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RESEARCH ARTICLE

Making scarcity "enough": The hidden household costs of adapting to water scarcity in Mexico City

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Data Availability Statement: This study primarily draws on a multidisciplinary research project that conducted in-depth, ethnographic research with participants who did not consent to share their potentially identifying data publicly. Because the field notes and transcripts contain detail that constitutes potentially identifying information, the full transcripts and field notes used for the qualitative analysis in this study are not available for public access. De-identified excerpts from the transcripts and field notes are included in the manuscript. Access to the restricted-used data is possible, subject to IRB approved research plans.

Abstract

In the face of water scarcity due to climate change and population growth, cities around the world, especially in the Global South, increasingly provide intermittent, rather than continuous, water supply. Because an intermittent water supply has negative effects on infrastructure and water quality, literature often recommends transition to continuous supply, but that transition may be unfeasible or cost-prohibitive for many cities. There are few policy recommendations for ensuring safe and equitable urban water access *within* water-scarce systems. By understanding how households bear the monetary and non-monetary costs of intermittency, we can make urban water safer, more sustainable, and more equitable. This study combines results from open-ended household interviews and ethnographic observations about water management (n = 59 households) with a large-N survey (n = 2,595 individuals) to understand how households experienced water scarcity in Mexico City. We found most residents reported satisfaction with the quantity of intermittent water supply but incurred monetary and non-monetary costs to achieve that satisfaction. We document the ways households *adapted to scarcity*, transforming the intermittent supply they received from the grid by storing, reusing, and conserving water. These adaptations "made scarcity enough," allowing families to store and preserve sufficient water to meet their needs for water *quantity*. However, these same adaptations simultaneously burdened households with financial costs, such as expenditures for storage, pumps, and alternative water sources, and non-monetary costs, such as time-intensive labor spent managing water and noticeable deterioration in drinking water *quality*. Because the scarce public water supply is distributed unequally throughout the city, the financial, labor, and water quality impacts of adapting to scarcity were borne privately, primarily by marginalized households. Our findings about intermittency have implications for water justice and equity. We conclude with policy solutions that address the deterioration of water quality during household storage and the inequalities of intermittency.

Requests and inquiries about data access for NESTSMX data can be directed to the Mexican Exposures Data Access Committee at the University of Michigan (email: mexposdata@umich.edu). The Citizen Public Services Survey results, as well as all replication code, will be made available on the Harvard Dataverse in early 2023 at the following address: https://dataverse.harvard.edu/.

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1 Introduction

Access to reliable, clean water supply at home is fundamental to achieving Sustainable Development Goal (SDG) 6 of ensuring "availability and sustainable management of water and sanitation for all," [1]—a right that is fundamental to health, well-being, and gender equity [2–5]. Although the global population with access to an improved water source has increased since 2000 [6], inequalities in water access persist. Facing the strains of water source depletion and population growth, many urban water utilities manage water scarcity by providing an intermittent water supply (IWS). An IWS system distributes water a few hours a day or a few days a week to subsectors of the population, either by intentionally rationing some areas of the water grid or by failing to maintain uniform pressure throughout the grid.

Current estimates suggest that about one-billion people throughout the world live with an intermittent water supply, with a disproportionate share in the Global South [7]. As many as one third of Asian and more than half of African urban water systems provide water intermittently [8], and more than two thirds of the population of Latin America receives IWS [9]. Intermittent supply damages the water grid infrastructure and is associated with deterioration in water quality both within the grid and within households [10–17]. Additionally, research into the health consequences of intermittency shows associations between IWS and diarrheal disease [7, 18]. Thus, intermittent water supply threatens SDG 6 by restricting access to water that is available when needed and free from contamination.

As climate change exacerbates water scarcity and as urban populations grow, the share of the global population living with an intermittent water supply is likely to increase [7]. To face these challenges in the coming decades, many cities will respond with increased reliance, either planned or unplanned, on intermittent water supply. Even cities historically able to provide reliable, clean, continuous water may shift to IWS. Most existing literature recommends that cities move toward continuous systems of water supply [19]. However, amidst increasing scarcity, transitioning to continuous supply may be unrealistic or prohibitively costly. There is very little research documenting how households bear the cost of and adapt to IWS. Consequently, policy advice for how to ensure safe and equitable urban water access *within* intermittent or water-scarce systems is lacking. By understanding how households cope with an intermittent water supply, we can learn how to make urban water more accessible, safe, and sustainable considering the realities of scarce water supply.

This study offers an innovative approach to understanding the impact of IWS. We combine results from open-ended household interviews, ethnographic observations about household water infrastructure and water management, and a large-N survey analysis from Mexico City for a more complete picture of how working-class households experience urban water intermittency. Mexico City, where urban water demand regularly surpasses supply, can offer insights into the likely future for many water-scarce urban water systems and provide insights on how to improve water justice in the face of scarcity.

Our findings suggest concrete areas of focus for cities hoping to provide safe, equitable, and sustainable water amidst increased urban water scarcity. In the discussion, we consider how our findings might be applied to understand urban water scarcity in other locales. We conclude with policy proposals to address the inequalities that intermittency perpetuates and to mitigate the deterioration of water quality during household storage. In doing so, we aim to provide policymakers with a more comprehensive picture of how they might provide equitable, reliable, and clean water in a context of scarcity.

2 Materials and methods

2.1 Study area: "Governing beyond capacity" in Mexico City

Our study focuses on Mexico City, home to 9.2 million residents. As in many cities in the Global South, water provision in Mexico City suffers from aging infrastructure, underfunding and privatization, inadequate supply to meet demand, and vulnerability to both droughts and flooding due to seasonal rains [20–23]. Supply has outpaced demand, leading Mexico City's water authority, Sistemas de Aguas de la Ciudad de México (SACMEX) to "govern beyond capacity," a process which Chahim (2022) describes as "maintaining control over a potentially disastrous situation that. . .should logically be uncontrollable" [21].

Mexico City is in an endorheic valley, which means that without human intervention, its water supply is self-contained and does not draw from external sources like rivers. This valley's water supply has come under strain as the city's official population grew from 3.1 million habitants in 1950 to 9.2 million in 2020 [24]. The city sources its water from local aquifers and wells and the Lerma and Cutzamala aquifers which are piped into the city from over 100 kilometers away [22, 25, 26]. When initially harnessed, these aquifers increased the city's water supply to 19 m3/s [22], but today, the flow is far less due to its diffusion across the expanded urban population. Since at least 2004, the city has instituted formal and informal water rationing to cope with growing water demand [27]. SACMEX determines initial quantities of "bulk water" to distribute to the city's sixteen boroughs, who then allocate that water across communities. Rationing is especially common in the working-class neighborhoods in the south and east peripheries of the city. These neighborhoods' distance from the aquifers and their lack of political power mean that they are often the last to receive water and receive water less frequently than neighborhoods in the city center [20, 21].

Many cities in the Global South are similarly dependent on seasonal rainfall and increasingly strained due to expanding population. Thus, Mexico City offers a useful window for understanding how urban residents cope with the negative effects of increased scarcity. Our study combines two primary data sources: qualitative evidence and descriptive survey measures from Neighborhood Environments as Socio-techno-bio Systems (NESTSMX), a series of ethnographic, mixed methods household visits (n = 59), and population-representative quantitative data from the Citizen Public Services Survey (CPSS, n = 2,495). We describe these two approaches below.

2.2 NESTSMX: A mixed methods approach to understanding household water management

2.2.1 NESTSMX sample and design. To understand how households experience, respond, and adapt to urban water scarcity, we analyzed qualitative and descriptive survey data from a mixed methods project titled "Neighborhood Environments as Socio-Techno-bio Systems: Water Quality, Public Trust, and Health in Mexico City" (NESTSMX). NESTSMX recruited 59 households from "Early Life Exposures in Mexico to Environmental Toxins" (ELEMENT), an ongoing 25-year birth cohort study that recruited mother-child pairs from public maternity clinics between 1994 and 2005 [28–30]. ELEMENT households are predominantly working class because mothers were recruited from public clinics. NESTSMX sample selection was multi-level and purposive. The project first identified 150 families who had participated in recent ELEMENT data collections. From these, the NESTSMX team purposively selected 80 households for recruitment, choosing based on maximal variation in neighborhood water availability, access to public sanitation, and socioeconomic status. 59 of 80 households agreed to participate in NESTSMX data collection (73.8% response rate), from 38 distinct neighborhoods.

NESTSMX data collection involved three in-person household visits in 2019 and one follow-up phone interview and survey (which we refer to as "Visit 4") in 2021. A team ranging from 2–5 interviewers conducted the visits in Spanish. The interview team included men and women from the United States and Mexico City trained in anthropology, sociology, political science, biology, public health, and environmental engineering. The focal interviewee was the ELEMENT mother (the adult female household member), but during the in-person visits we invited all household members who were present to participate in the conversation. Visits 1–3 were unstructured and ranged from two to five hours long. Covid-19 interrupted the Visit 2 and Visit 3 data collection for many households, prompting the addition of Visit 4 as a follow-up phone interview and survey. Visit 4 was semi-structured and ranged from 15 minutes to 1 hour. 59 households completed Visit 1, 24 households completed Visit 2, 7 households completed Visit 3, and 55 households completed Visit 4.

2.2.2 NESTSMX data. Each visit generated ethnographic and qualitative data about household water supply and management, water quality data, and biological samples from the study participants. Visit 4 generated survey data in addition to qualitative data. This analysis relies exclusively on the ethnographic and qualitative data from Visits 1–4 and the survey data from Visit 4, which we detail more below.

The ethnographic data collection for Visits 1–3 was guided by a list of topics for each visit, with time to discuss other topics as they emerged in conversation. Visit 1 focused on the water supply and infrastructure in the household, water management tasks and roles of the family, history of water supply in the household, beverage and food consumption related to water availability, water-related costs, and water-related stress. Participants also guided the interviewer on a tour of the household water infrastructure and assisted the interviewers in drawing household water maps. These tours generated rich conversations about the household's experiences and adaptations to the public water supply that may not have surfaced if we had relied on a pre-determined set of questions. Visit 2 focused on health related to water availability and changes in water supply, use, or management between Visits 1 and 2. Visit 3 focused on stress related to water, trust in the reliability and quality of the water supply, and changes in water supply, use, or management between Visits 1, 2, and 3. For all four visits, within one day of completing the visit, each interviewer independently wrote field notes to document their observations and reflections and a professional Spanish-language transcriber transcribed the audio recordings.

The Visit 4 data collection used a semi-structured interview guide that generated closed-ended survey data and open-ended qualitative data. The Visit 4 survey measures used in this analysis documented the continuity and sufficiency of the respondents' water supply. We measured whether the respondent had "intermittent," "continuous," or "other" water supply with the question, "In a normal week, does water arrive to your house from the public supply continuously or intermittently? For example, continuous is 24 hours 7 days a week." "Other" included households that did not receive piped water from the public grid. We measured sufficiency in two ways. First, we asked participants whether, in the past month, they had enough water to meet their basic needs, or if they had run out of water. Second, we measured sufficiency of water supply with a series of "anchoring vignettes" [31] that asked participants to consider three hypothetical water supply scenarios and their own water supply and evaluate whether each scenario was "not at all," "not very," "almost," or "totally sufficient" to meet their daily needs. The hypothetical scenarios included water arrival one day a week, from 6 am–12 pm; three days a week, with water all day; and five days a week, with water all day.

The qualitative data for Visit 4 focused on changes in water supply, use, or management between Visits 1–3 and Visit 4, water trust, economic impacts of water, participants' evaluations of the sufficiency and quality of their water supply, water management practices, the impact of water on everyday routines, and impacts of Covid-19 on household well-being and water supply. We used these narrative responses to contextualize and add nuance to our understanding of the survey measures.

This analysis relies on the Visits 1–3 ethnographic materials including audio recordings and transcripts, field notes, photographs, and maps of the household water infrastructure, as well as Visit 4 audio recordings and transcripts, field notes, and survey data.

2.2.3 NESTSMX analyses. We used iterative, qualitative coding in Atlas.ti Version 9 to organize and analyze the ethnographic and qualitative materials. The full NESTSMX team identified priority research questions. Two analysts, who were also interviewers, and a supervisor generated an initial code list derived from the project research questions. The analysts coded all Visit 1–3 field notes using the initial high-level code list. When the Visit 4 data collection was complete, the authors revisited the initial code list and added codes from themes that emerged from the data in Visits 1–3, and codes to capture the new information collected in Visit 4. We also identified more focused codes related to our interests for this analysis. The same analysts coded all field notes from Visit 4 with the revised code list. Additionally, they returned to the Visit 1–3 field notes to code using the focused codes that were added in Visit 4. This two-step iterative coding process, which started with semi-open coding and progressed to more focused coding, organized the ethnographic material into themes searchable by household, visit, and field note author.

For the analysis phase, a supervising team member drafted analysis prompts organized around the research questions and relevant codes for this manuscript. Relevant codes included "living with scarcity," "household water management," "water allocation," "experiences/fears of water scarcity," "participants' evaluations of water sufficiency," "ideal water situation," and "water quality." The analysts who coded the materials generated reports of each relevant code and read all the quotations in that code. They drafted reports synthesizing their findings and describing emerging patterns related to our research questions, citing specific examples from the field notes. For field note quotations that were particularly illustrative, we searched the transcript for the corresponding original conversation. In the results, we present both our aggregate synthesized findings and exemplary quotes sourced from the transcripts. S1 Table lists the codes we used for this analysis, with the code names and definitions in English and Spanish.

We supplemented our primary qualitative analysis with descriptive statistics from the Visit 4 survey data to present participants' reports about the continuity of their water supply and evaluations of the sufficiency of their water supply comparably across NESTSMX households. We tabulated the respondents' reports about the continuity of their water supply and the sufficiency of their supply to meet their daily needs in the last month. We created two bar graphs using R Version 4.1.1 to plot the responses to the items where participants evaluated whether the supply is sufficient for their daily needs. The first bar graph displayed their evaluation for three hypothetical water supply scenarios and the second showed their evaluation of their own water supply.

2.3 Citizen public services survey: Situating ethnographic findings in a larger sample

Throughout the paper, we situate our ethnographic findings with results from a large-N survey titled the Citizen Public Services Survey (CPSS), directed by Huberts. CPSS data offer insights into the prevalence of practices we observed in the small ethnographic sample among a larger, more representative sample. Because household-level, representative data on water supply was not available, this survey aimed to collect information about the distribution of citizens' water, their household storage capacity, and their perceptions of quality.

2.3.1 CPSS sample and design. This survey involved an in-person sample (1,258 individuals) from the five eastern boroughs of Mexico City (Gustavo A. Madero, Venustiano Carranza, Iztacalco, Iztapalapa, and Tláhuac). We chose these boroughs because, by SACMEX measures, they receive less water than the rest of the city. We randomly selected 209 neighborhoods, stratified to ensure balance across political affiliation and features which might shape residents' propensity to make water-related claims (traffic density, presence of public housing, and distance from mayors' office). Within each of these neighborhoods, we randomly selected a city block using Microsoft excel, and from this city block selected 6 households using random-walk sampling. To expand the sample, the in-person sample was pooled with an online convenience sample recruited via Facebook from the same five boroughs, for a total of 2,495 observations. Both the in-person and online survey data were collected via Qualtrics. The in-person data was collected on tablets, while the online survey was completed by individual respondents on their personal cell phones and computers.

2.3.2 CPSS data. From the Citizen Public Services Survey, we focused on four measures: intermittent or continuous water supply, types of water storage, storage capacity, and any water interruption in the last three years. For the intermittent or continuous water supply variable, we first calculated a measure of hours of water supply per week. We combined participants' responses about how many days of water a week they received water from the public supply during a typical week in March, April, and May, with responses about how many hours of water they received from the public supply during a typical day in which they had water during those months. We multiplied days of water a week by hours a day to calculate hours of water per week. This measure should represent the lower bound of residents' annual water supply, as these months constitute *estiaje*, or the dry season. We defined residents as having continuous water if their responses to these questions reported receiving water from the public supply 7 days a week, 24 hours a day (168 hours a week), and intermittent otherwise. We constructed types of water storage from the item that asked residents how they store water. Respondents could identify one, multiple, or none of the following options: tinacos (rooftop storage tanks), cisterns, and buckets or water drums. We coded storage capacity from participants' report of how many days (or weeks or months) they could last with the water they currently had stored. This approach was based on earlier ethnography that confirmed most residents had sufficient knowledge of their infrastructure and water use to accurately estimate how long their stored water would last them. Finally, we created a binary measure of water interruption from participants' responses about whether they had a water outage in the last three years.

2.3.3 CPSS analyses. We conducted descriptive analysis on the CPSS survey data, which we present as frequency calculations and plots. We conducted these analyses in R Version 4.1.1, using the tidyverse suite of packages. In order to address concerns about bias and representation from the stratified sampling design and the convenience online sample, we weighted our results using data from the 2010 Mexican census and the rake_survey() command in the pew.methods package in R. Our *design* weights reweighted such that each neighborhood was equally likely to be represented in the in-person data, and such that each demographic group reflected its proportion of Facebook users in the online data. We then further applied *post-stratification* weights, which reweighted the data based on demographics to match the populations of age, city borough, gender, and education level in the 2010 Mexican Census. This approach sought to address bias in the "online" nature of the expanded sample.

2.4 Ethics statement

NESTSMX fieldwork was approved by the University of Michigan Health Sciences and Behavior Sciences Institutional Review Board (HUM0015594) and the Research Ethics Committee of the Mexico National Institute of Public Health (CI1508). The focal interviewee, the adult female of the household, provided written, informed consent. The Citizen Public Services Survey was determined to be exempt from human subjects review by the Harvard University Institutional Review Board (21–0462). For the in-person survey, interviewers obtained verbal consent from survey participants, documented in Qualtrics on the survey tablets and phones. For the online survey, respondents provided written consent. Additional information regarding the ethical and scientific considerations specific to inclusivity in global research is included in S1 Text.

3 Results

How do residents experience and cope with water scarcity? Drawing on both ethnographic and survey data, we observed that, amidst a *collective experience* of water scarcity, residents made costly (in monetary and indirect ways) adaptations to their homes and their lifestyles to make the unreliable public supply meet their water needs. In wealthier households with large storage capacity and automatic pumps, residents bore the cost economically, so that their household infrastructure mimicked a continuous supply. In households unable to make these more costly investments, residents bore non-monetary costs, integrating water management practices into their daily routines to ensure there was enough water, and that the water they consumed was safe to drink. In both cases, coping with an intermittent public supply had implications for residents' trust in their water quality. The ethnographic data demonstrated that residents were reluctant to consume tap water after storage.

3.1 The collective experience of water scarcity

The residents in our study experienced scarcity *directly*, through regular intermittency or irregular outages, as well as *indirectly*, through what they heard on the news and from family members living in other parts of the city.

The most extreme form of water scarcity we encountered was experienced by households who were not connected to the public grid. In Visits 1–3, two NESTSMX households were not connected to the public grid. One of these families (household 808) relied solely on water deliveries from *pipas*, or 10,000-liter tanker trucks that deliver water to fill neighborhood or household storage containers. The other off-grid household (267) received water from their neighbor's public supply until they became connected to the grid themselves between Visit 2 and Visit 4.

Among the households who did receive piped water from the public supply, less than continuous water supply was common. For example, some households received water in the mornings, every other day, or in the evenings, depending on their allotted schedule. Other households received water less than once per week. In the Visit 4 survey, 15 of the 59 households in our sample reported their public supply arrived intermittently, one was off grid, and four were missing because they did not participate in Visit 4.

Because intermittent systems are more leak-prone and more likely to have problems allocating adequate pressure across the grid, even households that reported continuous supply experienced other forms of water scarcity or unreliability. Many households observed decreases in the *pressure* with which the water arrived. Residents attributed the pressure change to increases in the city's growth. As one participant told us:

> "The flow has decreased. . .before they finished those buildings, the water pressure could get all the way to my rooftop tank. The construction has changed that"
>
> (household 280).

Another shared:

> "Just look around here. . .[Before] it was just single-family homes, now. . .there are *a lot* of apartments. So all of this has meant that the water is running out, becoming more scarce, because if you think that before the same water was for 20 people, and now it's for 100, it's logical that now it's not going to come in the same way that it did before"
>
> (household 514).

Residents also experienced the city's water scarcity through the near-endless cycle of leaks, repairs, and maintenance that left them without water semi-regularly. Residents were often left to infer the reasons that their taps had run dry:

> Participant: "It's sporadic, I'd say that in a month, there are two times that we don't have water. . .for example there have been repairs after earthquakes and they've had to cut the supply for days, we've been three days without water. . ."
>
> Interviewer: "And for example now there is no water and there wasn't water at all this morning?"
>
> Participant: "Right, since yesterday we haven't had water"
>
> (household 499).

Local authorities "don't tell us" when or why their water will be cut off, one interviewee said, "but we realize because there's a really obvious water leak and we are left totally without water" (household 246).

Data from the Citizen Public Services Survey suggested a similar, but more extreme picture, given that the survey was conducted in the five eastern boroughs, where the water distribution is the most irregular. 73% of surveyed households in those five boroughs reported receiving water intermittently, with an average of 87 hours a week, or roughly 12 hours a day, and 61% of surveyed households reported having experienced an outage of their water supply in the last three years.

Even when they themselves did not experience water scarcity, residents described Mexico City as short on water. News on the radio, television, and social media, together with the accounts of people they knew, shaped residents' experiences of water availability in the city. "There are these news stories where they go directly to the houses and they check the tap," one woman told us, "and they are completely without water: Xochimilco, Iztapalapa, all those places," she said, referring to two of the city's poorest boroughs, both of which suffer from water scarcity. "No, there are plenty, plenty of zones that I see are affected where people. . .literally don't have even a drop of water!" (household 647).

These types of news stories served as an important touchstone for residents:

> "I even heard it on the news that there was no water. . .You hear things like they are taking the water from Xochimilco and sending it to some other place, and they come and empty their reservoirs to send it to Iztapalapa"
>
> (household 290).

They also learned about water from collective action. One participant described how in places without water, the neighbors protested, blockading Avenida Iztapalapa, one of the city's central arteries (household 2140). Another deduced that Xochimilco must not have had enough water because "they have had to protest so that they give those neighborhoods more water" (household 290).

For residents living in this water-scarce city, both personal experience of water scarcity and the knowledge that neighbors were suffering from water insecurity generated a collective experience of scarcity, knowledge that poorer areas suffered more scarcity than others, and a sense that scarcity could become more common throughout the city.

3.2 Households made their own adaptations to water scarcity

In Mexico City, residents did not take for granted their ability to turn on the tap in their home and expect clean, safe drinking water without modification—or even water at all. Instead, they proactively managed their water between the street and the sink to make their water supply meet their needs and to prepare for the risk of outages, shortages, and potentially unsafe drinking water. This management involved purchasing water delivery from pipas (water tanker-trucks), storing water, and reusing water whenever possible.

Purchasing water delivery from private pipas to supplement municipal water supply was a common practice. The off-grid household described above occasionally received pipas free of cost from the municipality. A single pipa delivery of 10,000 liters of water usually lasted the family between one and two months. Between our first visit to this household in February of 2019 and our second visit in May 2019, the family did not receive any government pipa. Because the subsidized pipas arrived so infrequently, they had to purchase private pipas, at the cost of about 950 pesos ($49.4 2019 USD) regularly. Some households who were connected to the grid but received intermittent water very infrequently also purchased private pipas to supplement their water supply.

To avoid running out of water for their daily needs, almost all households—whether they were off-grid or received intermittent or continuous public supply—stored water. The most common form of water storage were *tinacos* (rooftop tanks; see S1 Fig for a photograph of tinacos). In addition, many families had also built underground cisterns for storing water. Although municipalities occasionally supplied government-subsidized tinacos to residents, the expense of building cisterns or purchasing tinacos most often fell to individual households. Additionally, many households stored water in large buckets and barrels, either as a substitute or a complement to their tinacos and cisterns. The households with less frequent water supply tended to have larger storage capacities.

Fig 1 presents an example of the kinds of complex storage infrastructure that residents invested in. In this home (household 514), which received intermittent supply, three rooftop tinacos together stored about 3,300 liters of water, which served as the main water source for day-to-day use. When the tinacos were empty, a family member would turn on the manual pump to move water from the underground cistern up to the tinacos. The home also had a direct line (depicted in black) that ran straight from the street to the kitchen sink, without going through the storage infrastructure. This tap only worked on Fridays, Saturdays, or Sundays, when the family received water from the public supply. The household members used this line for drinking because it was not contaminated by storage infrastructure. They also used the tap to know when the public supply was flowing so they could turn on the additional faucet to fill their cistern. Additionally, the family also stored water in barrels and buckets.

We found that most households' storage infrastructure was similarly complex. Most of the families we interviewed managed their water through a system of pipes and vessels that they often designed and installed themselves. Consequently, most households had detailed knowledge about how to manage their water supply. In some households, this storage process was near-automatic; either water arrived from the grid with sufficient pressure to reach the rooftop

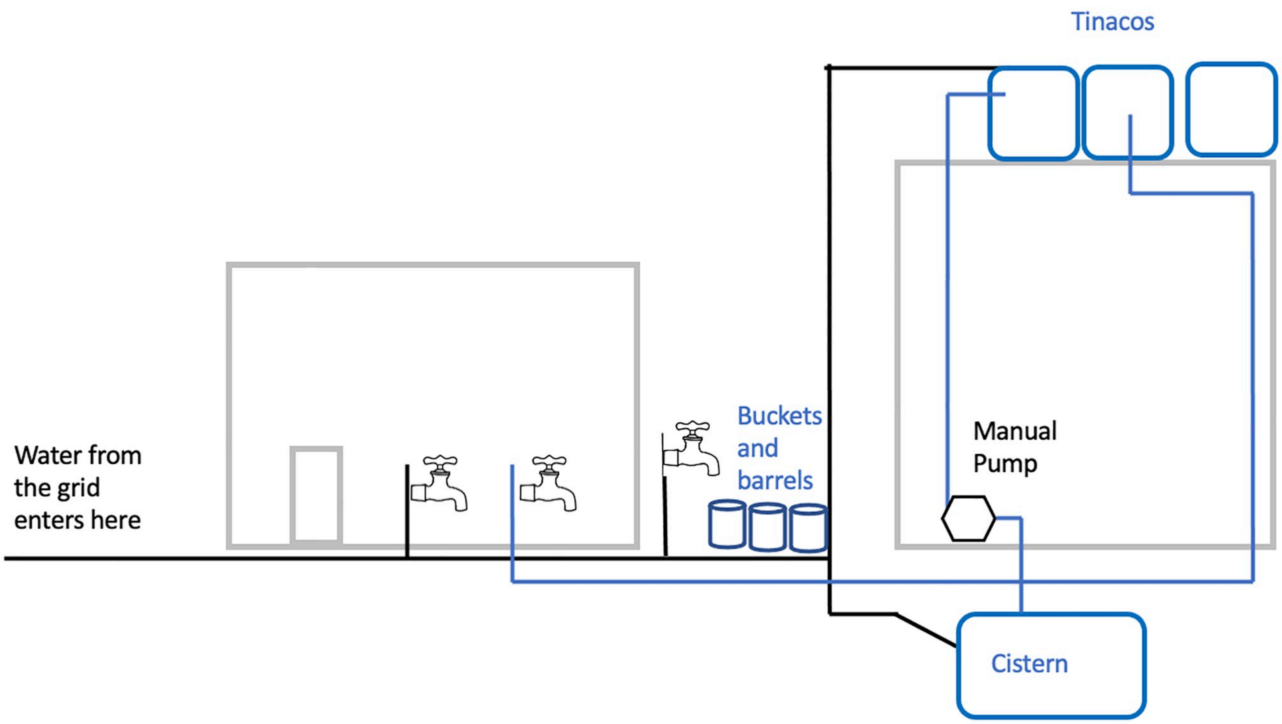

Fig 1. An example of the complex household storage infrastructure which residents commonly construct themselves. NESTSMX household 514.

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tanks, or the family had invested in an automatic pump, which sensed the water and channeled it to the storage infrastructure. But in others, the process entailed costly time and attention. In these cases, an adult woman was usually responsible for managing the household's water supply.

One participant explained that throughout the day she would listen for the sound of water from the filling pipes to cue her to fill the cistern. She had developed a comprehensive knowledge of how much storage was required to provide enough water for her family:

> "I have to go up [on the roof] to look what level it [the water] is at. . .I know, for example that this tinaco will last me for three days, four days if I don't do laundry"
>
> (household 823).

The collective experience of water scarcity has made water storage a near-universal norm in Mexico City: "[In the past] we suffered from lack of water for many days, a long time, so it forced us to see the necessity of water and to store it, among other things, because we see that in the future it's possible that this could happen again" one woman observed. Thinking, she added, "Also it became a habit for us" (household 434). Once they made investment in storage, the practice of storing water was integrated into the family's routine, and often the home's physical infrastructure.

Data from the Citizen Public Services Survey confirmed the essential role that storage played. 95% of respondents reported using some form of water storage. While families only sometimes knew the storage capacity of their household infrastructure in liters, nearly all of them could tell us how long their stored water would last their households. Fig 2 shows most

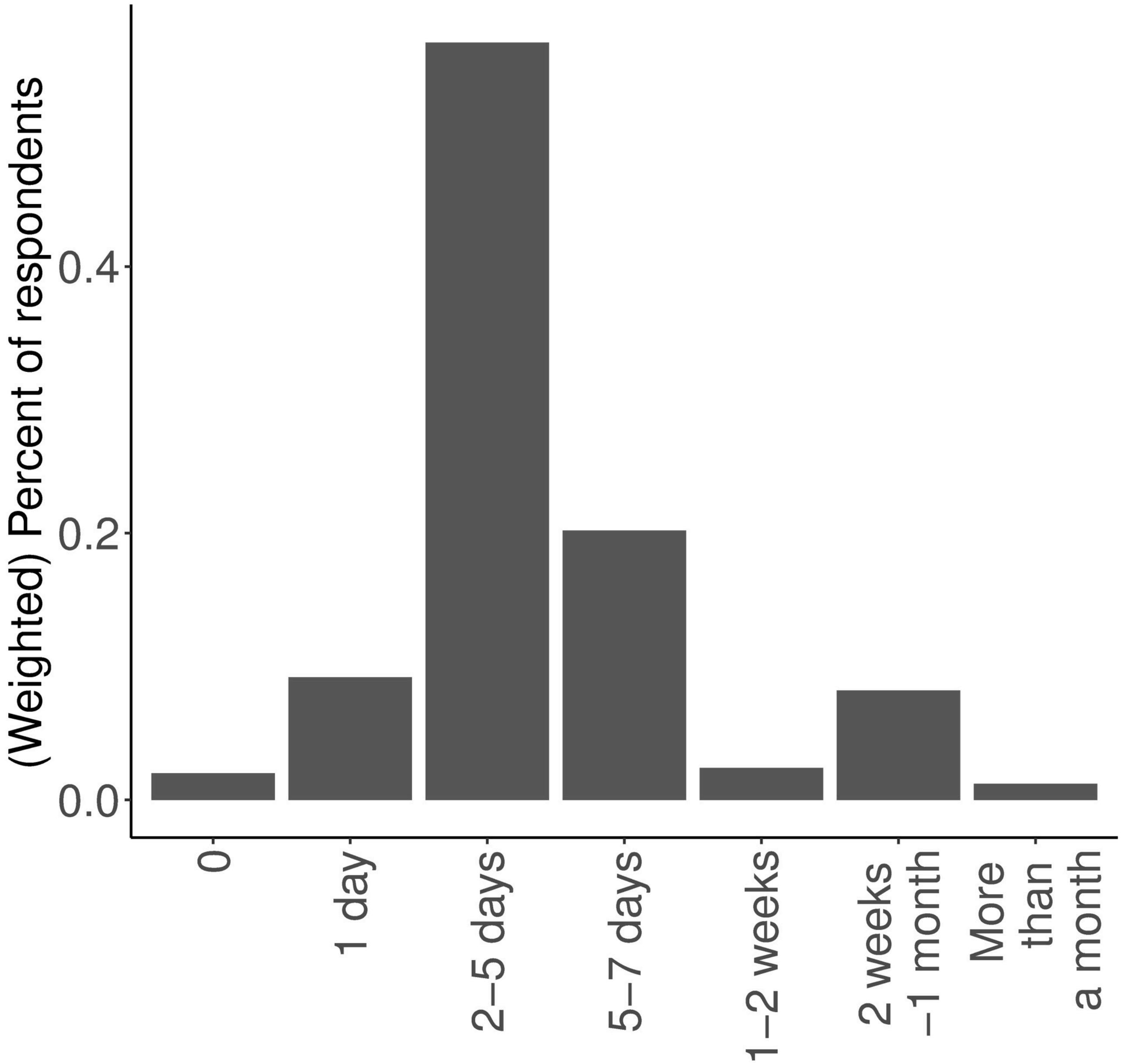

Fig 2. CPSS residents' storage capacity in length of time. Weighted percentages from CPSS (n = 2,495).

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residents reported they had water storage capacity to last them 2–5 days. Residents used household storage infrastructure to compensate for intermittent or unreliable water.

In addition to storing water, families were careful to conserve and reuse the water their household did have. One woman explained all the steps her family took to ensure they had enough water:

> "We fill buckets, in the bathroom we don't use the tap, we fill the water with a bucket, the whole week we don't do the laundry, when it rains my mother puts buckets out for the rain"
>
> (household 514).

Another observed:

> "I try to save it. . .With the water that I use to rinse clothes when I'm doing laundry, I do another load of dirty laundry. . .or if not, I save it for the bathroom and to wash the patio, and I wash my dog on the patio"
>
> (household 434).

The families we interviewed classified which water could be used for which purposes. One woman commented:

> "For example, the water that comes out of the washing machine, I use to wash the hallways and the patio, when we can't use the shower we bathe with a bucket. Whatever's left we put to use in the toilet. . .When we disinfect our vegetables, with that water we water the plants. . .we use only a bucket of water to wash the bicycles and the motorcycles, nothing else."

When asked why she reused water, she explained,

> "Well because the truth is that the water is scarce, that is to say here we suffer sometimes. . .it has created conflicts between neighbors, and even within the family. . .and we aren't the only ones, no, the truth is that many people are in situations similar to ours and so we have to be conscientious of saving water, what we can"
>
> (household 290).

Managing a household's water also required the time and flexibility to fill cisterns, turn on pumps, and boil water. Many mothers told us they were strategic about when they did laundry, only washing their clothes when they had a steady supply from the grid. One woman reported:

> "I only get water at night and it's inconvenient because I don't like having to stay up late at night to set aside water"
>
> (household 434).

Intermittency forced families to use their water strategically, based on the priority of tasks:

> "If there is water in the morning then the members of the household who have to go out [to work or to school] bathe, and the others we have to wait until the cistern fills again. . .If it's the weekend and we had planned to go out, I don't know, to do the shopping, and the water comes, then the shopping waits because we have to take advantage [of the water] to wash"
>
> (household 290).

Although most families stored water and engaged in quotidian management of their water supply, those with the least frequent water supply tended to be better equipped to adapt to scarcity. Infrequent water supply households generally had large storage capacities, some had automatic pumps to move water from the cistern to the rooftop tank, and many had robust practices of water rationing and reuse. Those that usually had more continuous water supply were less prepared to adapt to unexpected interruptions in their supply:

"About 15 days ago we were left without water for a few days. Here that's extremely rare. . .We were some days without water and my son had to go shower at his girlfriend's house so that he could go to work. We couldn't do the laundry and the dishes stayed dirty in the sink"

(household 522).

By investing money, labor, and time into storing, conserving, and reusing water, residents intervened to make the intermittent or unreliable supply of water they received from the city meet their needs, and the cost of these adaptations varied in relationship to the severity of water scarcity.

3.3 Resident adaptations made for "enough" water

The adaptations that residents pursued to make their water meet their needs led to a somewhat surprising result: most interviewees expressed satisfaction with their water supply. In the ethnographic visits, we found that most respondents, including those who received intermittent water, reported they were satisfied with their water quantity:

"I don't complain, I have a cistern and so it's good. Well, I've gotten used to checking if I need to fill it and I don't run out, in fact I've never run out because of the cistern. I think that I would complain if I didn't have a cistern"

(household 267).

Many citizens approached their water supply pragmatically: especially given the overall level of water scarcity in the city, they saw their water supply (after adaptation) as sufficient. Almost none of the residents we interviewed would change anything about the frequency or predictability with which their water arrived.

During Visit 4, 50 out of 55 respondents reported they had enough water to meet their basic needs in the past month. The anchoring vignettes, where respondents evaluated the sufficiency of three hypothetical water scenarios and their own, also displayed overall satisfaction with less than continuous water supply. Fig 3 shows the distribution of responses to the hypothetical water scenarios. Fig 4 shows the distribution of respondents' evaluation of how sufficient their own water supply was to meet their daily needs. Most respondents were satisfied with their own water supply (Fig 4) and did not assume 24-hour continuous supply was necessary for water to be sufficient for daily needs (Fig 3).

Almost half of respondents stated that receiving water three days a week was almost or totally sufficient, and 36 responded that five days a week was "totally sufficient." The household depicted in Fig 1 received water one to three days a week, for less than six hours a day. When asked what they would change about their water supply, they expressed that water everyday was "Nothing more than an illusion" (household 514). They hoped for water three to four days a week and more storage capacity.

Many participants reported that if they could change something about their water, they would improve its quality: color, smell, composition, and potability. One household, when asked how sufficient their water supply was to meet their daily needs responded, "In terms of the supply [quantity], totally sufficient, in terms of quality, not at all sufficient," and when asked what their ideal water situation would be they responded, ". . .that we would have the same supply, but with better quality" (household 477).

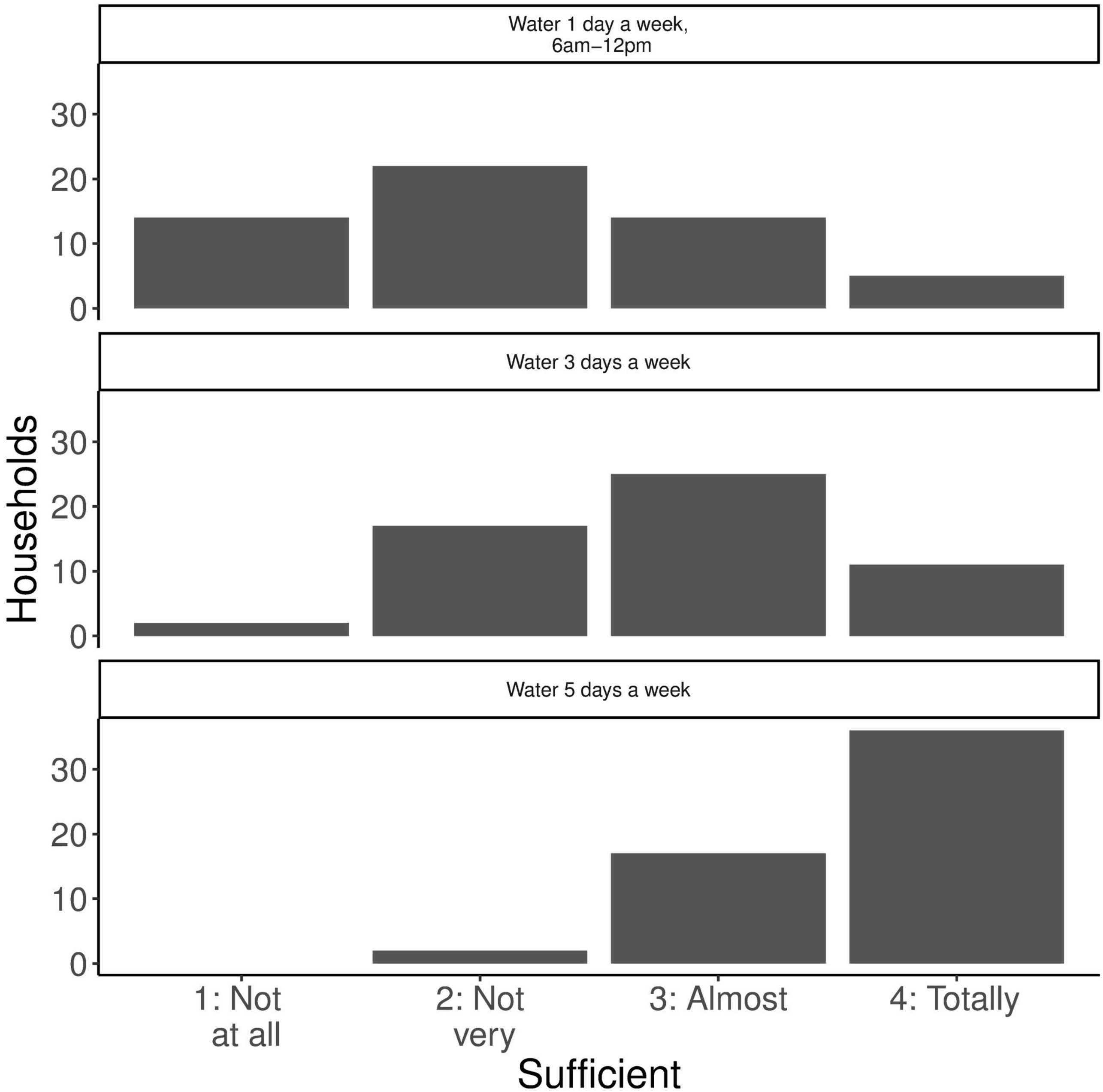

Fig 3. Evaluation of the sufficiency of hypothetical intermittent water supply scenarios for daily needs. Tabulation of households from NESTSMX Visit 4 (n = 55).

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3.4 Adapting to water scarcity negatively impacted residents' trust in water quality

Most of the families we interviewed did not drink the water from the public supply, especially after it had been stored within the household, often because they inferred contamination from how the water looked, tasted, and smelled.

Many participants reported they did not drink the water because it was cloudy, yellow or brown, had sediment in it, or smelled. One woman, living in Iztapalapa, described her water as

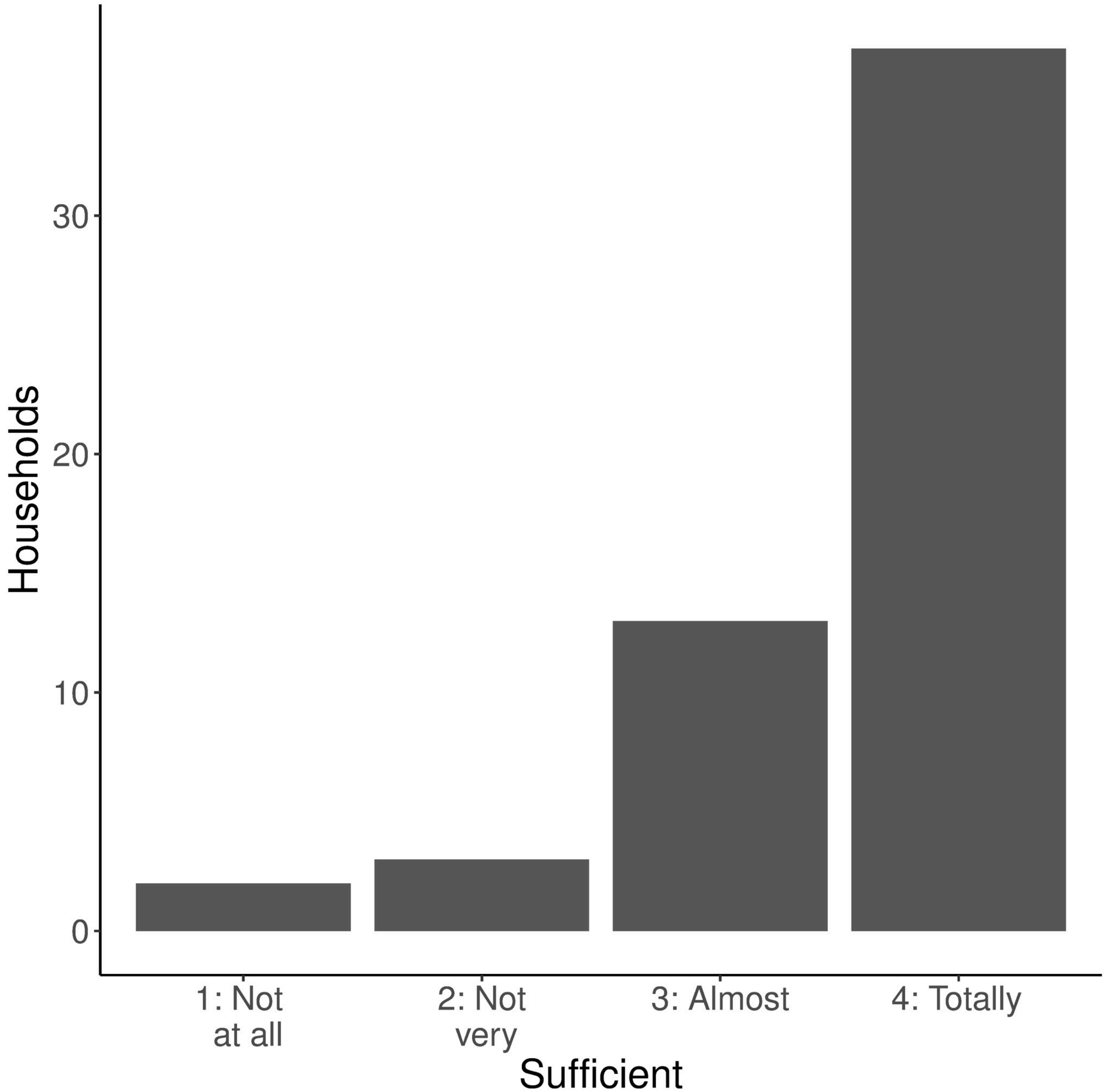

Fig 4. Evaluation of the sufficiency of their own water supply for daily needs. Tabulation of households from NESTSMX Visit 4 (n = 55).

https://doi.org/10.1371/journal.pwat.0000056.g004

"dirty. . .It's brown all the time, and then also it sits [stagnant], and ends up looking kind of muddy" (household 2140). Another said that "the water, for example right now during the dry season, it smells like sulfur" (household 655). One respondent reported that she does not reuse water, because "it is so dirty when it arrives that I use it once and only for what's necessary" (household 477).

In some cases, household members explained that the water from the public supply arrived to their homes clean and without smell, but the need to store water made it dirty. The family whose domestic water infrastructure is described above in Fig 1 felt comfortable drinking the water from their tap that came straight from the street, but not water that had sat in their storage infrastructure (household 514). Another woman had a similar observation about the effects of storage:

> "I think that tinacos and the cistern contaminate the water, because you're supposed to be washing them in some form and the truth is that I don't wash them, I've never washed them"
>
> (household 267).

As a consequence of their distaste for stored water and the public supply, most residents either boiled, filtered, or treated their tap water or they purchased bottled alternatives, including water or soda and other sugar sweetened beverages. Asked how the water from the public supply tastes, one woman said, "Hmm well, you know I've never drank it, except through filters because generally we boil the water whenever it's for drinking" (household 120). "We boil the water," another interviewee said, "I used to cook with it directly from the tap and the rice and soup tasted terrible" (household 290).

Similarly, in the Citizen Public Services Survey, only 17% of households reported drinking the tap water, and even then, most of those households treated it. By boiling, treating, or buying their drinking water, and using the rest of the public supply for non-drinking purposes, residents again intervened between the street and the sink to make the public supply meet their needs.

When residents chose not to drink water from the public supply, the decision did not come without cost. The majority of residents purchased *garrafones*, 20-liter jugs of drinking water, which they reported buying either name-brand from local convenience stores for about 40 pesos ($2.08 2019 USD), or from local water purifiers for about 15–30 pesos (about $0.78 or $1.56 in 2019 USD). Again, residents used their own private resources to make up for the inadequacies of the public grid.

4 Discussion

Our study offers new insights about how households bear the costs of increased urban water scarcity, and with what consequences.

Our findings suggest that residents paid "coping costs"—both monetary and non-monetary—for water insecurity. The financial costs included the costs of purchasing household storage infrastructure like *tinacos* and cisterns, *pipas* to supplement supply, water treatment methods, and alternative drinking water sources, such as *garrafones*. The non-monetary costs included changes to household residents' schedule and habits, the administrative and mental labor of managing household water supply and pumps, and the deterioration of trust in the quality of tap water. Predictably, investment in storage and time varied in relation to the severity of scarcity a household experienced.

These findings about the adaptations to intermittency are consistent with other research showing households, especially women, deploy coping practices to manage limited water supply [32]. We extend this research by documenting residents' satisfaction with their water supply after undertaking these adaptations. We found that residents' investments of private resources and time to make a limited public supply "enough" were successful—meaning participants reported relatively high satisfaction with the *quantity* of water they received. This has two important implications.

First, it raises questions about how researchers measure water insecurity. Surveys that report participant evaluations of water security risk obscuring the private resources and labor involved in making limited water supplies enough. Although most households reported satisfaction with their water quantity, the time and labor spent securing that satisfaction varied greatly. Water security scales should be coupled with measures of water supply relevant to the study area to capture inequities in public water supply that households mitigate with their own actions, money, and time.

Second, our finding of overall satisfaction with less than continuous water supply is encouraging for cities' ability to adapt to increasing water shortages. Adapting to less than continuous water supply could decrease water consumption and waste, which is increasingly necessary as more cities face water shortages. However, our findings about the relationship between intermittent supply and deteriorations in the trust of water quality highlight that acceptability of intermittent water supply cannot be discussed without also considering the potential consequences of intermittent supply on water quality, health, and inequality.

We found that most residents, in both NESTSMX and CPSS, distrusted the tap water for drinking. The widespread hesitancy towards drinking tap water in Mexico City may be related to histories of public health campaigns that discouraged drinking tap water in favor of treating or purchasing bottled water after the 1985 earthquake and the 1990s cholera epidemic [23, 33]. In addition, however, we found the need to store water negatively impacted residents trust in and ability to drink the water from the public supply. This evidence is consistent with findings from water quality analyses. The NESTSMX water quality samples (reported elsewhere), documented deterioration in chlorine levels between the point of supply and the point of consumption [17], and findings from other studies where household water storage is common documented both decreased chlorine levels and increased coliform levels between supply and consumption [5]. Participants' distrust in their water quality after storage and management reflects measurable deteriorations in their water quality. Given that in the 2020 census 64.4% of households in Mexico reported owning a tinaco and 27.5% reported owning a cistern [34], water safety must be considered at the point of consumption, not only at the point of arrival to the household.

These findings underscore the necessity of investigating the health implications of an intermittent water supply. In other settings, an intermittent water supply was associated with increased risk of diarrheal disease [7, 18]. Deteriorating water quality and distrust in the public supply for drinking must also be explored in relation to chronic health conditions. If residents distrust the water from the public supply and rely on treated or purchased drinking water, they may be less likely to drink water and rely more on bottled, sugar-sweetened beverages. Evidence for such an association has already been documented in the United States [35, 36]. In settings where soda is heavily subsidized and often less expensive than bottled water, such as Mexico, documenting the relationship between intermittent water supply, distrust of drinking water, and soda consumption is a high priority that could change our understanding of the risk factors associated with diabetes, cardiovascular disease, and obesity.

Our mixed methods approach, while innovative, also has limitations. First, NESTSMX sample design was purposive and not representative. This approach strengthened our ability to elucidate nuances in residents' experience of water scarcity but was not statistically representative of residents across Mexico City. Our ethnographic data was drawn from primarily working-class households, limiting our ability to identify how wealthier citizens experience and cope with water intermittency.

We mitigated the non-representativeness of NESTSMX households by situating our ethnographic findings in conversation with findings from the CPSS sample. This improved our ability to speak to the frequency of patterns we observed in NESTSMX among a larger population. The CPSS in-person survey used random sample selection, however, it still reflects a subset of the diverse geographies and situations within Mexico City itself, given its focus on the five eastern boroughs of the city. The in-person CPSS sample was pooled with an online convenience sample of residents to help represent a larger population, but the convenience sampling suffers from more response bias compared to the randomized sampling of the in-person survey. We applied design and post-stratification weights using 2010 Mexico census data to the CPSS descriptive statistics to address these concerns. Although the representativeness of both the ethnographic and survey data have limitations, by putting our NESTSMX findings in conversation with CPSS descriptive statistics, we were better able to interpret the general satisfaction with less than continuous water supply and elucidate the costs of securing satisfaction.

Second, the study was limited by the suspension of Visits 2 and 3 due to Covid-19. We mitigated the loss of data from Visits 2 and 3 by adding the Visit 4 phone interview and were successful in following up with 55 out of our 59 original households.

Finally, our focus on the water scarcity dynamics of Mexico City and our use of both open-ended interview questions and survey questions that are not standardized across settings limited our ability to compare how residents experience water scarcity in our study to other settings. However, the commitment to local specificity through open-ended ethnographic data collection in Visits 1–3 allowed us to define research questions and design a Visit 4 interview guide and survey that were relevant to the concerns and lived experiences of participants.

We propose that our study can offer insights into both the costs that increasing water scarcity might impose, and how residents will cope with them, but we do not intend to make universalizing claims. Methodologically, our findings point to the need for water scarcity research to include measures of supply and management practices together with self-reported feelings of water security. Substantively, our findings are likely most relevant for other contexts in which intermittency is already present; coping with water scarcity is likely significantly more costly, if not impossible, in settings where residents are unprepared to engage in these types of water management practices.

5 Conclusion

In this paper, we used a multidisciplinary data set to provide a comprehensive picture of how urban residents “made scarcity enough.” We documented the myriad ways household members ensured that, despite interruptions to supply, they had enough water for daily needs. Specifically, residents of working-class neighborhoods in Mexico City managed elaborate systems of household storage to buffer themselves from the effects of interruptions, leaks, outages, or low pressure. Because of these actions, most residents reported high levels of satisfaction with their water *quantity*. However, household storage and management made their water *quality* noticeably less safe to drink, compelling residents to boil, treat, or purchase water for consumption. In this context, people often drank soda instead of water.

The fact that *intermittency can be experienced as continuity* is good news for the world’s cities, as IWS will likely become the norm for many of the world’s urban water utilities. Our study, however, reveals that currently, households privately bear the costs of “making scarcity enough.” Residents—especially women—paid for reliable water access in money (to install storage systems and buy alternative water sources), time (to manage household water systems and treat or purchase water), uncertainty (changing their schedules to complete priority household tasks when they have water), and inability to drink the water from the public supply. Thus, the inequitable distribution of limited water supply, where poor and peripheral households receive water from the public supply less frequently, exacerbates inequalities. Households with less resources spend a disproportionate amount of labor and funds to make their water enough, further exacerbating the inequalities and disadvantages associated with an uneven water distribution.

Our findings suggest several ways governments might consider making those costs less onerous at the household level, and address some of the inequities in current patterns of water management. First, when governments research water supply, security, and health, they must consider the coping and storage methods by which households adapt to their water supply to understand inequities in water access and the potential health risks of "making scarcity enough." Because households adapt to the frequency of their water supply, if not accompanied by standardized measures of water supply, self-reported measures of water insecurity may mask significant variations in water access. Similarly, measures that report water quality at the point of supply might mask inequalities in health risks if certain households are forced to store water for more prolonged periods.

Second, policymakers could do more to provision households with enough water *beyond the physical grid*. Our findings suggest that although continuous public water supply at the grid-level may be unrealistic in settings of increasing water scarcity, continuous *access* could be achieved with adaptations at the household level. Specifically, governments might consider subsidizing households' efforts to make their intermittent water mimic the experience of continuous supply, by providing storage tanks, automatic pumps, or other household infrastructure.

Third, city governments might attempt to mitigate inequity in the distribution of water scarcity to avoid forcing poorer neighborhoods to bear the brunt of the multiple costs of scarcity and increase solidarity across neighborhoods. De Coss-Corzo (2022) shows how the socio-economic status and political power of Mexico City neighborhoods affect the distribution of water supply and of resources dedicated to fixing leaks, drops in pressure, and water outages. The processes of managing and displacing catastrophic water shortage create circumstances of "unequal survival" that shape futures of water access unequally across the city [20]. Under current circumstances, in marginalized neighborhoods where residents have privately invested in adapting to scarcity, the water authority has an incentive to direct even less water to them in the future. There is a risk that poor and peripheral communities will be understood as deserving and capable of bearing more and more of the burden of urban water scarcity because they are the ones that have adapted to scarce supply. We propose city authorities make investments to address this inequity, by distributing water rationing more evenly across neighborhoods.

Finally, our findings suggest that to ensure safe drinking water quality, governments should subsidize water treatment at the point of consumption. In intermittent water supply systems, where most households store their water before domestic use, government resources spent making water potable when it arrives to the household are undermined by the need for storage. To address this, local governments could consider encouraging the installation of direct pipes from the households' connection to the grid to the kitchen sink, supporting or subsidizing household filters, providing separate drinking water services as part of one's utility package, and investing in research and development focused explicitly on treating water at the point of consumption.

As water scarcity becomes increasingly common, a much larger share of the global population will be forced to reckon with the costs of urban water scarcity. Our findings suggest that, with a more comprehensive and creative approach to policy that recognizes existing inequities, cities can improve our chances of achieving sustainable development goal 6 by intervening between the street and the sink to make urban water available, safe, and sustainable for all.

Supporting information

S1 Table. Qualitative codes and definitions. S1 Table shows the qualitative codes used for this analysis, with the code names and definitions in English and Spanish. All codes were

originally named in English and were assigned to field notes and transcripts written in both English and Spanish. While reading ethnographic materials, analysts referenced the codebook that included Spanish translations of each code name and definition.
(DOCX)

S1 Fig. Tinacolandia. Photograph of rooftop water storage tanks (*tinacos*), taken by first author, Alyssa Huberts. Some residents refer to Mexico City as *tinacolandia*, referencing the ubiquity of these rooftop storage tanks.
(TIF)

S1 Text. Inclusivity in global research.
(DOCX)

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References

1. Resolution A. RES/70/1. Transforming our world: the 2030 agenda for sustainable development. Sect. Seventieth United Nations General Assembly, New York, 25 Sep 15, 2015 pp. 86–97. https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf
2. Mújica OJ, Haeberer M, Teague J, Santos-Burgoa C, Galvão LAC. Health inequalities by gradients of access to water and sanitation between countries in the Americas, 1990 and 2010. Rev Panam Salud Pública. 2015; 38: 347–354. PMID: 26837519
3. Günther I, Fink G. Water, Sanitation and Children's Health: Evidence from 172 DHS Surveys. Rochester, NY: Social Science Research Network; 2010 Apr. Report No.: ID 1593423. https://papers.ssrn.com/abstract=1593423
4. Psaki SR, Seidman JC, Miller M, Gottlieb M, Bhutta ZA, Ahmed T, et al. Measuring socioeconomic status in multicountry studies: results from the eight-country MAL-ED study. Popul Health Metr. 2014; 12: 8. https://doi.org/10.1186/1478-7954-12-8 PMID: 24656134
5. World Health Organization. Safely managed drinking water—thematic report on drinking water 2017. Geneva, Switzerland: World Health Organization; 2017. https://washdata.org/report/jmp-2017-tr-smdw
6. World Health Organization (WHO), United Nations Children's Fund (UNICEF). Progress on household drinking water, sanitation and hygiene 2000–2020: Five years into the SDGs. Geneva: WHO and UNICEF; 2021. https://www.who.int/publications-detail-redirect/9789240030848
7. Bivins AW, Sumner T, Kumpel E, Howard G, Cumming O, Ross I, et al. Estimating Infection Risks and the Global Burden of Diarrheal Disease Attributable to Intermittent Water Supply Using QMRA. Environ Sci Technol. 2017; 51: 7542–7551. https://doi.org/10.1021/acs.est.7b01014 PMID: 28582618
8. World Health Organization, UNICEF. Global water supply and sanitation assessment report 2000. 2000. https://www.who.int/publications/i/item/9241562021
9. Pan American Health Organization. Regional report on the evaluation 2000 in the Region of the Americas: water supply and sanitation current status and prospects. Washington, D.C.: Pan American Health Organization; 2001. https://iris.paho.org/handle/10665.2/46024
10. Shrestha S, Malla S, Aihara Y, Kondo N, Nishida K. Water quality at supply source and point of use in the Kathmandu Valley. J Water Environ Technol. 2013; 11: 331–340. https://doi.org/10.2965/jwet.2013.331
11. Kumpel E, Nelson KL. Mechanisms Affecting Water Quality in an Intermittent Piped Water Supply. Environ Sci Technol. 2014; 48: 2766–2775. https://doi.org/10.1021/es405054u PMID: 24459990
12. Kumpel E, Nelson KL. Comparing microbial water quality in an intermittent and continuous piped water supply. Water Res. 2013; 47: 5176–5188. https://doi.org/10.1016/j.watres.2013.05.058 PMID: 23866140
13. Klingel P. Technical causes and impacts of intermittent water distribution. Water Supply. 2012; 12: 504–512. https://doi.org/10.2166/ws.2012.023
14. Shakya BM, Nakamura T, Shrestha S, Pathak S, Nishida K, Malla R. Tap water quality degradation in an intermittent water supply area. Water Air Soil Pollut. 2022; 233: 81. https://doi.org/10.1007/s11270-021-05483-8
15. Vacs Renwick DA. The Effects of an Intermittent Piped Water Network and Storage Practices On Household Water Quality in Tamale, Ghana. Massachusetts Institute of Technology. 2013. http://web.mit.edu/watsan/Docs/Student%20Theses/Ghana/2013/Thesis_D_Vacs_Renwick_FINAL_5-31-13.pdf
16. Matshinhe NP, Juizo DL, Persson KM. The effects of intermittent supply and household storage in the quality of drinking water in Maputo. J Water Manag Res. 2014; 70: 51–60.
17. Martinez E, Roberts E FS, Kerkez B, Cole F. Sensing Intermittency and Inequality in Mexico City. Virtual presentation presented at: Water Ways: New Social Science, Science Studies and Environmental Approaches to Water; 2022 Feb 14; Institute for Social Research, University of Michigan. https://rcgd.isr.umich.edu/2021/11/09/branko-kerkez-and-elizabeth-roberts/
18. Adane M, Mengistie B, Medhin G, Kloos H, Mulat W. Piped water supply interruptions and acute diarrhea among under-five children in Addis Ababa slums, Ethiopia: A matched case-control study. PLOS ONE. 2017; 12: e0181516. https://doi.org/10.1371/journal.pone.0181516 PMID: 28723927
19. Simukonda K, Farmani R, Butler D. Intermittent water supply systems: causal factors, problems and solution options. Urban Water J. 2018; 15: 488–500. https://doi.org/10.1080/1573062X.2018.1483522

20. De Coss-Corzo A. Working with the end of water: Infrastructure, labour, and everyday futures of socio-environmental collapse in Mexico city. Environ Plan E Nat Space. 2022; 251484862211003. https://doi.org/10.1177/25148486221100391

21. Chahim D. Governing beyond capacity. Am Ethnol. 2022; 49: 20–34. https://doi.org/10.1111/amet.13052

22. Rosales García A. Economía Política del Servicio de Agua y Saneamiento en la Ciudad de México. El Colegio de México. 2015. https://repositorio.colmex.mx/downloads/3t945r17t?locale=es

23. Kloster K, de Alba F. El agua en la ciudad de México y el factor de fragmentación política. Perfiles Latinoam. 2007; 14: 137–159.

24. Instituto Nacional de Estadística y Geografía (INEGI)\. En la Ciudad de México somos 9,209,944 habitantes. Ciudad de México: INEGI; 2021. Report No.: 98/21.

25. SACMEX. Sistemas de Agua de la Ciudad de México. Cumbre de Fondos de Agua; 2019 Jul 18. https://www.fondosdeagua.org/content/dam/tnc/nature/en/documents/latin-america/aguas.pdf

26. Uitto J, Biswas A. Water supply and distribution in the metropolitan area of Mexico City. Water for Urban Areas. United Nations University Press; 2000. https://www.nzdl.org/cgi-bin/library?e=d-00000-00—off-0fnl2.2–00-0——0-10-0—0—0direct-10—4————0-1l–11-en-50—20-about—00-0-1-00-0–4——0-0-11-10-0utfZz-8-00&cl=CL1.5&d=HASH7ecfef951c65b8a6f0da56.8.5.2&gt=1

27. Órgano del Gobierno del Distrito Federal. Gaceta oficial del Distrito Federal. 2004. https://data.consejeria.cdmx.gob.mx/portal_old/uploads/gacetas/Julio04_7_64.pdf

28. Wu Y, Peterson KE, Sánchez BN, Dolinoy DC, Mercado-Garcia A, Téllez-Rojo MM, et al. Association of blood leukocyte DNA methylation at LINE-1 and growth-related candidate genes with pubertal onset and progression. Epigenetics. 2018; 13: 1222–1233. https://doi.org/10.1080/15592294.2018.1556198 PMID: 30582410

29. Lewis RC, Meeker JD, Peterson KE, Lee JM, Pace GG, Cantoral A, et al. Predictors of urinary bisphenol A and phthalate metabolite concentrations in Mexican children. Chemosphere. 2013; 93: 2390–2398. https://doi.org/10.1016/j.chemosphere.2013.08.038 PMID: 24041567

30. Liu Y, Téllez-Rojo MM, Sánchez BN, Zhang Z, Afeiche MC, Mercado-García A, et al. Early lead exposure and pubertal development in a Mexico City population. Environ Int. 2019; 125: 445–451. https://doi.org/10.1016/j.envint.2019.02.021 PMID: 30763831

31. King G, Wand J. Comparing Incomparable Survey Responses: Evaluating and Selecting Anchoring Vignettes. Polit Anal. 2017/01/04 ed. 2007; 15: 46–66. https://doi.org/10.1093/pan/mpl011

32. Castorena Davis L, Martínez Valencia AM, Castorena Davis L, Martínez Valencia AM. Género, institucionalismo y marginalidad: la gestión del agua de uso doméstico como desafío para el empoderamiento de las mujeres. El caso de la ciudad de La Paz, Baja California Sur, México. Soc Ambiente. 2018; 175–199.

33. Delgado Ramos GC. Apropiación de agua, medio ambiente y obesidad. Universidad Nacional Autónoma de México; 2014. https://agua.org.mx/wp-content/uploads/2015/01/Apropiacion_de_agua.pdf

34. Instituto Nacional de Estadística y Geografía (INEGI). Principales resultados del Censo de Población y Vivienda 2020. Estados Unidos Mexicanos. México; 2022. https://www.inegi.org.mx/app/biblioteca/ficha.html?upc=702825198060

35. Javidi A, Pierce G. U.S. Households' Perception of Drinking Water as Unsafe and its Consequences: Examining Alternative Choices to the Tap. Water Resour Res. 2018; 54: 6100–6113. https://doi.org/10.1029/2017WR022186

36. Onufrak SJ, Park S, Sharkey JR, Sherry B. The relationship of perceptions of tap water safety with intake of sugar-sweetened beverages and plain water among US adults. Public Health Nutr. 2014; 17: 179–185. https://doi.org/10.1017/S1368980012004600 PMID: 23098620