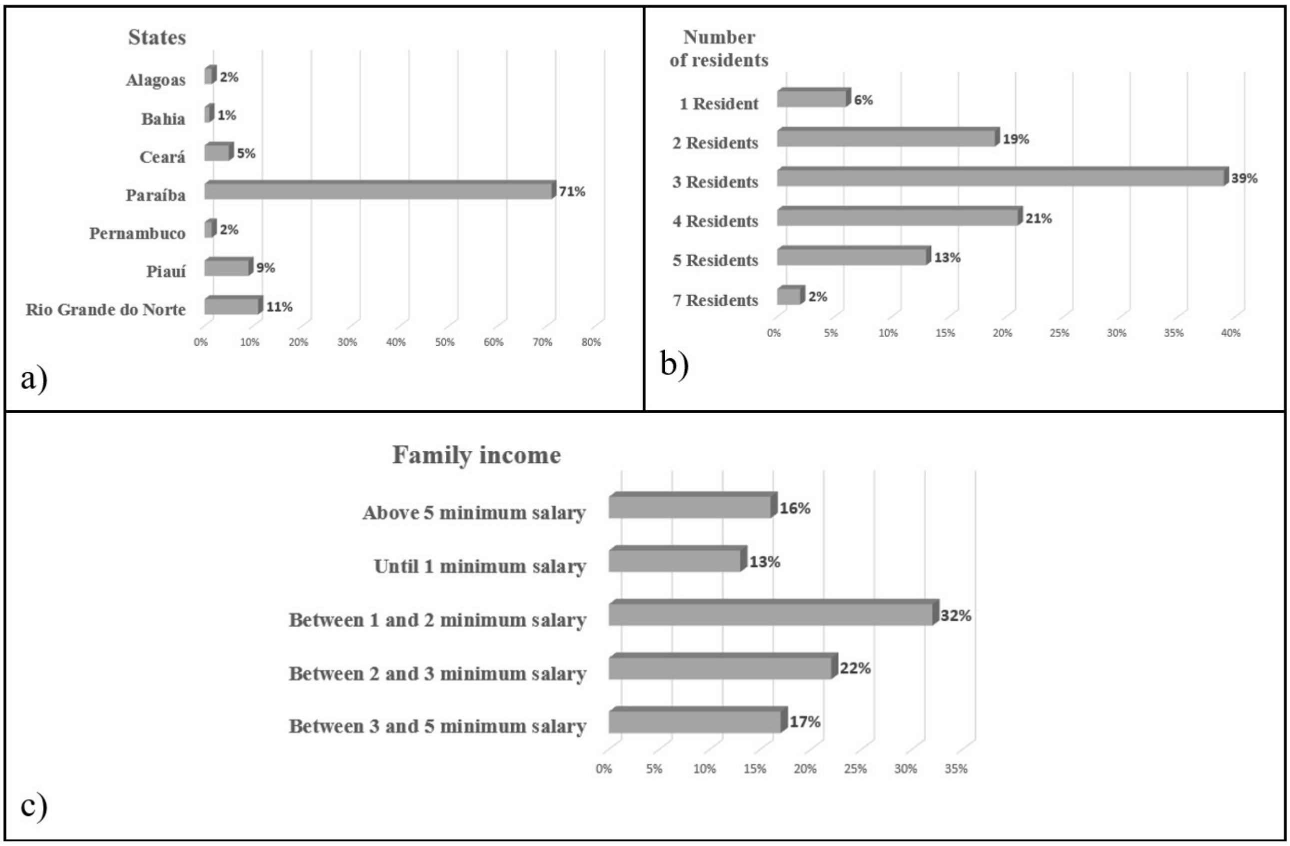

Figure 3. Socioeconomic and demographic characteristics of the surveyed households. (a) Distribution of households by state; (b) Number of residents per household; (c) Monthly family income.

study. Figure 3 shows the percentages of 123 cases according to locality, number of residents, and income. Identifying the number of residents is vital for understanding water demands (Veiga et al., 2022) and recognizing that households require different amounts even with the same uses. Family income is a factor that influences water consumption (Veiga et al., 2022), as well as information on efficient water usage and water saving (Balado-Naves et al., 2025).

Categorization of domestic water demand

The case studies' results on prioritization of meeting demands within the hierarchy, progressing from lower to higher-level demand, are presented in Figure 4. Once the demand of a lower level is met, the pursuit of the subsequent demand becomes the determining factor for user behavior. Economic

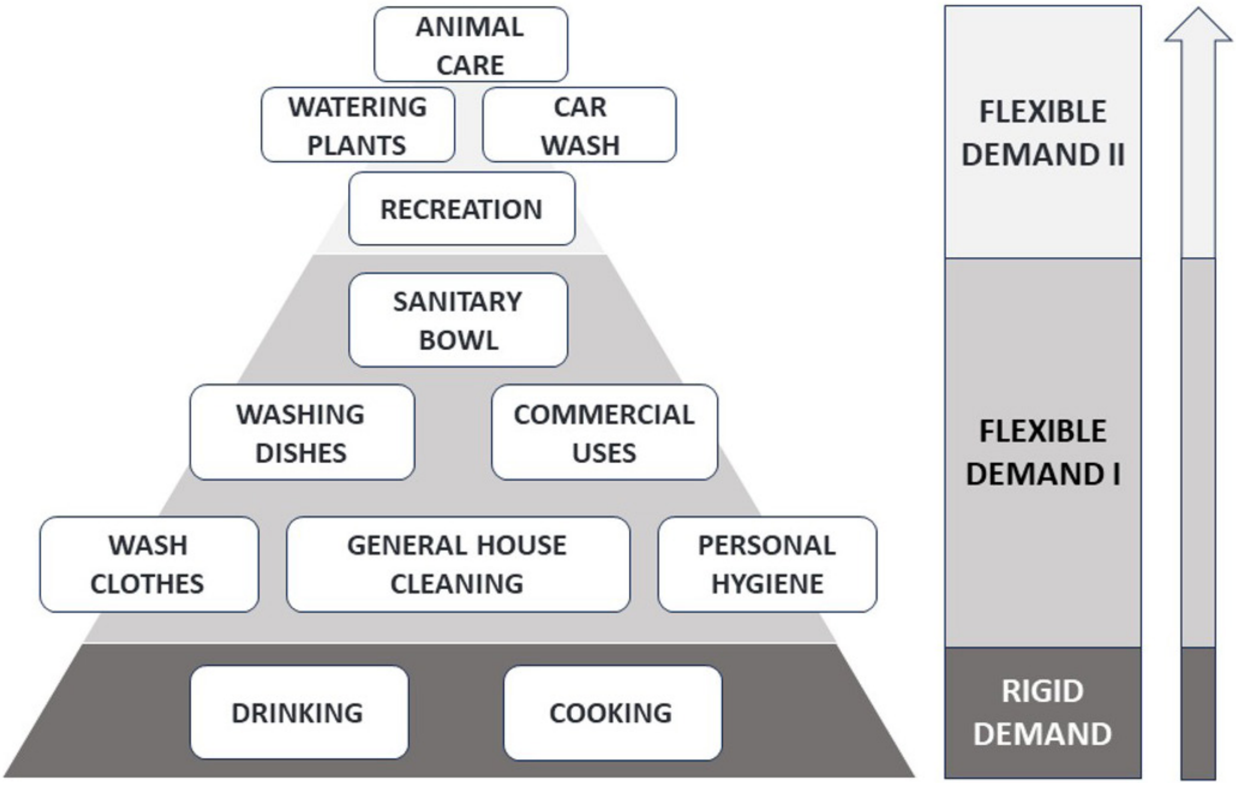

Figure 4. Hierarchy of domestic water demands in the cases studied, based on the categorization by Pan et al. (2018).

development and the quality of facilities are reflected in the different levels of categories and quantities of domestic water used.

In a study of the factors influencing urban water consumption patterns in 1,746 municipalities in Brazil, Veiga et al. (2022) identified that urban water consumption is influenced by family income, water tariffs, number of residents per household, temperature, percentage of households with washing machines, city population, gender, percentage of households with piped water, and the municipality's GDP.

Similarly, Xue et al. (2020) established a public participation model for water conservation, based on Maslow's theory of five levels of human demand. In their model, economic benefits, environmental improvement, and self-actualizing satisfaction from participation serve as driving forces. Crouch et al. (2021) analyzed individuals' absolute basic consumption and developed a theoretical model composed of 21 items that randomly describe individual water-use activities, considering the lifestyle level in Maslow's physiological demand hierarchy. This model was used in the formulation of strict water restriction policies.

Analyzing end uses of water in 39 large cities in developed and developing countries, Ismail et al. (2024) identified trends and critical factors in domestic water consumption. They highlighted six main trends in domestic consumption patterns, with the main water-related activities being: cooking, bathing, washing machines, faucets, and toilet use. They also categorized the factors shaping consumption patterns into five main groups: socioeconomic characteristics, physical, spatial, climatic conditions, and political restrictions.

Rigid demand

Rigid demand must be met under all circumstances relating to the primary water needs for the user's survival. This study categorized water for drinking and cooking in this group. According to the World Health Organization (WHO), a consumption of 100 liters per person per day is adequate for drinking, food preparation, and hygiene. Lower quantities compromise the quality and regularity of personal and household hygiene, increasing risks to human health (Howard et al., 2020).

In the process of managing demands, consumption at this level must be fully satisfied without being influenced by economic considerations, and it should be prioritized in terms of water resource allocation (Pan et al., 2018; Veiga et al., 2022), as already established by the Brazilian National Water Resources Policy (Brasil, 1997). Consequently, the provision of this demand cannot be compromised, and restriction measures cannot be applied to this group, as minimum quantities must be met. However, excessive use and waste can be controlled, thereby increasing water use efficiency.

Flexible Demand I

After meeting the rigid demand, users seek to fulfill Flexible Demand I, which includes personal hygiene, toilet flushing, house cleaning, dishwashing, laundry, and commercial uses. This level of water demand tends to gradually increase as living conditions improve (Pan et al., 2018; Xue et al., 2020). This demand ensures the users' quality of life, enabling the development of daily activities. At this level, there may be some flexibility in meeting the demands, allowing for reductions in consumption of some uses during water scarcity situations. Another characteristic is that toilet flushing and house cleaning do not need to be performed with potable water; they can be done with reused water, thereby increasing the availability of potable water and reducing wastewater generation. In the cases studied, users rely on water from the utility company to meet these needs, which aligns with the State's management. Below is one of the responses obtained from the questionnaire.

> *The water collected during showers is used for flushing toilets and cleaning the house.* (Case 71).

Flexible Demand II

This demand exhibits more flexibility for alteration or, in extreme situations, may not be met. In the cases identified, we found 47 cases (38.2%) involving animal care, 48 cases (39.0%) for vehicle washing, 61 cases (49.6%) for garden watering, and 4 cases (3.3%) for leisure activities, such as pool use. Within the hierarchy, this demand is the last to be addressed and, in situations of scarcity, the first to be reduced. Below is one of the responses obtained from the questionnaire.

> *Water company - used for bathing, washing the house, washing clothes and dishes* (general cleaning), *filling the swimming pool* (only done with a direct connection to the water company, does not use water from the tank so as not to compromise daily uses). (Case 23).

Similar to Flexible Demand I, some uses do not need to be performed with potable water at this level. For instance, vehicle washing and plant watering can be done with reused water, providing an appropriate destination for wastewater and increasing the amount of water available for other purposes. Below is another response obtained from the questionnaire.

> *Water from the kitchen sink and service area was used to water fruit plants.* (Case 67).

As residents improve their standard of living, they should reduce water consumption associated with this level during dry periods, as these demands are considered as of low necessity (Pan et al., 2018; Ismail et al., 2024). Public policies must plan how to meet this demand, especially in situations of scarcity (e.g., Belmeziti et al., 2025).

Hierarchization of demand and urban water management

Primary data show that, in some cases, drinking water is supplied through bottled water, while cooking water comes from the water utility. Below is one of the responses obtained from the questionnaire.

> *Water company for domestic use and mineral water for drinking and preparing some food.* (Case 9).

Thus, the water utility and the bottled water trade manage the supply of water, while users manage demand by purchasing bottled water and paying for the services of the water utility. Therefore, regarding urban water management, the State partially influences this demand by providing water through the utility.

In their study, Inman & Jeffrey (2006) showed that demand management strategies can reduce residential water consumption by 10 to 20%. By studying alternatives for managing water demand in a city in the Brazilian semi-arid region, Guedes et al. (2014) estimated a reduction of up to 33.64% in consumption based on adopting efficient plumbing fixtures. Regarding wastewater, a significant amount of wastewater generated from domestic use can be recycled at the source (Makki et al., 2015). Residential wastewater, excluding that from toilets, has a low organic load and a high potential for reuse as graywater, constituting an economical method of water conservation (Shaikh et al., 2019).

As family income levels increase, the use of household devices that consume water also rises, while the influence of water prices on reducing consumption becomes less effective (Yuan et al., 2014). Water consumption habits are associated with resource availability, which influences levels of awareness regarding water conservation. In regions with water scarcity, users tend to be more aware of water conservation (Otaki et al., 2017b).

The results of the water demand hierarchy generated in this study can support the development of instruments and analyses related to demand management. From this hierarchy, it is possible to identify other water sources that can be used to increase resource availability and ensure that demands are met, in addition to possibilities for water reuse. Understanding these demands from the needs perspective is essential for managers to have a reference for decision-making. An essential tool for planning urban water supply system operations is demand forecasting. However, the limitation of consumption data and users' responses to extreme supply restriction situations, when they will have to prioritize demand uses, reduce the accuracy of these forecasts, as reported by Brito et al. (2023), who studied a municipality in the Brazilian semi-arid region.

The results can also contribute to selecting urban water demand management alternatives by analyzing conflicts over water uses (Ribeiro & Vieira, 2005), where user behavior in prioritizing uses and their demands is an essential input for the analysis (Fan et al., 2014). Therefore, a detailed understanding of domestic water demands, in addition to contributing to the proper allocation of resources and increasing their efficiency in use, also provides data to resolve conflicts of interest in water usage (Belmeziti et al., 2025).

Metabolic structure of domestic water

The metabolic structure of domestic water, illustrating circulation through its five processes, is presented in Figure 5. For each of the 123 cases, the circulation was mapped, i.e., the pathways of water between entry and exit from the household, with a predominance of the groups highlighted in blue in Figure 5.

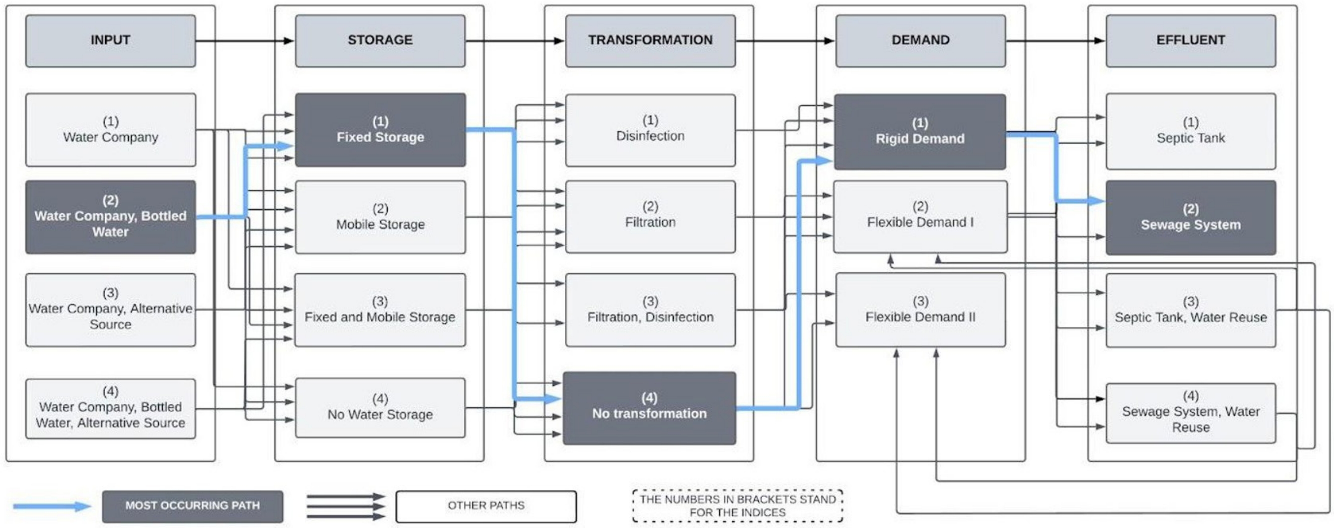

Figure 5. Metabolic structure of domestic water.

Between entry and storage, 12 possible pathways were observed, with a predominance between entry type 2 and storage type 1, where 38 cases passed through this pathway. These occurrences may be associated with greater security, such as using bottled water for drinking and fixed storage to ensure more significant volume reserves. The second most frequent pathway is between entry type 4 and storage type 1, with 21 cases. In entry type 4, there are alternative sources that, unlike the utility company, do not control how this water is collected and used. The survey of the types of entries enables the identification of alternative sources for the utility company, which can be incorporated as complementary sources to the conventional supply system, decentralizing it. These aspects are essential for urban water management, especially in situations of low resource availability (Kumar et al., 2021).

The cases are grouped into 32 pathways for the transformation process, with the highest occurrence in the direction of transformation type 4. This corresponds to the situation where no transformation occurs, with 32 cases along this pathway. This situation can be explained by using bottled water for consumption and utility company water for other uses. Typically, transformation methods are applied to the water that is consumed, and it is understood that bottled water has the necessary quality and does not require any transformation.

The demand process type 1, which corresponds to rigid demand, has the highest occurrence because it is the demand that cannot be altered and needs to be met by everyone. The demands in all cases are for drinking, personal hygiene, cooking, and general household cleaning. The main differences regarding these demands are the source of water used for specific purposes and the occurrence of Flexible Demand II, such as watering plants, cleaning animals, and cleaning vehicles (cars, motorcycles, or bicycles), which does not occur in all cases.

In the final process, 58 pathways are formed, with most cases being of type 2, corresponding to the sewage collection system. This higher occurrence can be explained by the fact that most cases occur in medium-sized cities, which have a more established basic sanitation infrastructure and higher public investments, unlike small cities that typically have simpler infrastructure (Khan et al., 2023).

In 17 cases, water reuse occurred, demonstrating recirculation processes in the metabolism. The primary occurrence is the reuse of water for non-potable purposes. The effluent from the washing machine is used for general house cleaning, and the shower water is used for flushing the toilet. These types of effluent reuse may have initially been adopted in situations of water scarcity or high intermittency, and even in more favorable situations, the reuse procedures continued. Another occurrence is the diversion of kitchen sink effluent for watering fruit plants, which may be a practice brought by residents from rural areas.

These forms of reuse can also be explained by the impact on the costs of the water supply service; users may engage in reuse intending to reduce such costs. Water reuse, in addition to being an alternative that reduces the impact of pollution from improper disposal, increases the availability of water within the household, ensuring greater security in terms of quantity for the user (Chen et al., 2013). Recognizing these practices is an essential indicator for managers, both regarding identifying alternative sources and allocating according to their needs, thereby increasing the efficiency of use, as specific uses do not need to be carried out with potable water (Veiga et al., 2022).

In the semi-arid region of Brazil, water reuse is a common practice in rural areas and serves as an alternative to increase water availability. In many urban areas, particularly in small cities, this practice persists as a cultural heritage from rural life, and is driven by the intermittency of water supply systems and the need to expand household water availability (Grande et al., 2016). In Brazil, the absence of specific legislation to regulate water reuse makes its control difficult. Although this practice helps increase water availability, improper implementation can expose users to contaminants, posing a health risk.

The high frequency of occurrence of alternative sources in households with access to the conventional water supply system, coupled with several storage devices, and the need of transformation processes, such as filtration and disinfection, reveals the severe impact of the intermittent water supply on the households' infrastructure and daily life routine (Grande et al., 2016). The provision of such appropriate infrastructure at the household scale is conditioned to income level, a determinant factor leading to injustice in the access and availability of water, also documented by other studies (Grande et al., 2014; Price et al., 2019; Diniz et al., 2021; Mutono et al., 2022; Khan et al., 2023; Romero-Gomez et al., 2024; Belmeziti et al., 2025).

CONCLUSIONS

This study has an exploratory nature and contributes to understanding how the use of data on domestic water consumption, at the household level, can support water demand management in urban areas. The approach allowed for an analysis of water consumption patterns in residences, demonstrating how different levels of needs influence the use and perception of water in urban contexts.

The categorization of demands, based on Maslow's hierarchy, enabled the identification of priority water consumption that meets the basic needs of users. Thus, managers should also prioritize addressing these demands, regardless of economic factors. Higher-order needs, such as the pursuit of comfort, tend to increase water consumption, highlighting the importance of awareness and water efficiency policies targeted at different population segments. Using the social metabolism concept facilitated the mapping of water pathways within the household. This perspective allows for a more comprehensive understanding of water use and its implications, considering physical and technical aspects and social factors that directly influence demand management.

The results indicate that urban water management must consider the differences in demands and water uses at the household scale. The detailed analysis of uses presented in this work also serves as input for a more realistic demand forecast. As utilized in this study, the integration of household consumption data with robust theoretical approaches provides opportunities for developing public policies that are more attuned to local realities, contributing to water sustainability in urban environments.

Although this study followed the highest methodological rigor, it is important to recognize that some limitations may have influenced its results. Among these limitations, we highlight the restrictions related to the number of cases and the sampling technique used, the bias in the questionnaire responses through self-reporting, and the understanding of the questions being asked. These factors may have impacted the breadth and depth of the conclusions presented. Although these limitations do not undermine the relevance of the findings, they should be considered for a more cautious interpretation of the results.

This work suggests that future research should deepen the relationship between user needs and water consumption patterns, employing methodologies that integrate the complexity of water demands about water resources. Implementing water demand management strategies that consider these factors may result in more efficient and sustainable water use in cities, aligning with environmental preservation and social justice objectives.

DATA AVAILABILITY STATEMENT

Research data is available in the body of the article.

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Authors contributions

Diego Souza de Oliveira: Contribution to the conception and design of the study, construction of the conceptual framework, data collection and analysis, and manuscript writing.

Carlos de Oliveira Galvão: Contribution to the conception and design of the study, critical review of intellectual content, manuscript writing, editing and final approval of the version to be published.

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SUPPLEMENTARY MATERIAL

Supplementary material accompanies this paper.

Table S1. Answers obtained in the questionnaires applied.

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