

Infrastructural Violence, Water Insecurity, and Gender in Northern Peru
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Introduction:

The relationship between water insecurity and poor health is well-documented within the literature (Rosinger & Brewis, 2020; Adams et al., 2020; Jepson et al., 2021; Young et al., 2021) with scholars increasingly using the the concept of *infrastructural violence* to elucidate how a lack of water infrastructure can produce social and embodied inequities (Kumar et al., 2021; Truelove & Ruszczyk; 2022; Alda-Vidal et al.; 2023; Chaplin and Kalita; 2017). *Infrastructural violence* refers to the uneven risks produced when physical systems such as buildings, wires, pipes, and roadways are unevenly designed, maintained, or accessed; creating disadvantages for specific populations (Rodgers and O'Neill, 2012). While applications of this concept in studies of water and health highlight “infrastructure’s ability to create and shape deep inequalities” (Kumar et al., 2021; pg. 2), understandings of how *social* (e.g. local water governance, social labor networks, education services, etc.) and *physical* (water pipes, water treatment, access to taps etc.) *infrastructures* shape the gendered harms of water insecurity are just beginning to emerge (Truelove and Ruszczyk, 2022).

Here, we build on this small body of work to propose that in contexts of deficient physical water infrastructure, women’s labor functions as a form of gendered *social infrastructure* that makes it possible for this key resource to reach individuals, homes, and societies. As stated by Joshia and Aldrich (2025), “Much like the chimera, a mythical beast composed of disparate animal parts, social infrastructure combines the seemingly incongruous concepts of *social*, signifying human interaction, and *infrastructure*, traditionally referring to physical systems that underpin mobility and economic activity” (pg. 284). Although the literature surrounding *social infrastructure* is growing (Latham and Layton, 2021; Joshia and Aldrich, 2025), it has yet to be explicitly theorized in tandem with physical infrastructure to understand the range of harms being experienced by women in settings characterized by resource scarcities and gendered inequities. This is despite the fact that, globally, the burden of obtaining water for the household primarily falls on the shoulders of women (Sorenson et al., 2011), a task that is made substantially more difficult without access to easily reachable water sources (Akurugu et al., 2021; Sultana, 2020; Meeks, 2017; Truelove, 2019).

In this paper, we expand conceptualizations of *infrastructural violence* (Rogers & O'Neill, 2012), by underscoring the interactions between *physical infrastructure* and *social infrastructure* in our research on water insecurity and women’s health in a rural, arid area of the northern coast of Peru. Specifically, we examine how social and material systems in this patriarchal and water scarce context coproduce a range of gendered biopsychosocial harms.

Background:

In their seminal special issue on the topic, Rogers & O'Neill (2012) articulate that *infrastructural violence* refers to the ways that the distribution, design, and governance of infrastructure produce harm. This can occur through both active forms – where infrastructures are explicitly designed to be violent (e.g. barbed wire fences separating different neighborhoods) — and in passive forms where infrastructural limitations or omissions marginalize certain populations (e.g. uneven transportation systems to particular areas) (Rogers & O'Neill; 2012). As argued by McIlwaine and Evans, the “state is often the primary perpetrator of passive infrastructural violence in its failure to provide adequate facilities” (pg. 398). For example, Rogers (2012) shows how extensive infrastructural changes in Managua, Nicaragua created ‘abject urbanism’ (an internalized feeling of being “thrown aside”) in poor neighbourhoods excluded from the wider transformation of the city. However, there are also cases where control over infrastructure is intentionally used to subordinate certain groups. Examples include slum demolitions or militias acting on behalf of the government to restrict access to basic services to particular groups, especially women (Sawas et al. 2020).

While these examples and others importantly show how physical systems shape access to resources and influence everyday lives, the *infrastructural violence* literature typically emphasizes material deficiencies and governance, often treating social infrastructures and processes as contextual. Indeed, in their work on *slow infrastructural violence* in South Asia, Truelove & Ruszczyk (2022) argue that the nuances of infrastructure have been little conceptualized with gender. To address this gap, they utilized deep longitudinal and ethnographic work to reveal how women’s bodies and gendered labor form critical invisible infrastructures bridging fragmented water systems in Nepal and India. Other scholars have taken note, highlighting that the inadequacy of water infrastructures disproportionately burdens women due to a reliance on their labor (Kumar et al., 2021; Alda-Vidal et al., 2023, Chaplin & Kalita 2017). These studies demonstrate that these social dynamics are not peripheral, but rather central to the reproduction of inequalities associated with *infrastructural violence*.

Yet the concept of *social infrastructure* has yet to be positioned as variable equally important as *physical infrastructure* in understanding the compounded harms wrought by *infrastructural violence*. Scholars in the past have defined *social infrastructure* as a network of services that are accessed through tangible places such as community centers, schools, and public spaces (Small & van der Meulen Rogers, 2023; Latham & Layton, 2019; Klinenberg, 2018; Whitzman, 2001). These systems assist in structuring the organization of a society by creating a web of connections, or networks, which link the community to various services and actions (The British Academy & Power to Change, 2023). In contexts where water infrastructure is absent, or broken, or fragmented, we know that women and girls bear the brunt of water acquisition and distribution (Sorenson et al., 2011). Therefore, it is imperative to consider women’s labor as an essential *social infrastructure* that often takes the place of functioning *physical water infrastructure*. This

argument takes prior foundational research on infrastructure, water, and women (Sultana, 2020; Datta & Ahmed, 2020; Truelove & Ruszczyk, 2022) one step further to contend that *social infrastructures* interact with *physical infrastructure* as co-equal systems in the joint production of a wide array of gendered harms related to water insecurity.

These dynamics have the potential to most clearly emerge in resource scarce settings characterized by intense gendered inequities. Globally, over half of the world's population experiences severe water scarcity at least one month per year, with 1.8 billion people, predominantly the Global South, living without reliable access to safe drinking water (Adams et al., 2019). In Latin America, policymakers, community organizers, and researchers are decrying the magnitude and severity of the water crisis in the region (Melgar-Quinonez et al., 2023). At the same time, in Latin America, gendered norms such as *machismo* emphasize hypermasculinity and sexism (Glass & Owen, 2010; Ingoldsby, 1991), prioritizing men as the primary decision-makers (Davila, 2019) and leaving women to focus on household duties (Allen et al., 2024). This leaves women to disproportionately shoulder the responsibility for collecting water (Sorenson et al., 2011), particularly in the absence of functioning water infrastructure.

In this paper, we examine whether gendered *social infrastructures* (e.g. unequal labor networks and exclusionary water governance structures) interact with deficient *physical infrastructures* to produce compounded forms of biological and social harms. We define *biological harms* as the physical and health consequences of inadequate water access, and *social harms* as the gendered burdens, conflicts, and pressures associated with women's responsibility for water collection. While we distinguish between biological and social harms for analytical clarity, we recognize that these categories are heuristic and are deeply interconnected in practice (e.g. social processes generating biological consequences and vice versa). To investigate these connections we draw from our ongoing research in Tambogrande, Peru, which provides the perspectives of community members and leaders from governmental and non-governmental organizations regarding infrastructural deficits in water access and its unequal effects on women and girls.

Methods:

Research Setting

The study site of Tambogrande is located on the northwestern coast of Peru in the San Lorenzo Valley within the region of Piura (INEI, 2021). While this area is ecologically categorized as “dry forest”, extensive irrigation systems enable agriculture to be the most important economic activity in the region (Municipality of Tambogrande, 2021). A number of scholars have described the tensions between local agriculture and extractive industries in Tambogrande, which arose in the 1990s when the neoliberal policies of President Alberto Fujimori facilitated the entrance of a number of large gold mining companies into the area (Haarstad and Fløysand, 2007; Muradian et al., 2003; Orozoco and Veiga, 2018). Specifically, a

proposed large-scale gold mining project led by the Canadian company Manhattan Minerals led Tambogrande farmers to mobilize and oppose the project due to concerns over displacement, agricultural loss, and the contamination and depletion of scarce water resources (Haarstad and Fløysand, 2007; Muradian et al., 2003).

While the opposition to large-scale mining was successful, inequities in access to water infrastructure are still yielding significant threats to water security. The district of Tambogrande has a population of 107,495 people (INEI, 2021). According to local data, access to adequate drinking water services poses a major stressor to 85% of the rural population (Municipality of Tambogrande, 2021); primarily those who live on the “left margin”, which is to the south and west of the Piura River. Communities on the “left margin” do not have household access to piped water. In contrast, communities on the “right margin”, which is to the north and east of the Piura River have access to piped water in their homes and to irrigation systems for adjacent land. This is because there is a system of water pipes coming down from the San Lorenzo water reservoir, located in the Sierra de Huancabamba mountain range (Allan et al., 2002).

The resulting geographic and ecological differences between the areas can be seen via satellite imagery of study site Figure 1.0). The greenery on the “right margin” reflects high levels of agricultural activity and plant life, made possible by connections to the San Lorenzo water reservoir. Conversely, the “left margin” is brown reflecting the absence of an irrigation system and a predominance of desert.



Figure 1. Google Earth image of the “left margin” and “right margin” of the Piura River. Map Data ©2023 Google, Airbus, Maxar Technologies

Study Design and Data Collection

The data analyzed for this article were drawn from a larger mixed-methods research project entitled “Water Insecurity and Gender Based Violence: Exploring Links and Steps for Prevention. A Comparative Study of Indonesian and Peruvian Women,” which focuses on water insecurity and gender-based violence from a cross-cultural perspective. The larger project was divided into two phases. The study utilized a mixed-methods design to examine how inequities in water infrastructure shape experiences of water insecurity and gendered inequities in Tambogrande. We selected qualitative methods because they allowed participants to describe lived experiences and social dynamics associated with water insecurity in their communities. These methods, including semi-structured interviews, focus groups, and a multi-stakeholder meeting, fostered triangulation across participant groups which allowed the research team to compare perspectives of community members, organizational leaders, and governmental representatives. We compared the “left margin” and “right margin” of the Piura River to analyze how varying levels of access to water infrastructure shaped social and health-related experiences.

The first phase of research was conducted in January and February 2022 and included surveys (n = 358) with local women from communities on both sides of the Piura River (“left” and “right margins”) and semi-structured interviews (n = 51) with community members and leaders of both genders from governmental and non-governmental organizations in the region. The research design of selecting one community hypothesized to have high water insecurity and another to have lower water insecurity, dictated that the surveys were deployed in one community on the “left margin” (no piped water) and in one community on the “right margin” (piped water). The information about the presence/absence of water infrastructure was initially provided by contacts in the local government. The communities were also of sufficient size and accessibility to align with the research design. Surveys were conducted in a random sample of houses, in both communities, with women over the age of 18 who resided in the home. Survey data is not included in this paper.

The prompts for these semi-structured interviews were created by research team members and the UK-based non-governmental organization, Oxfam. Participants were asked questions about their perceptions of the cause of water insecurity in their community and how water insecurity has impacted community members such as their families and women. Inclusion criteria for the interviews was being an adult woman living in the study communities and/or being a representative from one of the local organizations working with a focus on water and/or women’s health. Participants in the semi-structured interviews were recruited via snowball sampling.

The second phase of research, conducted in April 2022, included focus group discussions (n = 22 men and women across both study communities) and a multi-stakeholder meeting (n = 25 men and women). Participants in the focus groups were members of the community that were invited through their local government point of contact. To recruit participants for the multi-stakeholder

meeting, we spoke with our local collaborators and asked them to identify stakeholders they felt were important in the study. Connections to the study community were facilitated by local governmental representatives, community contacts, and field interviews with previous experience working in this area. Local collaborators assisted the research team in developing appropriate recruitment strategies. Before recruiting participants, individuals were informed of the purpose of the study and the voluntary nature of participation. Participants were also informed of the measures taken to protect confidentiality. To prepare for the focus group discussions and multi-stakeholder meeting, we developed more specialized questions based on our preliminary findings from Phase 1, as well as potential solutions to the water inaccessibility and gender-based violence documented in the communities.

All focus group discussions, interviews, and the multi-stakeholder meetings were recorded and transcribed. Participants included adult women from communities on both the “left margin” and “right margin” of the Piura River and local governmental representatives and organizational leaders working in water access, agriculture, health, and gender equality. These demographics allowed the research team to capture a range of perspectives surrounding infrastructure, health, and gendered experiences of water insecurity. All participants consented to participate through a form that was approved by the Institutional Review Boards of Loyola University Chicago (Project #3386, approved on 12/14/21). Ethical review boards at the University of the West of England, Universitas Padjadjaran Indonesia, and Pontifical Catholic University of Peru also approved this project.

Data Analysis

The data that were analyzed were drawn from semi-structured interviews, focus group discussions, and multi-stakeholder meetings conducted in Tambogrande, Peru. The salience of the issues surrounding water insecurity, women’s health, and gendered inequality emerged through an inductive process (Woo et al., 2017), allowing for themes to emerge from participant narratives surrounding their lived experiences. We used Dedoose (Dedoose version 9.0.17) to identify all quotes pertaining to the topics of water infrastructure, health, and gendered experiences and then inserted these quotes into an Excel matrix containing our qualitative data. Semi-structured interviews, focus groups, and stakeholder meetings were conducted in Spanish by bilingual members of the research team and trained local interviewers. Audio recordings transcribed in Spanish and then translated into English. All materials related to the study including consent forms and interview guides were translated into Spanish. These quotes were “tagged” by authors in Dedoose. A review of the “tags” led to the emergence of common themes (“left vs. right margin”, health impacts etc.). An Excel matrix was created with separate tabs for the themes. Quotes matching the themes were inserted into the excel, facilitating comparisons across various participants (community members, government leaders etc.). These comparisons allowed the authors to identify the final categories presented in the paper (infrastructural asymmetries, infrastructure deficits, etc.). The rigor of the study development and findings were

enhanced through several strategies. The sequential study design allowed for preliminary findings from Phase 1 to inform subsequent focus group and stakeholder meetings. Additionally, triangulation across interviews, focus groups, and stakeholder meetings allowed for comparisons across multiple participant groups and organizational perspectives.

Participants were anonymized and given codes signifying whether they were community members (PC), governmental representatives (PG), or leaders from local organizations (PO) in semi-structured interviews or individuals from focus groups (PF) or from the multi-stakeholder meeting (PMSM). The focus group on the “left margin” is distinguished as “PF_L” and the focus group on the “right margin” (PF_R). Additionally, individual speakers from interviews have a number added, showing the diversity of individuals represented. The numerical part of the codes were not assigned for the focus groups and multi-stakeholder meetings, as the number of attendees made it impossible to track.

Themes became emergent once quotes were consolidated from the matrix through a series of discussions and analyses with the research team, local representatives, and stakeholders. The authors on this paper note that none of the authors are members or residents of the communities in the study. To address potential influence of outsider positionality, , we worked closely with local field interviewers who had previous experience working in the area and familiarity with the local social and cultural dynamics. The study was designed with the sequential phases to ensure that the initial findings could be revisited and discussed with local stakeholders throughout the data collection process to minimize bias or misconceptions, and refine and contextualize interpretations of findings with local experiences and contexts.

Results:

We have organized the findings from the interviews, focus groups, and multi-stakeholder meetings under larger sections for physical and social infrastructure and smaller sub-sections based on the salient issues that emerged in the qualitative data analysis. These were broadly centered on women’s health and water and revealed a prolonged pattern of concern regarding these specific issues among our study participants.

Physical Infrastructure

A representative from a local organization explained that “Tambogrande uses water from the Piura River to supply its agriculture (PG22).” Additionally, a local woman explained that “We use the river to wash clothes, sometimes even for bathing, for cooking (PF)” when household water supplies are low. Despite the reliance on the river, another local representative noted “Tambogrande has been going through a very large problem with the contamination of the Piura River for years, its wastewater has been pouring for more than 20 years directly to the Piura River, contaminating downstream (PG19).”

Infrastructural Asymmetries

Residents of the left and right margins must navigate contrasting landscapes to obtain water. The asymmetries in infrastructure between the left and right margin are due to the agricultural industry in this area of the Tambogrande region. A representative from a local organization explained that “The left bank is more affected [by water insecurity] because there's no irrigation system, there's no agriculture, so the irrigation canal doesn't reach. The entire right [margin] has an irrigation system because there's agriculture. There's a reservoir that supplies the entire [right margin], but it doesn't reach the left [margin]" (PG29).

As a result, left margin residents are forced to rely on other methods to collect water for their households. Another representative explains that “most families [on the left margin] will collect their water in buckets [from ‘noques’ (large cement water reservoirs that hold water from tanker trucks)]. Sometimes the Municipality [of Tambogrande] delivers water through a water truck, once a week. Or they have to buy water (PO5).” On the right margin, communities have a more developed water infrastructure. A local representative explained that “In the right [margin] they have regulated water, in the reservoir, they have supply of the water they use for agriculture and human consumption (PO5).” The supply of water is more regulated, or scheduled and controlled in specific amounts and managed by community members, compared to that in the left margin. Rather than traveling to noques to collect water, one local representative said, “...they get their supplies through household pipes and receive water for a few hours (PF_R).”

Infrastructural Deficits

Despite clear differences in physical water infrastructure -with the left margin without access to piped water in contrast to the right margin- infrastructural deficits still appear in both communities in Tambogrande. The following subthemes represent the infrastructural deficits that appear in Tambogrande:

Noques

Collecting water on the left margin can involve significant time. According to a representative from a local organization, women often “obtain water from the noques. They take between 1 to 4 hours when there is no queue, they take a total of 1 hour to go and return but if there are other women waiting at the noques, it can take 4 hours. This can even last all morning if due to a lack of water, they have to go to the river (PF_L).” As a result, “most access water directly [from natural sources], collect water and it does not have treatment (PG11),” forcing residents to rely on contaminated water for household needs.

Reservoir and Storage

The right margin struggles with adequate storage reservoirs for water, making consistent access to piped water difficult. A representative explains that “Users must have their own [water] tanks,

store their water each day when it's due, and save it until the next week when it's due. We can't provide water 24 hours a day because we don't have adequate storage reservoirs (PO2)." The rising population in the right margin contributes to this growing problem of inadequate storage. The above representative continued that "It was a reservoir solely to supply water to 500 families. More than 10 years have passed, and the population has increased, and we are no longer able to supply it (PO2)." As a result, many families "collect water from irrigation channels or wells (PG4)" to make up for water deficits.

Water Trucks

Residents of both the left and right margin struggle with the reliability of water trucks to make up for household water deficits. A representative explained that in "the left margin...they mostly do not have drinking water and we supply through tanker trucks that the Municipality of Tambogrande brings us, but it is far too little. Each family receives six 20-liter water drums. We make the 120 liters reach the whole family throughout the week (PG30)." These trucks are delivered "on Mondays...from there, it enters on Saturday...from Monday to Saturday the families no longer have water (PO3)." One woman noted how "Sometimes [the water truck] arrives weekly, sometimes it arrives every fortnight and sometimes they forget.... (PG26)" Often, various issues also arise that stall or inhibit water from being delivered. A representative from a local organization said, "You have to consider other factors, sometimes the water truck suffers from failures, it comes into maintenance...tire failure, they are unexpected things that happen. There are days when programming cannot be fulfilled (PG20)."

Additionally, the residents of the right margin face similar issues with water trucks in their community. Another representative from a local organization noted that "The service [in the right margin] is deficient, I think the population only has access to water 4 hours a day, sometimes they get it at night or early in the morning (PG10)." As a result, water is also delivered "through tanker trucks that leave water in each home...although the water [that] reaches the houses, it is insufficient (PF_R)" according to a local resident. A local woman explained, "Yes we have water, although we don't have water all day (PG18)," highlighting the struggles with water security faced in the right margin as well as the reliance of households on their capability of storing water.

Water Privatization and Costs

Due to the growing issue of water scarcity, privatization of water supplies have driven up costs in Tambogrande. A local representative explained that "What the population is doing is hiring private tanker trucks, which further increases the cost...for 10 liters it's costing them double or triple, in some cases 50 cents per can (PG19)." For reference, "each family contributes 20 cents per can (PO3)" from municipal water trucks. For left margin residents, "the economic difference is enormous. [The right margin] pay S/. 8.50 for the monthly rate [of piped water], while those

on the left bank spend an average of S./ 300 to 400 per month [including water from municipal and private trucks] (PG18),” according to a local representative.

Social Infrastructure

The social infrastructure of Tambogrande comprises the networks, institutions, and informal arrangements that govern and manage water access in the community. Machismo and inequitable administrative decisions shape how water is managed in local governance and within the household.

Local Context and Conflicts

To understand the social infrastructure, it is important to consider the local context behind water distribution. One representative explains how “the population is most affected [by water scarcity], because farmers, not having the resource, as for more water, even taking water without caring that the little that remains is for population use, so [people] go on strike, burn tires and they are given water (PG9).” Farmers in Tambogrande often divert the water supply to support agriculture, which takes away vital water resources from the local population in both margins of Tambogrande and causes immense social strife. This is despite the fact that the Peruvian Constitution (1993, rev. 2021) recognizes “the right of everyone to have progressive access to drinking water. The State guarantees this right by prioritizing human consumption over other use (PG9).” A local representative reveals that “Now we can easily see the farms and large companies that accumulate large quantities of water in their own reservoirs and that water is accumulated from the canal itself...and whether we like it or not, there is harm to the communities...the level of water sequencing [referring to allocation and scheduling of water distribution]...is further expanded (PO6).” Water is apportioned for human consumption and agriculture, but this uneven distribution puts immense stress on households. A local woman shares that “We need 20 gallons a week to cover 50% of our needs. When we have 6 gallons a week, we’re short 14. So, we’re forced to buy water; those who have [money] buy water. We have quite a few families who don’t have any [money], who live off tips from relatives. So, how can we solve the problem of water shortages? There’s suffering there. There’s where it affects the low-income (PG30).” Thus, lower income households feel a disproportionate burden when it comes to the already difficult burdens associated with water insecurity.

Water Governance

Women are often excluded from water-related decision making in formal governance in Tambogrande. A local representative noted that “Women’s participation on the board of directors [for water governance] was very low...We had 92% male participation on boards and 8% women in positions that are, let’s say, the main ones.” Male-dominated networks manage and govern the decision-making bodies related to water. A local woman who participates in water governance explains “There’s little to no participation from women in leadership positions...I know two colleagues; the rest are men. I think that due to a lack of awareness among women, some feel

inhibited, that they're not capable of holding public office. Perhaps there are limitations due to their husbands. It's clear that there's a problem (PG29)." Much of this is attributed to the presence of machismo in Tambogrande. One local representative shares that "Machismo goes as far so that providing water at home is [the role of] the woman, but the one who takes the liberty of participating at a meeting outside the community to discuss water issues has to be a man (PC)." Cultural attitudes reinforce the exclusion of women from water governance, despite playing a large role in water management for their families and community.

Community and Household Water Management

Although male-dominated networks govern the distribution of the water supply, women create invisible social networks and assume the roles of water acquisition and supply maintenance. A local representative states that "...women are part of the irrigation commission and [they] become invisible guardians of water (PO4)." Specifically, women manage the actual distribution of water at community noques. One representative explains that "At each noque, there are [two] women in charge of who receives the water...who for the distribution, are given extra containers of water, they have a family relationship and they give the [extra] water to their families (PO2)." Despite limited formal leadership roles, women create invisible social networks to support other women through extra water distribution. Additionally, another local representative states that "we also find an important role of women in the issue of supply and care...but also the way in which they can maintain the quality of [water] and guarantee with that the health of the family, as it is the role they have been assuming (PG7)." Women in Tambogrande maintain the order and care of the noques and other water access points, and try to ensure the water is clean before bringing it back to their families. This is often the case because, as one representative explains, "If there is no water there are going to be certain discrepancies...the man always goes out to the fields...and the ones who stay at home are the women and the ones who suffer from the issue of water are the women (PG10)."

Infrastructural Violence

The cycle of violence surrounding gendered tasks and inequality in household labor has become apparent among women in both margins of Tambogrande, as they have expanded into various harms stemming from infrastructural violence. These harms have been identified as gender-based violence, reproductive health burdens, adverse health conditions, and opportunity costs experienced by women and girls.

Gender-Based Violence

The pressure for women to carry out their gendered tasks of water acquisition, without adequate water infrastructure, opens them up to different forms of gender-based violence. A local representative noted how "the husband gets upset when they come home from work and can't find their clothes washed or cleaned up, then the violence comes" and further expanded that this "...is a vicious cycle. Inequality does not remain static, it is increasing and it is more difficult to

face it (P_MSM).” The inability to meet these particular obligations of water acquisition results in repercussions for women. One representative explained that “The woman has certain responsibilities at home...and she has to get water...because if I don’t cook then my husband arrives and will hit me (PG5).” As a result, women may find themselves in dangerous situations and experience sexual violence while attempting to collect enough water for their households. Another representative explains that “Given that women fetching water are likely impoverished, this can set up conditions whereby women feel coerced into providing sex or sexual favors in an effort to either gain access to water or advance their position in a water queue...It is a stark demonstration of the level of desperation felt by some women.”

Reproductive Health Burdens

These repercussions for women extend to reproductive health burdens surrounding childbirth and sexual health, particularly in the left margin. One representative from a local organization explained how “There are many cases of pregnant women carrying water and miscarrying (PO_2).” This struggle to collect water is exacerbated by poor infrastructure and household expectations. One participant said “Once her partner got angry because he came home from work and there was no water. She had just given birth. She was with the small baby, and she had not been able to go for water (PC1).” The expectation of household water collection is still faced by women in Tambogrande, even directly after childbirth. Additionally, a local woman explains how a lack of household water results in sacrificing personal shares for the family. She says “The problem we women face, sometimes vaginal infections, is due to a lack of water, because sometimes we can’t do our personal hygiene...For women on the left bank, it’s even more serious, because they get seven cans of water delivered to them a week, drinking water for human consumption (PO4).”

Health

The effect on health for women and children also becomes a much higher risk with the compounding effects of social and physical infrastructure. One representative from a local organization explained that, “When water is scarce, the only way out for [right margin] residents is to store more water, and when storing water there is the problem of dengue fever. Another issue is that they are used to drinking water from the canal, when they don’t have water, they go to the wells and many times the water is more contaminated and can cause stomach problems. Another representative revealed that “sometimes women on the left bank have more problems with kidney problems, due to their exposure to collecting water, overseeing production [at noques]...There’s an overload for women. There is differentiation in terms of illnesses among women (PO1).”

With limited access to water, women are often forced to use contaminated water from the Piura River and overexert themselves to maintain the water supply for their household which puts themselves and their children at risk. A local representative explained “[Tambogrande] has the

problem of anemia, unfortunately, this causes diseases in children, acute diarrhea directly from drinking water, because it is not treated (PG11).” Specifically, girls experience the brunt of the harms associated with contaminated water. An expert stated, “We are treating girls who have skin problems, who tell us that it is caused by [contact with] the water... Those who are most affected, I can see that they call more for girls than for boys, more girls or women who have skin diseases (PO6).”

Opportunity Costs

This increase in vulnerability is also heightened through opportunity costs created for women and girls due to water acquisition. One woman noted how “If we had water closer, there would be more time, we would have hours free, more time to be with the family, sometimes one has no time to talk with the family (PF_L).”

The expectation to collect water from a poor infrastructural system also causes children to forfeit their education. Specifically, girls are expected to miss out on their education to gather water for the household. Another representative stated “There is a town in Tambogrande where... the girls were the ones who picked up the water with their donkeys, I asked at what time they studied, and said they did not because there was no water.” This participant asked a follow-up question regarding “if they had little brothers, they said yes and that they were at school (PG22).”

Another representative from a local organization noted a similar experience stating,

“What I observe... is the neglect of parents towards the children... the children are in the care of grandparents, their aunt or their sisters... and at an early age, there are even girls of 13, 12 years I find them doing the house chores... Even in the [right margin], most do not study (PG28).”

Men and boys are not required to collect water for the household due to the expectation that this is part of a woman’s job. Women consider the economic ramifications of the long hours it takes to collect enough water for the household, however, “Because sometimes mothers want to go to work to bring more income to the home, sometimes they say, ‘Who will fetch water for me? If I don’t have water, I have nothing. Who will do the housework for me?’ So, perhaps they stop giving that girl an education in order to leave her in charge of the household as a housewife, and the main factor that makes it her obligation for that person to stay is to fetch water (PF_L)” according to a local representative.

Discussion:

This study demonstrates that infrastructural violence emerges from the coproduction of physical and social infrastructure, rather than material deficiencies or weak governance alone. In Tambogrande, social infrastructures, such as male dominated water governance, allocate the

responsibility of water acquisition to women while excluding them from decision making. Simultaneously, lacking physical infrastructures, such as piped water and storage systems, produce conditions of scarcity, unreliability, and spatial inequality. These interacting systems produce gendered harms across biological and social domains, including adverse health outcomes, interpersonal violence, and opportunity costs.

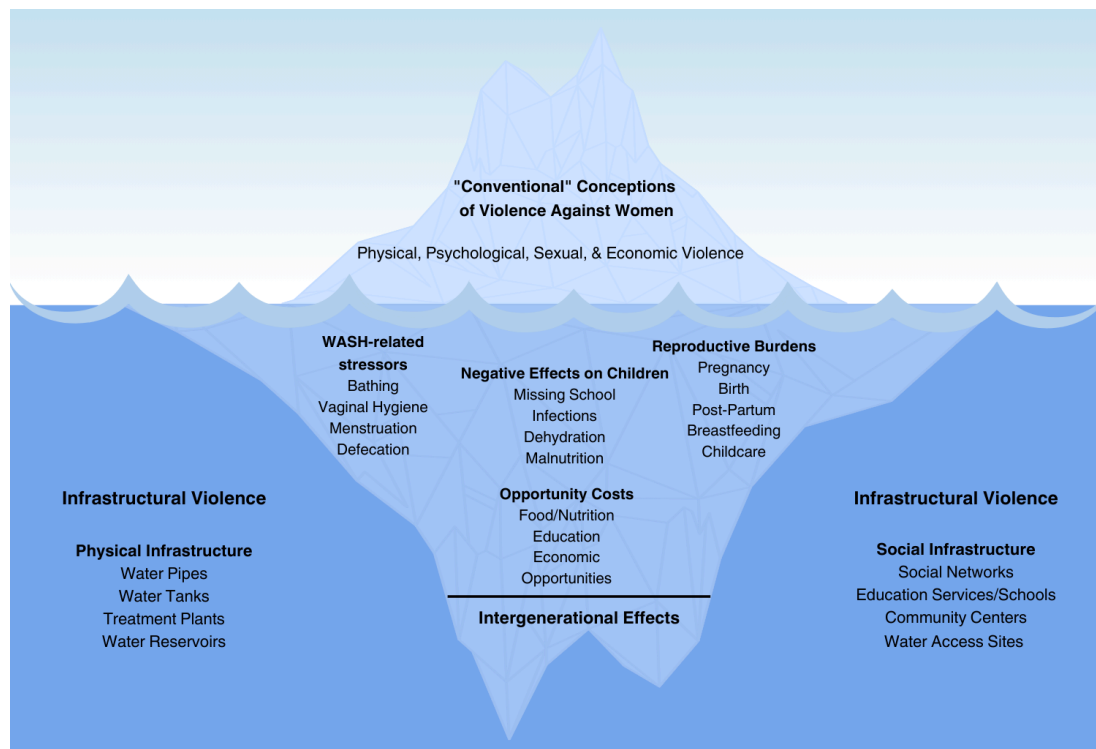


Figure 2: Iceberg model depicting the depths of violence against women associated with water insecurity (Tallman et al., 2024), reconceptualized to include infrastructure.

We rework the iceberg model of “gender-based water violence” (see Figure 2) created by Tallman and colleagues (2024) to illustrate the layered depths of harms associated with water insecurity. By incorporating infrastructure into this visual model, we highlight how interacting physical and social infrastructures produce a spectrum of harm that extends beyond conventional forms of violence. This reconceptualization shows how less visible forms of violence are not peripheral but rather critical outcomes of infrastructural violence, such as opportunity costs, health burdens, and socioeconomic opportunities.

This adaptation to the existing iceberg model allows for the conceptualization of infrastructure not as a single layer, but a constitutive system which operates across all levels of violence. We chose not to position infrastructure as a root cause beneath the visible harms, or “tip of the iceberg,” but instead illustrate how physical and social infrastructures act as coproductive forces across a spectrum of violence. Physical infrastructure shapes material systems of water access

(e.g. pipes, tanks, reservoirs), while social infrastructures (e.g. social labor networks and local water governance) influence how these conditions are experienced and reproduced in everyday life. Infrastructure is embedded throughout the iceberg, revealing visible interpersonal violence at the surface, and less visible harms (e.g. health burdens and opportunity costs) beneath the surface. This updated model allows us to view physical and social infrastructures as equal, interconnected systems that produce a spectrum of harms.

Social infrastructure in Tambogrande plays a key role in allocating the responsibility of water acquisition to women, upholding gendered expectations that shape everyday experiences of water insecurity. These findings are consistent in the literature on heavy gendered burdens associated with water acquisition (Truelove & Ruzcysk, 2022; Nunbogu & Elliot, 2022; Collins et al., 2019; Pommells et al., 2018; Sorenson et al., 2011). When household expectations are not met, women become more susceptible to gender-based violence (c.f. Tallman et al., 2023; Cole et al., 2024, Tallman et al., 2024). This only touches the “tip of the iceberg” of violence associated with water insecurity which expands into a greater spectrum of harm (Tallman et al., 2024), including lost opportunities for additional income (Truelove & Ruzcysk, 2022; Datta & Ahmed, 2020) and the ability for girls to pursue an education (Cole, 2017; Nunbogu & Elliot, 2022; Truelove & Ruzcysk, 2022). These gendered divisions in labor result in extreme rates of time poverty for women (Orkoh et al., 2020). This is extended to young girls within the family, thus perpetuating cycles of inequality through intergenerational effects (Archdeacon et al., 2024). These findings demonstrate that social infrastructures are not peripheral, but that they actively produce and sustain gendered harm.

Biological harms are worsened by failures of physical infrastructure. Participants reported reproductive health burdens, including miscarriages, childbirth complications, and vaginal infections, revealing a similar pattern of findings from other bodies of work (Collins et al., 2019, Cole, 2017, Das et al., 2015). Additionally, injury from overexertion during water collection and exposure to infectious diseases from poor latrine and sewer systems have also been documented (Truelove & Ruzcysk, 2022; Datta & Ahmed, 2020). Women also reported relying on heavily contaminated water from open sources when infrastructure fails, resulting in diarrhea (Rosinger, 2018) and schistosomiasis infections (Grimes et al., 2014). This increased exposure was associated with heightened rates of skin diseases compared to men and boys, who were not tasked with water collection. In a study conducted by De Guzman and colleagues (2023), it was explained that very few studies have disaggregated data by gender in relation to health. So while gendered differences in health outcomes due to contaminated water have been noted within the literature (Sommer et al., 2015; Pommells et al., 2018; Collins et al., 2019; Nunbogu & Elliot, 2022), more advanced studies are required to better understand these stark differences.

Infrastructure in Tambogrande has been revealed in our study to 1) act as a vital yet unreliable source of water, and 2) shape gendered labor and social expectations. Women are heavily

excluded from decision-making, yet still must fulfill expectations of water collection. Similarly, Nikhil Anand's (2017) work in Mumbai revealed a similar revelation in that infrastructure acts beyond just material systems, but shapes social life and hierarchies. Water in Mumbai was available for only 4 hours, revealing the temporality of the city's social organization of gendered labor and relational networks (Anand, 2017). Women in our study comparably experienced an unreliable and temporal water infrastructure, resulting in disproportionate gendered burdens associated with water scarcity and the shaping of social hierarchies. Similarly, residents of the left margin experience a more severe level of water insecurity, revealing passive infrastructural violence through omission of water infrastructure, which reinforces social hierarchies and socioeconomic differences. (Rogers & O'Neill, 2012),

In our findings, women emerged as "invisible guardians of water." These social labor networks, which maintain a supply of gendered labor, serve as an informal yet integral component of the social infrastructure of Tambogrande which is dependent on these services and resources. Our analysis goes one step further and exhibits how gendered labor, governance, and material systems operate in tandem to produce infrastructural violence and a wide array of harms. Similar findings have been observed in other contexts where gendered social and physical infrastructure produce intimate forms of harm for women. For example, Datta & Ahmed (2020) expand on the implications of caste on social labor networks of women in India. These examples highlight the importance of analyzing social and material systems in tandem to better understand infrastructural violence in broad, diverse settings.

Physical infrastructure alone does not determine outcomes and neither do social infrastructures operate independently. The dependence on women's labor is not erased due to absent infrastructures. Rather, it is their interactions where material scarcity aligns with gendered social responsibility that produces compounded harm toward women. Tanyildiz (2025) makes the argument that in feminist urban research, social reproduction and infrastructure are often treated as inseparable entities; but instead should push for analyzing the socio-spatial and historical contexts of which infrastructure and reproductive labor interact. In Tambogrande, the absence or temporality of infrastructure does not reduce the expectation of women securing water, but instead intensifies the burden leading to increased biological and interpersonal risk.

Gendered norms, specifically machismo, heavily shape social infrastructure and water-related responsibilities. Brewis and colleagues (2023) emphasize how social norms reinforce gendered bodies and their expectations to interact with water, specifically around feminine or masculine norms surrounding water. Machismo and related social expectations prioritizing men as decision-makers (Davila, 2019), reinforcing women's exclusion from governance while maintaining responsibility for water acquisition (Allen et al., 2024). Combined with lacking physical infrastructure, these norms compound women's experienced biological and social harms.

Existing studies on infrastructural violence often separate physical infrastructure and social processes when examining water insecurity. This study demonstrates that infrastructural violence emerges from the coproduction of physical and social infrastructures, which produce compounded gendered harm ranging across biological and interpersonal spheres. Through integrating these systems together, we provide a framework for examining a wide spectrum of harms which reveal how infrastructure shapes and sustains inequality. Future studies should continue to explore how these coproductive systems operate across a broad range of settings and contexts, to inform potential interventions that address both social expectation and material deficits.

The limitations of this study help identify important directions for future research in this area. Our analysis focuses primarily on the lived experiences of women, but further work is needed to understand how these dynamics are shaped by age, ethnicity, and socioeconomic status. Additional research should also aim to explore how these interactions develop across both rural and urban contexts to assess if this framework can be applied across broad settings. Lastly, more attention should be focused on the role of governance and policy interventions to address lacking physical and social infrastructures, specifically in ways which reduce and redistribute gendered burdens and expectations surrounding water access.

Conclusion:

This study advances the concept of infrastructural violence by highlighting that harm is not exclusively produced from material deficiencies or lacking governance alone, but rather from the interactions of physical and social infrastructures. In our analysis of water insecurity in Tambogrande, Peru, we demonstrate how unreliable and uneven physical infrastructures intersect with gendered social infrastructures (e.g. male-dominated water governance and social labor networks) produce compounded, gendered harm. These harms span across interpersonal and biological domains, ranging from adverse health burdens, opportunity costs, and gender-based violence.

Our study extends existing frameworks of infrastructural violence by moving past macro-level or material explanations to foreground the everyday mechanisms that produce this harm. Although prior work has revealed how infrastructure shapes inequality through unequal distribution of resources, our findings demonstrate how social infrastructures play an active role in the production and circulation of harm, not serving as just a contextual role. The reconceptualization of the iceberg model (Figure 2) illustrates how interacting infrastructures develop a wide spectrum of visible and invisible violence.

This study emphasizes the importance of analyzing infrastructure as a set of coproductive systems that heavily shape lived experience. To better address water insecurity and its associated harms, higher investments in physical infrastructures are required, but also transformations of

social infrastructures which shape labor, access, and decision-making is necessary. Through centering these interactions, this framework offers a more precise analysis and actionable approach to understanding the layered gendered impacts of infrastructural inequality.

Declaration: Generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the authors used ChatGPT to make lengthy sentences more concise. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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