Differential Access: Water infrastructure and Water Quality Awareness among Lahore's Urban Poor

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Abbreviations

JMP - Unicef's Joint Monitoring Program
Punjab - Punjab, Pakistan
SES - Socioeconomic Status
WASA, Lahore - Water and Sanitation Authority, Lahore
WFP - Water Filtration Plant

Abstract

This research aims to qualify how low-income urban individuals in Lahore, Pakistan obtain and utilize water for day-to-day use. The study uses qualitative research methods including observation of water filtration plants and of individuals in their homes, along with 39 semi-structured interviews primarily with low-income individuals, and also the local water utility, NGOs, and water researchers. It was found that water filtration plants have a strikingly positive reception among Lahore's urban poor, with individuals citing confidence in WFPs providing clean drinking water. The majority of respondents reported using WFPs to obtain drinking water or aspiring to do so. To facilitate more efficient use of WFPs we recommend that an inventory of WFPs in Lahore be created and disseminated to the local water sector. People obtained water for household use either from the local water utility, WASA Lahore, or via borewells placed inside one's home. Individuals who had borewells were much more aware and susceptible to fluctuations in the water table whereas individuals who obtained water from WASA were more concerned about water contamination. As all of Lahore's domestic water supply is sourced from the aquifer, we support the creation of a aquifer users association to administer tariffs that allow for more equitable distribution of cost and water.

1. Introduction

Access to safe drinking water has been acknowledged as a basic right of all human beings by the United Nations and the World Health Organization yet approximately one in three individuals lack access to safe drinking water [1][2]. The consequences of this inequity in access are severe, accounting for almost one tenth of global disease burden [3]. The costs of lacking clean water skew towards the most vulnerable in society. The coping costs of unreliable water supplies have been shown to disproportionately affect low-income households [3]. Diarrheal disease is the second principal cause of child mortality and the leading cause of child morbidity globally [3].

Lahore, Pakistan, faces a unique set of challenges in providing water to its eleven million inhabitants. Lahore has and continues to experience a massive rise in population due both to urbanization and population growth [4]. With some reports estimating a population of twenty two million by 2025 [5]. In addition to a rapidly growing population, water availability is expected to become even more erratic as global climate change continues to affect the Indus River Basin [6]. Along with affecting supply, “climate warming is expected to drive water demands up in Pakistan by 5 percent to 15 percent by 2047, in addition to the demand increases from population and economic growth” [7].

These problems are compounded by the fact that Lahore sources almost all of its water from its aquifer, the uncontrolled abstraction of water from the aquifer has resulted in a falling water table [8]. While a great deal of attention has been given to the management of the Indus water basin, groundwater management both in terms of sustaining the water table and also managing pollution have not been prioritized in Pakistan’s overall policy framework [9].

This research uses qualitative research methods to understand how urban poor individuals in Lahore, Pakistan access and utilize water for the day-to-day activities including for drinking. The experience of obtaining water was found to be striated by socioeconomic class. Those who were unable to access piped water from the local water utility, installed their own borewells inside their homes, paying a premium to both maintain and utilize this infrastructure. Households in private housing societies obtained water from physically separate water infrastructure than that of the local water utility. The research also revealed that the use of water filtration plants for access to drinking water was widespread. Water filtration plants, although being installed by disparate entities, were almost universally regarded favorably and as providing safe potable water.

2. Literature Review

2.1 Defining water access?

It wasn't until 2010 that access to drinking water was acknowledged as a human right by the United Nations General Assembly and Human Rights Council [1]. Unfortunately, defining and measuring access to safe drinking water is a complex task. While the World Health Organization (WHO) and the Joint Monitoring Program for Water Supply and Sanitation (JMP) do not conduct surveys or collect data themselves, they developed "harmonized surveys" that allow organizations to collect comparable data about water access [3]. They defined "improved water sources" as water sources that "by nature of their construction or through active intervention, are protected from outside contamination" with focus on preventing or treating for faecal contamination. These sources include all piped water sources, tube wells, bore holes, covered wells, protected springs, rainwater, and bottled water [10]. Improved water was the main metric measured for the Millennium Development Goal of halving the number of people without "sustainable access to safe drinking water" but this metric grossly misrepresents the reality of water access [10].

"Improved water sources" have repeatedly been shown to not function as good proxies for water sources that are free of faecal contamination. The percentage of the populations of Bangladesh, Ghana, Nepal, and the Congo that have access to "improved water sources" varies between 87-96%, however only 17-56% of these populations have access to water without faecal contamination [11]. This trend also holds true in Punjab, the province in which Lahore is located: while 98% of Punjab is reported to have access to an improved water source, only 63% of water sources are free from faecal contamination [12]. While global piped water supplies are generally correlated with lower levels of bacterial contamination, in lower income countries, this correlation often falls apart due to intermittent supply and poor maintenance which causes contamination when water pressure fluctuates. In Punjab, nearly half of households obtaining piped water had E. coli at the source of the water, and roughly two-thirds had E. coli at the point of use [12]. Other improved water sources don't fare well either, with a third of household bore wells with E. coli contamination at the source and over half with contamination at point of use [12].

In recognition of the limitation of using improved water sources as indicators for water access, the JMP revised the indicators it proposes to collect for the Sustainable Development Goals; they have refocused on "accessibility, availability, and quality", which were previously ignored [11]. They also introduced a new metric, "safely managed" water as "an improved drinking water source that is located on premises, available when needed and free from faecal and priority chemical contamination."[11]. They define "available when needed" as available at least 12 hours in a day [3]. When re-evaluating using this new metric, "Central and Southern Asia had the largest absolute numbers of urban residents who lacked safely managed water in 2015—258 million people" [3]. While in Punjab, access to improved water sources is common, a mere three sources, piped water access and motorized or manual hand pumps make up 80% of water

sources used for drinking have significant and well established problems in terms of access, quality, and availability [12]. While 98% of Punjab is reported to have access to an improved water source, only 43% of sources are “safely managed” [12].

This research focuses on qualifying the level of accessibility and availability of water sources in line with the definition used for “safely managed” water. Bacteriological testing was outside the scope of the research, but perceived quality was reported.

2.2 How People in Lahore Access Water

Similar to many large metropolitan cities in the global south, Lahore’s water infrastructure does not extend to the entirety of the city [13][5]. There are more than 11 million people in Lahore, and the Water and Sanitation Authority only serves approximately half of those [5]. Even within WASA’s jurisdiction, roughly a quarter of households are not connected to piped water supplies [7]. Punjab has the lowest provision of piped water at 46% of the population compared to Balochistan (68%), Sindh (65%), and Khyber Pakhtunkhwa (KP) (54%) [10]. Furthermore the “completeness of piped supply coverage has fallen over the last decade” [7]. According to the Pakistan Social and Living Standards (PSLM) survey conducted between 2014 and 2015, a national shift has been observed from tap water to motorized pumping in the last few years [9].

The experience of getting piped water in Lahore is challenging. Intermittent supply is the norm, with “only 27% of households in Pakistan receiving water for more than 6 hours a day” [7]. Intermittency is driven by multiple factors, WASA limits the hours during which water is available to the public due to dramatically declining water tables in Lahore [14]. In October 2018, WASA introduced limited hours of water access to the city, with officials stating “users will now get water only from approximately 4 am to 9 am, noon to 2 pm and 5 pm to 10 pm” [14]. Unreliable energy production, high energy demands, and high electricity costs are also to blame for the lack of reliability in water access, since most drinking water is obtained from groundwater sources, pumps and thus electricity are an essential part of water infrastructure. When the city faces high energy demands, rationing of electricity results in interruptions to water access. A report from 2014 cites 13 of 16 water supply programs in rural Lahore were found to be non-functioning due to the lack of payment of electricity bills [15]: “When a city the size of Lahore relies solely on groundwater, energy use is fundamentally tied to water use”[16].

Intermittency, regardless of its cause, incurs coping costs. The turning on and off of water pressure in Lahore’s piped water systems results in negative pressures which makes it easy for contaminants to enter the pipes. This is particularly concerning as sewage pipes often use the same trenches as drinking water pipelines [3]. In a nonrepresentative study which evaluated the quality of water supplied by WASA Lahore, 50% to 62.5% of samples from water distributions systems in Lahore had bacteriological contamination; when taking similar samples after monsoon season, that percentage rose to 75% [17]. Unsurprisingly, the number of households using tap water as their main source of drinking water is lowest in Punjab at 18% [9]. This is significantly lower than Pakistan’s other provinces with Sindh at 41%, Khyber Pakhtunkhwa at 35%, and Baluchistan at 33% [9]. Access to piped water in one's home “did not have any

statistically relevant influence on stunting and diarrhea [in children], in fact access to piped water seemed to worsen outcomes for stunting in children in certain age ranges" [18]. Beyond contamination, intermittent supply also causes households to reserve water in tanks, buckets, and other vessels to ensure they are not left without water when they need it. Coping costs associated with intermittent water supply have been shown to disproportionately affect the poor in South Asia with "coping costs comprising 15 percent of income for lower income households and 1 percent for wealthy households in India"[3].

A significant portion of the population of Lahore does not have any access to piped water in their homes. A study shows that in Lahore access to piped water decreased as district poverty increased [10]. According to the Multiple Indicator Cluster Survey (MICS), 35% of households access water from a well via a motorized or hand pump. These wells are likely to be much shallower than the wells utilized by the local government to provide piped water to its constituents, which are more likely to be affected by contaminants [10]. Shallower wells are also known to be affected by seasonal variation in the depth of the water table; shortages in water become most acute in summer when consumption is highest [19].

This research addresses the different types of water sources i.e piped supply, motorized or hand pumps being used by urban poor residents in Lahore, Pakistan. It focuses on establishing the current degree of intermittency urban poor residents face and the specific coping strategies people rely on to manage their water related problems.

2.3 Financial Sustainability of Lahores' Water Utility

Cost recovery is central to the financial sustainability of water utilities and only 39% of utilities in a worldwide survey (2004) were able to cover short- and long-term operation and maintenance costs from the tariffs they charged. Even in OECD countries, only half of the utilities were able to cover all operation and maintenance costs from tariffs alone [20]. Water provision is expensive and balancing the affordability of water with the financial needs of the utilities can be difficult, particularly when a large percentage of the population served by the utility is poor. WASA Lahore relies on government subsidies to continue service in Lahore; several factors hinder WASA Lahores' ability to be financially sustainable.

The financial instability of WASA can in part be attributed to what has been referred to as the "build-neglect-rebuild" model which has been used to describe Pakistan's approach towards much of its infrastructure. In a 2011 report, the Pakistan Council of Research in Water Resources (PCRWR) stated that WASA's "distribution pipelines are very old and have completed their design life" and goes on to say, "maintenance such as ... servicing of valves and hydrants, leak checking, [conducting] repairs, ... etc. are totally neglected by the operation staff "[10]. This disregard for operations and maintenance of water infrastructure is likely linked to political involvement in water allocation. Due to its low cost recovery, WASA is highly dependent on government subsidies and becomes accountable to the politicians who allocate them rather than to the people whom they serve [21]. Politicians have greater incentive to expand water service and take credit for these expansions rather than to maintain infrastructure that already

exists [5]. This reality is reflected in the budget allocations of WASA; allocation of funds has overwhelmingly gone towards new projects with negligible funding allocated towards operations and maintenance [10].

Another significant factor influencing WASA's financial stability is the lack of use of water meters. The presence and use of water meters is known to be a "significant factor in a utility's ability to successfully account for and regulate water use". A study conducted by the International Benchmarking Network (IBNET), which analyzed more than 2000 water utilities, confirmed this finding and suggested that metering could go a long way towards facilitating a transition to continuous service [3]. According to a Japan International Cooperation Agency (JICA) report written in 2010, about half of WASA's connections are unmetered and only 15% of the metered connections are functional [15]. The difficulty of using meters is not only in installing them but also in ensuring they remain functional; intermittent water supplies which are common across South Asia, introduce varying pressure differentials in the water distribution system which water meters are not designed to handle. Widespread water metering is necessary to utilize volumetric tariffs. Volumetric tariffs are used to ensure affordable water costs by setting progressive water rates for increasing use, subsidizing costs for the poor by charging higher rates for excessive use by the wealthy. The lack of metered connections in Lahore makes implementing progressive volumetric tariffs impossible. The Pakistani government acknowledged the importance of metering when it set a goal for "100% metering for water supplies" in its 2018 National Water Policy. Unfortunately the document offered little about how 100% metering could be achieved [22].

Limited access to data about volumetric water use or maintenance makes data driven decision making extremely difficult. In 2010 the Water and Sanitation Program administered by the World Bank attempted to push water utilities in South Asia to utilize performance benchmarking with limited success [23]. While a total of four rounds of benchmarking data was collected, it was found that data collected by different entities within a utility often could not be reconciled, furthermore the Pakistani government showed "limited engagement" with the benchmarking data [23]. No benchmarking data has been collected under the Water and Sanitation Program since 2016 [23]. "Without comprehensive measurement of flows and metering of consumption, utilities cannot reliably calculate consumption per connection and per capita, the actual volumes of water they sell, how much water is lost through leaks and bursts, or the percentage of non-revenue water. Without comprehensive and up-to-date customer databases, utilities can only estimate how many people they serve, what their aggregated demand is, and how effectively they are billing and collecting payments from them"[23]. Lack of even the most basic data makes all attempts to improve utilities mere guesswork.

The gap in service provision for piped water in South Asia is widening increasingly due to population growth and rapid urbanization [3]. It is further compounded by the shortcomings of the current infrastructure which fails to meet the needs of the cities' current residents. [3]. The population density in persons per square km in Pakistan increased fivefold from 43 to 218 from 1951 to 2010 respectively; Lahores' population density increased almost eight fold, from 640 to 4,983 in the same time frame [15]. Growing demand for clean drinking water poses a substantial

challenge for Lahore, which relies exclusively on groundwater to meet municipal water needs [15]. It is estimated that WASA Lahore will need to serve 9 million people by 2030, which would require nearly doubling the number of tube wells in use in 2013, reducing average water demand, and reducing the percentage of non-revenue water by 10% [15]. While a growing population drives increased water demands, Pakistan is also among the most inefficient in its water use: the country's average annual water withdrawal per capita is 885 m^2 compared to 600 m^2 in India and 420 m^2 in China [7]. Even when adjusted for population growth, Pakistan's water use has been steadily increasing over the past several decades: in 1967, the demand for water was 180 liters per capita per day (LPCD) and it has since increased by more than 50% to 274 LPCD as of 2013 [24]. WASA Lahore is unable to meet the needs of the current urban population and due to rapid urbanization, the need for water access is ever increasing.

The Water and Sanitation Agency serves as the main water utility particularly for urban poor residents in Lahore. The problems it faces go a long way in explaining the quality of water access they are able to provide and speak to the challenges faced in improving water access to Lahore's urban poor population in the future. This research focuses on the connection between WASA's existing problems, the resulting experience of obtaining water for urban poor individuals and posits ways in which WASA could pivot towards better service and financial stability.

2.4 Lahore's Groundwater Resources

Lahore is highly dependent on groundwater to meet its needs, "except for partial reliance of the agricultural sector on surface water resources, all other sectors [in Lahore] rely entirely on groundwater to meet their demands."[15]. Domestic water needs make up the largest portion of the groundwater allocation, with 53% of groundwater extracted in Lahore being used for domestic purposes [15]. Instability in precipitation and streamflow in Pakistan makes the 16 million hectares of groundwater reserves under the Indus basin a "critical" resource which the city has become highly dependent on [7][15][25]. Much of Lahore's reliance on groundwater is a function of the growing number of tube wells installed by individuals. The use of tubewells by farmers was encouraged by the Salinity Control and Reclamation program initiated by the Pakistani government, "Until the 1960s, the number of tube-wells was limited to less than 30,000, [the number of tubewells has now grown to] over 1 million" [24]. This problem is particularly potent in Punjab where the tubewell density per 1000 hectares has increased 15 fold from 1965; The tubewell density in 2013 was nine times higher in Punjab than in NWFP and Sindh [18]. "Over 80 percent of groundwater exploitation takes place through small capacity private tubewells" which makes gaining control over the resource extremely difficult [18].

Lahore's reliance on groundwater has resulted in extraction rates for groundwater exceeding the rate at which groundwater is replenished via recharge [24]. The unsustainable extraction of groundwater has resulted in the water table falling at a rate of half a metre per year since the mid 1980s [15]. " In 1987, depth to [ground]water was approximately 10 m, which has decreased to 52 m in 2010" [15]. It is expected that by 2025 the water table could be as low as 70 metres and in 2040 as low as 100 metres below the surface [5]. The reasons for the

decreasing water table are complex; the growing need for domestic water as the population in Lahore increases has placed more pressure on groundwater, reduction in recharge due to greater expanses of impervious surfaces as Lahore has urbanized has also affected the water table [15]. River Ravi is the largest source of recharge for the aquifer but has generally been dry except during monsoons in recent years [15] [26].

A depression zone has been defined as the water table exceeding a depth of 40 metres at which depth the susceptibility to salt water intrusion increases drastically [15]. “In October 2004, the maximum depth of groundwater [in Lahore] was found to be 37.86 metres at Shadman market”, a market centrally located in Lahore. Over-extraction of groundwater has led to a “cup-shaped depression” in the water table of Lahore [27] [26]. The water table varies in depth across Lahore and, while the depression zone has been shifting eastward, it has also consistently been expanding; Mahmood et al conclude that “the area in the city with groundwater below depth of 38m is increasing continuously at an average rate of 24.5 Km^2 per year”[26]. Continued groundwater extraction from the depression zone increases the risk of saltwater intrusion from the underlying saline water layer upon which the freshwater aquifer in Lahore sits. Intrusion of saltwater into a freshwater aquifer contaminates the water and, if enough saline water is introduced, makes the water undrinkable. It is extremely costly and technically difficult to remediate aquifers that have saltwater intrusion [15]. With 23% of Punjab’s groundwater already saline, it is exceptionally important that steps are taken to protect the resource that the city relies on so heavily [7].

The economic costs of the falling water table are also severe. The cost of installing tubewells increases non-linearly with increasing depth of groundwater: “The cost of installing a tube well in an area having a water table at or below 24 meters is seven times higher as compared to an area where water table depth is around 6 meters” [22]. The increasing cost of extracting groundwater at greater depths is also exorbitant: at 20 meters, extracting 1000m3 of groundwater costs approximately 20 USD, at 40 meters it increases to 50, and at 70 meters that cost rises to 100 [15]. These costs pose a particularly high burden for individuals with small capacity private tubewells but also have a tremendous influence on WASA which sources all of its water from aquifers. In 2013, just under half of WASA’s budget was allocated to pay for the electricity costs to operate its tubewells, with increasing water depths the costs of operation will only grow making it even more difficult for WASA to become a financially sustainable organization [28].

The exploitation of groundwater is possible due to the lack of regulation over its use. While a great deal of attention has been given to the management of the Indus water basin, groundwater management has not been prioritized in Pakistan’s overall policy framework [9]. Groundwater is pumped indiscriminately by all who have access to a tube well or a bore hole: private housing schemes, industry, and numerous private tube wells that account for over 80 percent of groundwater exploitation [18][15]. “Groundwater entitlement is not explicitly defined or regulated, generally access to groundwater is a function of land ownership” [24]. Pakistan’s first national water policy was introduced in 2018 prior to which there was no national level water policy in place [24]. While the introduction is a positive step and addresses the declining water

table, there is little information on how the proposed “alternative water sources” or “adequate groundwater recharge” can be achieved [22]. Experts have identified the limited coordination between multiple agencies that are involved with water infrastructure, causing there to be no accountability regarding water provision, access, or protection of water resources [5] [10] [27]. Some have suggested the use of “Aquifer User Associations that are supported by the government that function as overseers of aquifer use/ make decisions about limitations on water withdrawals etc” [27]. Others have suggested phasing in limits to the depths of tube wells that are bolstered by the provision of safe public water supplies [10].

The exploitation of Lahore’s groundwater resource has had and continue to have repercussions for Lahore’s urban poor residents, particularly those who rely on their own borewells to access water. The existence of a large number of privately owned wells also poses a challenge to addressing the falling water table.

3. Methodology

This research aims to qualify how urban poor individuals in Lahore, Pakistan obtain and utilize water for daily use. This study uses qualitative methods including observation and interviews conducted over the span of 12 weeks from May to July 2019 in Lahore, Pakistan. I observed individuals in multiple contexts, within their homes or at their workplaces. I also observed multiple water filtration plants in several neighborhoods in Lahore, as well as attending a meeting of water utility officials discussing possible utility improvements. Interviews were conducted with individuals and with nonprofit organizations that are involved in water provision as well as with local water utility officials. The participants in the study are not meant to be representative of the urban poor population in Lahore. This study aims to characterize the landscape of available water resources to the urban poor in Lahore and to outline some of the obstacles faced by urban poor individuals in obtaining water for themselves and their families.

3.1 Language and Translation

All interviews in this study were conducted in Urdu which is the national language of Pakistan. As the child of Pakistani immigrants, I am fluent in spoken Urdu and was able to conduct all the interviews. At times communication was difficult which I attribute to two factors. The study context was confined to Lahore in the province of Punjab, in which presumably, individuals mix Punjabi within their Urdu. I am unfamiliar with Punjabi as I hail from a different province of Pakistan where Gujrati or Sindhi are the main languages spoken in addition to Urdu. Additionally, it came to my attention that I am more familiar with a formal variant of Urdu as opposed to the informal variant that many of the participants in the study were more familiar with. The difficulties caused by these problems were almost always overcome by my asking questions of the participants to clarify the information they provided me.

In a few exceptional cases I had a very difficult time communicating with a few participants. These participants were of Pushtun origin and did not speak Urdu fluently. I hypothesize that these individuals were marginalized in part due to their ethnic origin. These participants lived in informal tent dwellings. In this particular case I communicated with them with help from the individuals from a local health office who brought me to the participants. These interviews do not contribute to the findings outlined in this thesis.

For the purposes of analysis, I translated all the interviews and notes taken into English. Additionally, a translator was hired to transcribe those interviews for which there were audio recordings into transliterated Urdu. In the case that I was unable to understand something said in an interview I had access to the translator particularly in the case that the terminology used by the interviewee was in Punjabi or used informal language I was unfamiliar with.

3.2 Work Contexts

Two types of interviews were conducted, one with individuals regarding their daily water use and another with organizations that were involved in varying ways with the provision of water

within the city of Lahore. I found individuals to interview in (1) the building in which I was stationed Arfa Software Technology Park (Arfa Tower) and (2) in neighborhoods that were serviced by a Basic Health Unit that I was in contact with. Organizations I interviewed include the Water and Sanitation Authority (Lahore's water utility), World Wildlife Foundation, Al Khidmat Foundation Pakistan, and Akhuwat among others. Interviews conducted with organizations often took place in the organization's work spaces.

In Arfa Tower, I became familiar with the custodial and security staff and began interviews with them a month into my time working out of the building. I asked individuals I was familiar with if they would feel comfortable talking to me about how they access and use water in their day to day lives and scheduled times during their lunch breaks or while they had down time during their assignments. Upon learning that I wished to conduct interviews with many individuals, the custodians I had become familiar with introduced me to other custodial staff I was less likely to come across. As such my interview selection functioned as a snowball sample confined to Arfa Tower. Because interviews were often conducted during working hours many interviews had interruptions due to the individual needing to get back to their work momentarily or address their superiors. Additionally at times interviews were conducted in locations where multiple people congregated and there would be some interjection into the conversation I was having with the interviewee. There were limitations on the degree of privacy and leisure time individuals felt they had in talking to me which made interviews more challenging and could have biased or limited the responses I received.

In addition to the interviews conducted in Arfa Tower, I conducted interviews in people's homes. These interviews were possible because I shadowed health workers from a basic health unit I was in contact with. In total I shadowed three health workers in their respective neighborhoods. Additionally, I was taken by several health workers to a region where families lived in informal tents to conduct interviews there as well. Each health worker I was assigned to, took me to their respective neighborhood, as such they were very familiar with the families who lived in the neighborhood. The health workers made choices about who they would take me to in their neighborhood which were likely driven by the likelihood that someone would be available to speak to me but also perhaps driven by who the workers were themselves more friendly and familiar with. The health workers themselves were considered better off and more liberal particularly as they were working women and as such there may be some bias in the selection of families they introduced me to. In these interviews I was better able to observe the housing and water infrastructure inside people's homes (piping, faucets, nozzles etc.).

3.3 Observation

Observations mainly took place in one of three contexts, (1) during interviews in families' homes, (2) in Arfa Tower, and (3) during trips out to see WASA WFPs.

Observations of families' homes were limited to the duration of the interviews I conducted in their homes and lasted in total approximately 6 hours. During the interviews I was better able to utilize the context to spur conversation on how water is stored and utilized in the household, I

also took pictures with the interviewees' permission of water jugs, pumps for bore wells in the household, among other items.

There was a wider scope of observations I was able to take from Arfa tower due to my access to the building. I wrote observations in my notes during interviews. In addition I was able to notice behaviors related to water use both by observation and conversations that were not part of interviews. These observations and conversations were mostly (though not exclusively) with female staff because women talking to men frequently is understood to be culturally atypical. One notable observation was that multiple women I was familiar with had complained of stomach upsets or pain and two women that I know of had taken time off (albeit cuts in their meager pay) due to stomach issues.

Lastly observations were taken of water filtration plants in different areas of Lahore. These plants were often belonging to WASA but plants that belonged to NGOs and mosques were also observed. Water filtration plants were found in varying conditions with some well kept and others clearly neglected. Notes were taken on the state of the plants and supplemented with images.

3.4 Interviews

Semi-structured Interviews were initially planned to be conducted at water filtration plants while individuals come to collect water. It quickly became apparent that the environment made it difficult to establish credibility and trust with the interviewees. Most individuals who spoke to me at the water filtration plant felt uncomfortable being recorded; some refused to speak to me outright. This in part may be due to the cultural sensitivity around mixed gender interactions in Pakistan. Furthermore interactions at the WFP were rushed as it generally took less than five minutes for individuals to fill water. Due to this interviews were restructured to allow for longer 30 minute interviews.

In total 35 semi-structured interviews with urban poor individuals living in Lahore were conducted, lasting an average of 21 minutes. Interviews were semi-structured and focused on three main topics: water access, water usage, and perception of water quality. The interview questions were updated to reflect discoveries of interesting behaviors over the duration of the study. The full text of the questions outline is provided in the appendix.

Ultimately interviews were conducted in three contexts, with custodial and security staff in Arfa tower, in people's homes while accompanied by basic health unit staff, and with organizations in a variety of different locations. Interviews conducted in Arfa tower were with individuals with whom I was able to develop rapport prior to the interviews being conducted, as such individuals I interviewed were much more willing to consent to recording the interviews. Interviews conducted with BHU staff generally had more individuals who refrained from recordings. In these cases extensive interview notes were taken. Discomfort with recordings was also prevalent in more socially conservative neighborhoods.

3.5 Analysis

Once interviews were conducted, hand written notes were formally written into a typed document and marked by a number to indicate they came from the same source. I translated the transliterated text from the audio recordings also marking them by number. Notes from observations were also included and numbered by location. Once all the content was compiled in one document in a uniform format, iterative thematic clustering was utilized to produce 8 broad themes amongst the data.

4. Results

4.1 Water Sources

Water for the urban poor in Lahore, Pakistan is often obtained from multiple sources. Most though not all households use two separate water sources. One is used for laundry, household cleaning, washing, bathing i.e. household water use and often a separate source is used for drinking water.

Two of the main sources for household water among urban poor families who have permanent housing include water provided by the regional water utility, Water and Sanitation Agency (WASA), and household boreholes used among families that do not have access to piped water supplies. These sources are also used for drinking purposes by some households.

WASA's jurisdiction does not extend to the entire city of Lahore and not all households within WASA's jurisdiction have piped water connections. There are multiple housing authorities within Lahore that provide water to their residents via separate water infrastructure. These housing societies generally house only to the affluent and wealthy. There remain significant swaths of Lahore that are not covered either by WASA or a housing society and thus these areas are not provided with household water connections. In these areas families drill their own bore holes on their property, generally in their homes to obtain water. Drinking water is often obtained from a separate source, at Water Filtration Plants (WFPs) which are sites where water is filtered and available for collection across the city. Water filtration plants are almost exclusively used for the provision of drinking water and sometimes for water used for cooking. Notably not all families utilize WFPs, many will simply use the water obtained from WASA in their homes or from their bore holes. Some families will take precautions to try to improve their household water's potability prior to using it for drinking purposes.

4.1.1 Water and Sanitation Authority (WASA)

Water provided by WASA to households within its jurisdiction is sourced from deep tube wells located throughout the city of Lahore. Water from tube wells is extracted using a large motor or water pump which 'sucks' water from the aquifer. **In most areas, the tube wells are directly attached to the water distribution infrastructure. No functional large scale water storage was observed at any interview sites** which is consistent with research and reporting of WASA Lahores' water infrastructure [15]. In general, several wells will feed into one localized distribution network for one neighborhood or locality.

WASA operates the tube wells for a limited number of hours in the day, and due to the lack of storage within the water infrastructure, water is only available during these limited hours to the population. While it is reported by World Wildlife Foundation in in a 2014 report that WASA runs the motors for its tube wells between 14-18 hours in the day (~20 hours during summer) [15], my interviews, which took place in the summer suggest that the length of time water is available varies much more broadly and is generally much less than the cited hours. Most individuals I

spoke to reported water being available for several hours in the morning and several hours in the evening. Due to the limited duration for which water is available, families utilize water storage tanks within their homes to collect water when it is available.

Furthermore, the pressure at which water is distributed in WASA's infrastructure is often too low to reach the taps of homes, especially if the family lives on the higher floors of the home. Since water pressure is low and storage tanks are generally kept on the roof of the home families utilize water pumps to supplement the pressure from the WASA's infrastructure in order to get water to the rooftop storage tank. This is detrimental to the water infrastructure, causing fluctuations in the overall pressure in the system and weakening joints in the water piping according to an individual from the Agence Française de Développement (French Development Agency) who works closely with WASA to fund projects to improve water infrastructure and institutions in Pakistan.

Using WASA's Household Connections for Drinking Water

Some families directly utilize the water coming into their homes from WASA for drinking water, others utilized the water for drinking but also took some precautions. Multiple people noted that they did not trust the cleanliness of their water tanks and as such diverted the water coming into their homes in different ways to use it for drinking water. One person elaborated, "We'd close the valve to the water tank and run the motor and collect that water (directly from the tap) in bottles for drinking" and another said "there is a small tap in the bottom of the home that connects to the governmental water where we get drinking water from a new bore and so the water at that tap is clean". Others practiced precautions such as boiling the water. "We don't use WFPs instead we boil and strain the water in our home and drink that", claimed one woman.

Interestingly, there was one case in which an individual noted that once connected to the governmental water supply their family stopped going to the WFP for water and began using the water in their home for drinking purposes. Transitioning away from using WFP for drinking water was uncommon among the people I interviewed, but one reason for this may have been that when communities are first connected to governmental water, the piping infrastructure is new and the wells are relatively deep and thus the water is likely much cleaner. One individual in another interview said that when new infrastructure was put in place by WASA in her neighborhood the water quality and pressure were much better than the previously installed WASA infrastructure which might explain the interviewee's behavior.

4.1.2 Household Bore Wells

Communities that do not have access to piped water connections rely almost exclusively on bore wells for household water access. One person I interviewed reported: "*There is no governmental water supply in our neighborhood, the entire neighborhood has put in bores in their homes*". These bores are shallower versions of the tube wells employed by WASA with smaller, electric water pumps to pull up the water. In my interviews, all but one family utilized a storage medium, a large plastic tank that was generally situated on the roof of the home to pull

water from the bore and store in the tanks for later use. One individual did not have a storage tank at the time that I interviewed him because their family had extended their home and were unable to find a place for the tank. He reported that the lack of a storage tank resulted in much higher water waste and anxiety over high electricity charges for extracting more water than they otherwise would have used. While families who have bores could pull water from the aquifer at any time, most families ran their water pumps in the early morning to fill their water storage tanks and then utilize the water throughout the day.

Fig 1: Electric water pump connected to a borewell installed inside an interviewee's home. Pumps were generally run once a day, often in the mornings siphoning water into large storage tanks on the roofs of families' homes.

Using Household Bore-Wells for Drinking Water

Communities that fall outside WASAs jurisdiction though still inside the city of Lahore vary in their access to water resources. Some communities in such areas had access to several WFPs in their neighborhood, generally from local mosques, non-profits, and nearby factories or companies. But there were also neighborhoods in which there is only one WFP which would therefore make it difficult for many individuals to get to, making use of water from bore wells for drinking purposes a necessity. Other communities didn't have any WFPs in their neighborhoods

at all, such as this individual who stated "*When we didn't have WFP in the neighborhood then we drank the house water from the bore*". Some individuals noted that they tried to take precautions when using water from their bore well for drinking purposes. One individual said, "*We use the water we get in the house (from the bore) and boil it and then strain the water with a cloth (before drinking it)*". Other individuals noted the difficulty of using these precautions, stating, "*we tried to boil the bore water but it took lots of effort and so we didn't do it much*" and "*We used to think about boiling the water at home when we used the bore water for drinking but back then there was no gas and we bought cylinders of gas for cooking. We thought it would take so much gas to boil the water that it wasn't practical to do. Also boiling takes so much time*".

4.1.3 Water Filtration Plants

Water filtration plants (WFPs) are installed throughout Lahore and provide purified water to the neighboring areas. WFPs all involve a row of taps generally out in the open from which people can fill water as seen in Fig 1. Water collected is generally used for drinking and sometimes for cooking. On occasion, individuals will also collect water when their household water supply is not working. Water filtration plants are installed by many different entities and differ from one another in small ways. Many WFPs are installed and operated by WASA but there are NGOs, factories and businesses, and mosques that also operate WFPs across Lahore. Most water filtration plants provide water for free, though some do charge a subsidized fee. Some WFPs will cool the water which is particularly pertinent in the summer months when temperatures can remain in the upper 40 degrees Celcius for long stretches. There were also some WFPs that publicly post the results of water quality tests completed on the plants' water for individuals using the plant to see.

Fig 2: Taps at a water filtration plant in Lahore, Pakistan. The broken head of the tap can be seen on the floor tile.

A large number of water filtration plants are installed by WASA. These plants include an onsite tubewell, a large pump, and storage tank for the extracted water. WASA's tubewells are operated by individuals who turn them on and off according to a set schedule. Water extracted from the tubewell is immediately chlorinated and then stored in the water tank. A separate small housing structure exists for the filtration equipment which includes a pump to increase pressure and force water through ultrafiltration membranes, and three additional filters, one for adsorbing arsenic, one sand filter, and one activated carbon filter. **No additional chlorine is added to the water after it is filtered, which has been noted as problematic by multiple water experts I spoke to in Pakistan. The activated carbon used as part of the filtration process removes free chlorine from water.** Without any free chlorine in the water when it is dispensed, there is increased risk of recontamination of water in the vessels used to collect it.

While a large number of water filtration plants are put in by WASA, there are also WFPs put in place by housing societies, factories, mosques and even the World Wildlife Foundation (WWF). While providing drinking water is not part of WWF's core mission, the agency chose to pursue this given the significant lack of access to clean drinking water in Pakistan. The provision of water by factories and mosques is generally philanthropic. Many NGOs provide the option for

individuals to fund the installation of WFPs as well. I observed at least one filtration plant that was labeled as being funded by a family, located in a low income area in Lahore.

Water Filtration Plants Use for Drinking Water

A majority of individuals I interviewed stated that they got their drinking water from WFPs. In regions where WASA provides water to homes, it also provides WFPs for people to collect drinking water. In regions of Lahore outside of WASA's jurisdiction non-governmental WFPs service some neighborhoods but other neighborhoods do not have adequate access. Water filtration plants outside WASAs jurisdiction belong to many different entities and are often unmarked; this section does not differentiate as to what kind of WFP individuals went to.

Many individuals alluded to the fact that getting water from WFP had become a habit. One woman explicitly said, "*Now when we drink water from the bore in our home it tastes bitter to us. It's not that the water coming here is not good, it's just that we've gotten into the habit of drinking the water from the WFP*".

Among all the different water sources available to the urban poor, WFPs were most commonly seen as dispensing water that was clean to drink. One individual noted, "*The water coming into our homes hasn't really improved but now since we don't have to drink that water (due to the addition of a WFP in our neighborhood), it is much better and we're more content with the water situation*".

Many individuals noted that they used water from WFP for cooking as well. But some noted that while they understood that they should use water from the WFP for cooking, it was often too difficult to do so. One person said she should use water from the WFP *"for cooking as well but we'd have to carry more water*". Another person claimed "*if for some reason we weren't able to get water from the WFP we'll use the house water for cooking. We have to do the cooking so we don't have a choice*".

4.2 Perception of Water Quality

There is no reported use of surface water for the provision of drinking or household use throughout Lahore. All water obtained is groundwater pumped from the aquifer. The main difference in water provision is not the origin of the water but rather the manner in which the water gets from the well to the families.

There is a general perception that water coming from the aquifer is clean. Often individuals would remark "*we don't have groundwater but if we did then that water would be clean, of course, because groundwater is always clean*". In some interviews individuals mentioned that they believe the mechanisms used for water transport or water storage are unclean and thus they obtain drinking water from the tap before it is stored in their household tanks.

4.2.1 Water quality of WASA

Among families that had household water connections through WASA, there is general knowledge about governmental water lines mixing with sewage lines and providing contaminated water to the public. One person noted: "*there are old pipes that are laid near sewage piping and you get a mixing of sewage and the clean water going to people's homes"*. Other people stated that this was more of a problem when there were heavy rains and flooding which caused the sewage pipes to overflow. Some noted that they believed they got water mixed with sewage at certain points in time but did not believe this was due to any event. There appears to be a feeling of resignation among many individuals: "*nothing can be presumed about the water situation getting better because the underground piping is so complex*".

A WASA official admitted "*in some cases, when piping has been replaced, the old piping was never removed and some of the connections were not made to the new pipe, resulting in the water still traveling through some of the old pipe system*". He went on to address the poor water quality: **"*The biggest source of the problem of contamination is that the supply is intermittent. Water is obtained from the tubewells and when the tubewell is turned off, it creates large negative pressure which encourages contamination and fatigues the infrastructure, particularly joints in the piping."***

4.2.2 Water Quality of Bores

Some individuals describe water that they get from bores in their home as being discolored, either whitish or yellowish, or simply tasting bad. Individuals complained: *"the bore water was exceptionally smelly, absolutely not worthy of drinking"*. Some distinctly noted discoloration: "*When we used to boil the tap/bore water, the contamination in the water would sit on the bottom, it was a white-ish color and would separate out and the clean water would be on top" and "the bore water appears clean when it comes out of the ground but becomes a yellowish color when it's sat in the tank for some time"*. One individual I interviewed insisted the bore water was causing his children's teeth to rot.

4.2.3 Water Quality of Water Filtration Plants

The vast majority of interviewees, regardless of if they used WFPs or not spoke of the water filtration plants providing much better-quality water than what they used in their homes, either from WASA or from bores; 26 of the 35 individuals interviewed used water filtration plants to obtain drinking water, of the remaining respondents all except two respondents expressed a preference for WFPs but cited obstacles to using them. WFPs would sometimes post the results of water quality tests, in an effort to increase public trust. I've only seen this once at a WASA filtration plant but also heard about it from individuals I interviewed. Perceptions of cleanliness were also supported by health professionals and government workers promoting the use of water filtration plants as a way to get safe drinking water. One woman I spoke to said the water from the WFP "*shines*" and is "*absolutely clean*".

There were, however, some reports that cast doubt on the quality of the water. A government worker doubted WASA was completing water quality tests as frequently as required. She also expressed concern about the lack of chlorination of the water which made recontamination of water easier. One individual I spoke to who used their in-home water supply for drinking stated they didn't like the taste of water from the WFP which they'd tasted in the homes of neighbors.

4.3 Changing Consciousness of Water Borne Illness and Water Quality

While stomach ailments likely resulting from unclean water are still common, many individuals in this research noted changing perceptions of the importance of clean drinking water. Many individuals noted doctors advising them to collect water from WFPs. Others noted family connections encouraging them to treat their water before drinking it. The knowledge of requiring clean drinking water was found among most of the respondents but may have been affected by a bias in the sample. About half of the participants worked in a building with businesses and a university surrounded by people of higher income and education level who are more aware of waterborne illnesses.

The prevalence of stomach illnesses remains fairly common in urban poor populations in Lahore, which is considered normal among the people I interviewed. One man mentioned: *"I get stomach upsets and diarrhea frequently but never too severe. Really the illness of the stomach isn't really an illness at all* ". Another man noted that in his worker housing, where nearly twenty people lived, at least one or two people were ill at any given time.

Many individuals noted that their perception of the water quality of their in-home water source has changed in the recent past. Access to individuals with greater knowledge about water quality issues appears to have had some influence on the way people use and understand water. One individual I spoke to said, "*we started boiling our water a couple of years ago, our older brother is in a health post in the government and he recommended to us that we should boil our water but we had ignored him for a long time but then came around to the idea, now boiling our drinking water is habit*".

Many families reported that when someone, generally children, in the household got sick and were taken to a doctor they were advised to start getting water from filtration plants for drinking. Others began doing this even without instructions from doctors showing awareness of water quality and its relationship to health. One individual noted: "*I used to say that the bore water is clean since it was coming directly from the ground but then my children got very sick and the doctor told us we should give the children filtered water and that the bore water is not comparable in quality to the filtered water*". This happened three years ago and since then this family has used water filtration plants to get drinking water. Others stated that they changed their behavior momentarily while they or their family members were ill. Some would take water from the building in which they worked which provided clean drinking water, others said they would buy Nestle water or get water from WFPs while they or their family members were ill.

The reports of changing perceptions on the importance of clean drinking water may be skewed by the fact that many of the respondents in the study worked in a building that houses a university and businesses. Being in an environment where people value access to clean water may predispose them to adopting the same ideas. This can be seen clearly in one interviewee's comment "*in being among educated people ... I began to understand about water, the people [who live] near me didn't bring water from the WFP, only I got water from WFP".* Changing perceptions were seen among individuals recruited from the basic health unit also, who were not exposed to the university or businesses.

4.4 Inequities in Access

Several factors contributed to inequality of access to different water infrastructure. The greatest deterrent for people using WFPs was distance. In addition to not having a WFP close enough to collect water, norms around women not going out alone made collection of water impossible or very difficult to collect water for families where the men were unable to collect water. Inequities in access could also be seen in the workplace where lower income workers were expected to provide their own water while higher paid jobs would provide clean water access within the workplace. Piped water access was also varied with closed loop water infrastructure allowing for widely varying quality and quantity of water to be provided to different neighborhoods.

4.4.1 Challenges Accessing Water Filtration Plants

Access to water filtration plants is determined almost entirely by the distance from families' homes and by the means of transportation available to the family. Having access to a motorbike eases the task and expands the area over which one can travel for water but does not eliminate distance as a significant factor contributing to clean water access. One interviewee noted, "*When we didn't have WFPs in the neighborhood then we drank the house water from the bore".* Another said *"The WFP is far from us. We can go walking to it but carrying water back from the plant is not possible at such a distance which is why we don't get water from the WFP".*

Many people mentioned scenarios under which they were not able to access the WFP so they would use whatever water supply was in their home (WASA or water from bore wells) for drinking. One individual said "*sometimes we don't have water from the WFP and so we'll say a prayer and drink the water from home, what else is there to do? At least there is water"*. Another individual noted that they took precautions when they couldn't access water from WFP, stating: "*some time ago we didn't get drinking water from WFP, instead, we'd boil the water that we'd get in our taps at home but even after boiling the water was not good, it would smell".*

There are several infrastructural and institutional problems that make accessing water from WFPs difficult. The tube wells that feed WFPs are operated by human operators. Their primary job is to turn on and off the motor for the tubewell in the WFP based on a predetermined schedule. WASA officials acknowledge that these workers are often inconsistent, which lowers the consistency and quality of water services. One individual noted, "*the WFP isn't open all day*

because the person who runs it only shows up to open it in the evening". Another said, *"sometimes the person that runs the tubewell who has the key for the room isn't there and you can't make use of the WFP"*. Besides the inconsistency of the tubewell operators, there is no official schedule communicated to the public. One interviewee said, *"there was once that my husband went to get water and the timings for the plant had changed and he wasn't aware so he was only able to fill half the bottle and then he came home; the tube well operator told him that he was shutting the plant down*". Water filtration plants are also often closed without warning on a somewhat regular basis. One person I spoke to was unsure why they were unable to get water from plants, *"some people say it's some internal problem with the plant, others say it's the electricity".* Closure of WFPs often occur without warning or explanation. These closures are at times attributed to intermittent electricity or maintenance of the plant. There is a general sense that timings for WFPs while consistent enough for people to have an approximate sense of when they are open, often do not strictly follow their schedule which makes accessing water more difficult. One person expressed to me, "*sometimes we go to get water and there isn't any so we come back*" and this sentiment was echoed by everyone I interviewed who used WFPs.

4.4.2 Gender Roles

Within the urban poor population, water is generally retrieved by men. This is a function of the social norms where women going out alone is seen as taboo. This occasionally poses a problem for families in which the men are unable to get water. In three cases women noted a physical injury, illness or limitation preventing the men in the family from being able to collect water. In one case the woman's spouse had respiratory problems; she would go to get water but expressed concern over the safety of going out by herself. Another family would have the younger brother bring larger quantities of water once a day to ensure water did not run out and the father in law, who has a physical disability, did not have to go out to get water. One woman referenced her husband's long hours as a difficulty: "*my husband works a government job and his hours make it so that it is difficult for him to get water*". When I asked as to why she didn't collect water since she was home she responded "*we (women) don't leave the home"*. In this case, the family is forced to drink the water from their household water source despite being aware of and having a desire to obtain cleaner water from the WFP.

4.4.3 Variability Among Neighborhoods

There is also a great deal of variability in water access for individuals who get water from WASA. **Since the water infrastructure is a closed loop within each locality or neighborhood there can exist very stark differences in water access between different neighborhoods that are quite near one another.** One woman remarked *"I used to live in my parents home not far from where I live now and we didn't have any issues with water, we didn't even know that water access was disrupted because it was seamless*", since she'd moved in with her spouse a few houses down she said the water situation has been very problematic with water hardly coming to her home. While in both homes water was being provided by WASA, the quality of service differed drastically albeit that the houses themselves were not very far apart.

Other individuals live in neighborhoods that fall on the border of where WASA provides water, with neighbors having access to WASA and the next neighbor requiring a borewell. One participant noted that his mother lives minutes away in a nearby neighborhood where they didn't have access to piped water from WASA. He noted that his mother needed to install a much deeper bore well to ensure she accessed water as the water table fell. He lamented the cost of installing the well. He on the other hand didn't have to worry because he had government provided water in his neighborhood.

4.4.4 Inequities in Water Access in The Workplace

The availability of water in workplaces varies and is far from guaranteed. **The provision of water generally follows class boundaries, with lower level jobs such as janitors, security personnel, police officers, etc. having to collect their own water for drinking purposes. This is in stark contrast to universities and businesses which pay for the provision of water for their workforce.**

During interviews conducted at a water filtration plant in early morning hours, I found two individuals who were collecting large quantities of water for their respective workplaces, a police station and a nearby factory. They told me that this was a part of their daily routine, collecting water for all the individuals in their workplaces as drinking water was not provided for them.

Arfa Sotware Technology Park (commonly referred by respondents as Arfa Tower), the building where I worked, housed a university, multiple businesses, an incubator, library, and various other spaces. Water dispensers some of which also cooled the water were located throughout the building but were only available to select personnel. Based on limited observations, there was consistent water provision for faculty and staff within the university, as well as for many of the businesses. A secondary tier of access consisted of individuals who had access to spaces where water was provided, such as janitorial staff. One participant reported that they *"get water in the building to take home everyday; 1-2 bottles from different places, no one stops me. They let me fill large and small bottles*". There was an understanding that while the water was not intended for their use, no one would stop the janitorial staff from using it. Additionally, individuals who had personal connections to other individuals who had access to water dispensers were also able to get water or ice from water that was allocated for the university or businesses. One woman told me she would get a friend of hers, who also worked in the building, to freeze water so that she was able to take ice home during the hot summers; she said that this was "under the radar". The last tier of individuals were those who did not have access to water provided for the university or businesses and needed to collect their own water. Some individuals reported that "*The water available to the staff of the building is a separate system. That water is not for the guards so we make provisions for our own water".*

4.5 The Role of Water Pumps and Electricity

Access and use of electricity is inextricably tied to water access in Lahore. Households who rely on borewells use electrical pumps to pull water from the aquifer; households that rely on piped water from the water utility utilize water pumps to supplement the low pressure from the utilities water mains. Problems in electricity access such as voltage fluctuations, intermittency, and high costs are fundamentally tied to water access as they affect the electrical water pumps utilized by the majority of households.

4.5.1 Usage of Water Pumps

Since all the drinking water in Lahore is sourced from aquifers beneath the ground, everyone who accesses it requires electricity to do so. Water filtration plants, provided by WASA and other entities, household water access via WASA, and individuals who access water from bores in their homes all rely on electricity to access water. **The voltage fluctuations, high cost, and unreliability of electricity, all adversely affect water access regardless of the medium used to access water.**

WASA sources water from deep tube wells and pumps water directly into water mains to distribute it throughout the neighborhood. Most households require additional water pumps to be able to access water, due to WASA's inconsistent water pressure and limited hours. Households which have their own water pump are sometimes able to access water even when WASA's tubewells are not running. One individual noted "*for people who are connected to governmental water but have pumps, they don't have an issue because they can pull the water, other people have to wait if they don't have a pump"*. Additionally the pressure provided by WASA in the water mains varies between homes; most people claim that it is insufficient. This problem is worse for families who live on the second or third story of the home, which is a common occurrence since several families will often share a single multistory house. This makes water access for those on higher floors much harder. One individual noted, "*previously we didn't have a motor in our home, the water used to come with greater pressure but now it comes at very low pressure at the ground floor and not at all up (on the higher floors)*". Another individual, whose family lives on the third floor of the home, said *"in our home we always have to use the motor because the water pressure isn't enough*". **This is supported by the fact that 80% of the interviewees who have water provided by WASA also had water pumps in their homes.**

Those who get their water from WASA do not necessarily need to have their own water pumps, unlike those who rely on household boreholes. Those families have no choice but to have a water pump to suck water up from the aquifer. In one case, an individual at a water filtration plant told me "*we're not getting water in our home because something is wrong with the water pump, so we've come here to get water",* illustrating the reliance on household water pumps to access water.

4.5.2 High Costs

The use of water pumps to access water is ubiquitous; if you get your water directly from a bore in your home, you have no choice but to use a water pump. If you live in a home where you are connected to WASA's water supply, you also likely will require a water pump because of low pressure in the water mains. Water filtration plants themselves rely on water pumps and electricity to access water and also to purify it. The prevalence of water pumps and the fluctuations in voltage throughout Lahore often lead to problems. One person notes about the WFP he uses "*since the electricity is not consistent ... Sometimes the motor burns out due to that. In those cases there is a 24 hr disruption to the availability of water"*. Another person made a similar observation about their household pump: *"The old motor broke due to an electrical surge and thus we needed to replace it"*. Other people mentioned similar problems with their water pumps, claiming *"small issues with the water pump are normal, sometimes it'll stop or the electricity isn't working properly"*. Others reported repeated issues with their household water pumps like this person who said *"at some point we gave money to put in a water pump to pull up water to our floor but the motor ran for 2 weeks and then stopped working… [we were told to] just collect the water from the bottom floor of the home manually"*. Problems with water pumps were widespread regardless of how the water was accessed.

Access to electricity in Lahore is intermittent. One person put it quite succinctly: *"Electricity, you are aware, in Pakistan is unreliable"*. This poses an additional hurdle for water access. The degree of intermittency varied among those I interviewed. Some people noted that electricity loss only lasted for a small amount of time and thus wasn't as disruptive: *"the electricity goes out but we never have an issue with water due to the electricity; the electricity only ever goes for 5-10 min"*. Others, however, said *"There are some days when there isn't any electricity for the whole day, and so on those days we have trouble with the water*". The loss of electricity was noted by the vast majority of people as being unpredictable. I found one peculiar case in which an individual told me *"consistently on Mondays the electricity will go from 8 am to 6 pm and so those days we struggle a little bit (with getting water)* ". This case was unusual as all other respondents said that loss of electricity was unpredictable both in occurrence and duration.

Electricity is both vital to accessing water and is also very expensive. WASA's 2016 key performance indicator report states that electricity costs made up nearly half of the total operating costs incurred for that year. Costs are also incredibly high for families who have bores in their own homes. Many individuals expressed concern over their electricity costs and tried to limit it as much as possible. Some said "*We try really hard to not turn on the water pump",* another noted *"typically we run the water pump 2-3 times a day, we try to only run it twice because the bill comes for the electricity, so we try to use it less"*. One saying *"of course his family struggled to get water with electricity costs so high*". WASA's customers, on the other hand, incur lower electricity costs, particularly when the water is also being pumped by WASA, which provides some starting pressure within the infrastructure.

Electricity costs also make up a large percentage of the cost of running filtration plants. The electrical costs for non-WASA WFPs vary. In the case of WFPs put in by the World Wildlife Fund, while costs were initially footed by WWF, the costs were slowly, over the span of a year, transitioned to the community that used the plants [with varying degrees of success]. In another instance, a political party established a filtration plant in a community as a means of winning votes. The party had an ad hoc method of ensuring payment which sourced the money from the political party itself. On one or two occasions, the WFP was closed because the electricity bill was not paid on time. Other WFPs run by NGOs, factories, and mosques likely have their own schemes for paying for the electricity needed to run the WFPs. Some WFPs charge for the water they provide which is much lower than the cost of buying bottled water. This fee is used to offset electricity costs.

4.6 Household Water

The experience of accessing water in ones' home was found to be a function of the type of housing people occupied. Many families lived in two to three story buildings that housed multiple families, often one family per floor. In these situations water access from WASA Lahore was divided among households. The manner of dividing cost and infrastructure varied. Water infrastructure in homes was found to be informal with rubber tubing and other materials used to split taps, and ad hoc solutions employed to direct water. The experience of contracted workers who lived in shared housing was markedly different than most others. For contracted workers water provision was arranged for inside their shared housing. These individuals did not know or worry about water access in their homes in the manner that most other households did.

4.6.1 Shared Homes

Living arrangements among the urban poor individuals I interviewed often involved joint families living in one home or multiple families renting within one house. In one case there were four related families living in one home, eighteen people in total within the house. There were also plenty of families that would occupy rented floors of a home in which the landlord often lived on the ground floor. This often resulted in large numbers of people living in one home and often sharing both household amenities like kitchens, washing areas for laundry, water taps and water infrastructure like water pumps, water tanks, and electricity meters.

The main cost of getting water is the electricity cost (both for bores and governmental water) and as such people I interviewed had devised different ways of handling the division of electricity costs. Some split the electricity costs and others shared the costs of installing infrastructure such as water pumps. Some people have separate electric meters to track individual family electricity costs. One particular family manually changed the wiring of the meter to ensure that the electricity costs were being properly attributed, while others alternated paying the bill each month. In shared homes, determining electricity use for obtaining water with any accuracy is nearly impossible. Another woman I spoke to lived with her spouse on a rented floor of a home with another larger family with children occupying the main floor. Since one family

was much larger and had children who utilized much more water, the water costs were split unevenly between themselves. The degree of difference was set arbitrarily as they shared all the water infrastructure in the home and it would be very difficult to determine the exact cost by usage.

The ambiguity that resulted from mixed water infrastructure among multiple families and the power imbalance between tenants and landlords creates unequal water sharing arrangements and often frustration among families. One person said *"we don't have permission to turn on the water pump to get water*", noting that the family downstairs controlled how long the water pump was used and how much water was filled in the tanks. Others noted similar situations where they didn't have control over water pumps and would ask the landlord's family if they could turn on the water pump when they needed to. Someone else noted "*before the house owner had rented out the other space in the house to a family that used a lot of water. I would return home and there would be no water in the tank for us to use"*.

There was a lot of variability in how water costs were split among people living in the same space. While people noted frustrations in sharing water infrastructure and lack of control over water access, the general sentiment was that these arrangements were normal. In order to split costs by water usage, families would require separate water tanks and electricity meters. This was not the case for any of the individuals I spoke with.

4.6.2 Worker Housing

Another subset of people I spoke to were workers who were employed by large companies that provided security and janitorial staff to large corporations that required them. These individuals were working in Lahore but came from other cities around Pakistan. They are provided housing by the companies that recruit and employ them, often in very dense housing. One individual noted that he lived in a room with three other individuals and that when the four of them left for their shift another four people would occupy the room while they were at work. Importantly, the provision of water was entirely handled by the employers. The workers are often unaware of the cost or storage of the water; this is in stark contrast to the experience of those in shared housing. Some individuals I spoke to noted the water was available all day, others provided timings that lined up with when WASA provides water in residential areas. The general sentiment among people who were in worker housing was of inattention to water provision. One person said that a fixed sum of money was taken from their paychecks to cover utility costs such as water though it is unclear based on my interviews if this was the case for all workers. Another noted that he was unaware of where water was stored and that there was likely a tank on the roof of the building but he was unable to see it. Individuals who lived in worker housing did collect drinking water from a nearby WFP for drinking purposes but didn't worry about water scarcity nor did they worry about the high electricity costs for the provision of water in their housing.

4.6.3 Household Level Water Infrastructure

Household water infrastructure for water storage, piping water throughout the home, and for dispensing drinking water is generally set up informally. For example, a pipe is attached to the top of most water tanks which will fill when the tank is full. This pipe is laid such that the falling water is visible to the people in the home such that they are aware of when to turn off the water pump when filling water in their tanks. Families would utilize rubber piping to split taps and provide water in different parts of the home. Of the households I observed, many of these joints leaked or were otherwise not secure. With respect to water collected from water filtration plants; families collect water in large containers. Many families said they would get water for cooking or drinking by dipping cups or pots into the water container to get water. These aspects of the household water infrastructure add to concern about contamination of drinking water and the level of hygiene one could maintain given the rudimentary water infrastructure.

4.7 Obtaining and Storing Water

Almost all the people I interviewed described obtaining water as a task that required significant time, planning, and coordination. For families that get water from WASA, a significant amount of time and planning goes into ensuring that they utilize water when it is being pumped by WASA's water pumps because obtaining water at other points in the day is more difficult and costly if it is possible at all. Effort is also put into ensuring that they have enough water stored to endure unexpected electricity shutoffs.

People will schedule their lives around the availability of water, often completing tasks early in the morning when water is generally available. One person said *"since the water comes consistently only in the morning, we wake up and fill the tank and do any work related to water early in the morning"*, another noted *"we make sure to do all the things that require water before the water goes at 9 am"*. Notably this finding might be biased by the fact that I spoke to many working men and women who left their homes for work in the mornings and thus might need to complete any tasks before leaving for the workday. That noted, individuals, particularly women often noted the availability of water as a key driving factor in when they completed certain tasks. One woman said "*we take note of the time there will be water coming so that we can do our water related work during that time".*

Another way in which people organize their lives around the availability of water is by consistently storing water in anticipation of not being able to access it later. Loss of electricity significantly affects water access. People will store water in order to prepare for possible electricity outages. Often people will store water in their large water tanks, some people have two tanks for this purpose, but for those who do not have large water tanks, storing water in buckets and other containers is common practice. One individual I spoke to described filling buckets after washing in the morning as part of his daily routine since he obtained water from WASA but did not have a water pump or water storage tank to rely on. One individual noted, **"*Before we didn't have the drums and buckets (to store water), and we realized without access to water, how humiliating it can be and so now we make sure to store water* ". The**

concern of having water is ever present and drives the behavior of individuals. When electricity outages do occur people ration water in attempts to make their stored water last.

In addition to the planning for utilizing and collecting water obtained at home, families also collect water from WFPs. For many people collecting water is a daily chore, 10 families I interviewed claimed they collected water every day, an additional 3 claimed to visit WFPS at least twice a day to collect water. Families will strategically try to plan times of day to go to the WFP when there isn't a rush. Yet still while people can account for travel time to and from the plant well, rush at the plants themselves is difficult to avoid and often increases the amount of time needed to collect water and introduces variability to the amount of time needed to get water. One individual notes, "*there is a huge rush at the WFP, it can take anywhere from 20 min to an hour to get water".*

4.8 Water Usage Patterns

In addition to complexities of water collection and storage the manner in which urban poor individuals utilize water in Lahore is in some aspects markedly different from the ways in which water is used in the West. Ofcourse water is used for cooking, cleaning, bathing, and laundry but in addition water is also used for cooling down in the summer months when temperatures are very high. In the summer months cooled water is often the only source of cooling available to families who don't have refrigerators or air conditioning. One woman noted to me *"if we have money then we'll ask someone for ice, if we don't have money we don't ask of anyone. I'll get 20-30 rupees worth of ice for the kids if we're able"*. Another woman noted she would ask friends who worked in the building who had access to the fridges and freezers in the building to freeze water for her which she would take back home after work as ice for her family. Some families are lucky to have access to cooled water from WFPs that are nearby but by and large most WFPs do not cool the water they provide including WFPs operated by WASA. Another way in which water is used for cooling is by showering, this is particularly true for families who have bore wells. Water when freshly pumped from the aquifer is cool and several families reported that they pumped fresh water to shower (as opposed to using water stored in their storage tanks). This was particularly true for children. One woman said "*Nowadays since it's so hot the water consumption is higher, it's very hot so we shower repeatedly , the cool water is used more. When we pull up the water fresh from the ground. It's nice and cold and we feel like showering... one feels fresh after showering in this heat, the water that remains in the tank becomes hot so we'll bypass that water and pull up fresh water to shower*". Many mothers lamented that water use became very high in the summer months when their children would take upwards of 3 showers a day due to the heat.

Routine chores involving water are conducted differently by the urban poor in Lahore. For instance washing clothing is a very high water use activity, clothes are washed by hand in large basins. Each item of clothing is washed out individually. One woman noted that the days on which she washed clothing they'd use much more water than on the days they did not. Showering on the other hand is a comparatively low water use activity when compared to the west. Everyone I spoke to took bucket showers, effectively filling a bucket with water and using

a smaller vessel to pour water on top of themselves. One participant when pressed about how she took showers noted "*You guys shower with a tap that flows water, that sort of amenity obviously isn't available to the poor. we use buckets to shower"*. These showers presumably utilize much less water than showers in the Western context do.

4.9 Knowledge of Water Scarcity and Water Conservation

Knowledge and concern about water scarcity fell in line with the method of water access used by the family. Families with bores had a greater knowledge and fear of fluctuations in the water table while individuals who lived in worker housing expressed a perception of abundance of water in Lahore. Families who utilized WASA for water access in their homes had varying perceptions of water scarcity.

Families who have bores in their homes are much more attuned to fluctuations in the water table, both seasonal and otherwise. One individual noted "*In the winter months water access is fine but in summer the groundwater level falls, it takes 10 minutes for us to fill our tank in winter months but up to 3 hours in summer months*". Others noted similar discrepancies in the amount of time needed to fill their water tanks. Many families recollected the need to deepen their bores to be able to access water from a falling water table as an inevitability. One participant matter of factly noted, "*As time progresses, the bore well's ability to get water is depleting and the water (in the aquifer) is going lower and lower. Then it finishes we have to get another bore put in*". Others expressed less optimistic timelines for requiring replacement of their bore wells, saying "*the bore pump has been here for 4-5 years and we need a new deeper bore now"*. There was a sense of anxiety over the falling water table and the need for deeper and deeper bore wells as one participant expressed "*Now the ones that are coming (new kind of bore wells) , they are placed at deeper depths . Before it used to be that at 100-150 ft water would come, now it's 250-300; the bore is bigger, the motor is also bigger, it has more power, those are the kind of bore wells they put in the ground now".*

Individuals who lived in worker housing perceive there to be an abundance of water in Lahore. Water is provided for these individuals by the company that employs them. A fixed amount of money is deducted from their paychecks for utilities every month and the logistics of providing water is handled for them. In one case an individual I interviewed noted that there was a woman employed to handle all water related work and he had never had to interact with her. One individual noted "*People have come here (to Lahore) from all over Pakistan, particularly Karachi because there is no shortage of water here in Lahore*". Water shortages in Karachi are highly publicized and part of the consciousness of Pakistani individuals and many others noted the known scarcity of water in Karachi when I expressed my research aims in Lahore. None the less families with bores have a sense of fluctuations of the water table and the lowering of the water table in a way that many others do not.

5. Discussion

The research conducted focussed on water access for the urban poor in Lahore. The water landscape for these individuals consists primarily of the city's main water utility, WASA Lahore, that provides access to piped water in peoples homes. In addition to WASA there exist an unknown number of private borewells put in place by individuals who lack access to piped water in their homes. In addition to household water access there are water filtration plants put in place by WASA Lahore and numerous other entities that provide potable water at communal locations for the masses.

5.1 Strata of Water Access Based on Socioeconomic Status (SES)

The type of water access available to households in Lahore was unsurprisingly found to correlate with wealth. The water infrastructure of Lahore is conducive to having many closed loop systems and as such lends itself well to the separation of access by socioeconomic class.

There exist many private housing societies in Lahore, a previous case study on housing shortages in Lahore establishes that just the plots within private housing societies are immensely expensive and thus housing in these societies is inaccessible to most of the population [29]. Private housing societies "are responsible for supplying water to their respective areas", separate from WASA Lahore [15]. The separation of private housing societies from WASA Lahore results in WASA being cut off from affluent users who would otherwise cross subsidize the cost of water across its users. Cross subsidies are widely understood to be the tool used to ensure financial sustainability of water utilities across both developed and developing countries [20].

Outside of private housing societies, a quarter of households living within WASA Lahore's jurisdiction do not have piped water access [5] in addition to those who live outside WASA Lahore's jurisdiction altogether. Households without piped water from WASA are forced to use borewells that they install inside their homes to access water from the aquifer. These families are intimately aware of seasonal fluctuations as well as the overall decline in aquifer level. In Lahore "the water table has fallen at more than half a meter a year for the last thirty years" [27]. The falling water table is a known reality to the poorest people of Lahore, and a source of financial worry and fear. It affects these people before any other segment of the population.

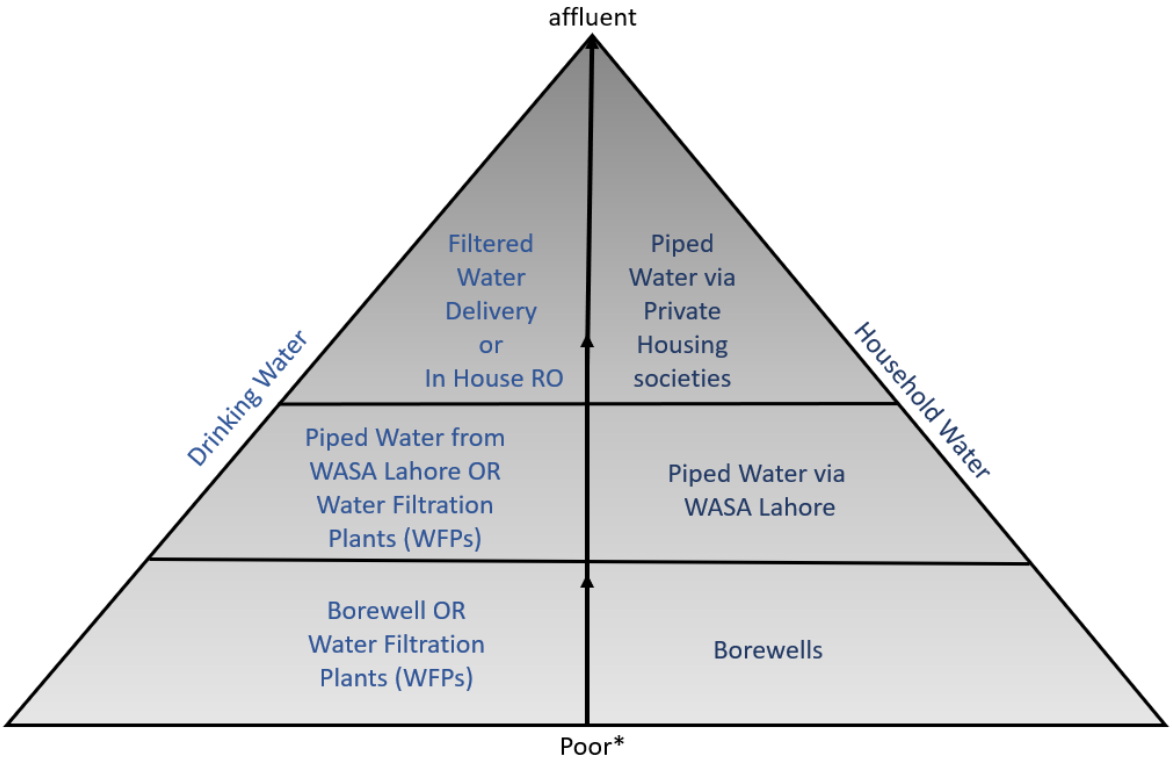

Figure 3: What water infrastructure one has access to in Lahore is in large part a function of social and economic class. This diagram does not show an exhaustive list of all water infrastructure and only includes families that have stable housing*

Furthermore, households using borewells incur a poverty premium for their water, the cost associated with using borewells is higher both for daily use and for maintenance than other water sources. Installation of a borewell is expensive and it is known by borewell owners that a replacement will be required as Lahore's water table continues to fall and borewells are no longer deep enough to reach the water table. Additionally, the ongoing cost of using electricity is the most significant regular cost incurred in using borewells. As the water table falls these costs will continue to rise as more electricity is needed to pump water from even deeper in the ground [24].

In the workplace, drinking water access follows the same class boundaries seen in household water access, with lower paid jobs such as janitors, security personnel, police officers, etc. having to collect their water to bring to work for drinking purposes. This is in stark contrast to universities and businesses which pay for the provision of water for their workforce. Individuals who work, especially in lower paid positions can spend nearly 12 hours of their day at work and as such drinking water access at work is a significant issue which has not been studied in great detail and deserves greater attention.

On the extreme end there are those who live in "katchi abadis" whose residents I have few interviews with. The experience of collecting and using water in these makeshift tent housing

communities is vastly different than any individuals living in stable housing. They did not have access to any household water supply and collected water from a pipe residing in the dirt in an open space near their encampments as seen below. This water was utilized for both drinking and household use.

Figure 4: Water pipe outside of “katchi abadis” used for drinking and all other uses.

5.2 Struggling Water Utility

The local water utility is caught in a cycle of poor performance and poor revenue that continue to feed into each other.

Among families that have household water connections through WASA, there is general knowledge about governmental water lines mixing with sewage lines and providing contaminated water to the public. According to one nonrepresentative study which evaluated the quality of water supplied by WASA Lahore, 50% to 62.5% of samples from water distributions systems in Lahore had bacteriological contamination; when taking similar samples after monsoon season, that percentage rose to 75% [17]. Contamination of water due to intermittent supply is well established [30][3] and was acknowledged as a problem during interviews. While WASA Lahore’s piped networks are pressurized, limited to no water storage within their infrastructure, along with very limited hours of operation of WASA’s tubewells, incentivise people to use additional water pumps and storage tanks in their homes; this helps to increase the quantity and duration of water they can access. The use of additional pumps is detrimental to the integrity of the piped infrastructure but is necessary for individuals to get water, often because the pressure produced by WASA Lahore’s pumps is not sufficient to get water into their home, particularly if the family occupies the second or third story of the home.

Water availability for families that rely on WASA Lahore is limited by the number of hours that WASA runs their tube wells. Interviewees reported varied hours of operation but most reported 2-4 hours of water availability around the time of morning prayers, roughly 2 hours around midday and an additional 2-4 hours in the evenings. This is a fewer number of hours than cited

by Reuters in 2018, which stated the hours of availability were temporarily reduced to 4-9am, 12-2pm, and 5-10pm [14]. While the reduced hours are cited as temporary, the reported hours of operation stated by interviewees indicate that these temporary measures may have never been repealed. Intermittent supply is a common phenomenon in the developing world, “Only 27 percent of households [in Pakistan] receive water for more than 6 hours per day.” [7]. An earlier report of water resources in Lahore from 2014 cites that “on average, WASA tube wells work for 14-18 hours per day. However, in summer their working hours increased to 20 hours per day” [15]. Given that this research was conducted in the summer months, it is likely that the number of hours water is being pumped by WASA has decreased substantially since 2014. The reduction of time that water is available to the public is a common practice for addressing water scarcity in developing countries but comes with many costs such as increased levels of contamination when intermittency is introduced to water supply systems, inequitable distribution of water, and coping costs incurred by individuals [31].

5.3 Drinking Water and Water Filtration Plants

The widespread existence and use of water filtration plants appears to be a new trend. Examination of previous studies on drinking water sources in Lahore reveal that WFPs were not specified as sources of drinking water, and categories specified that could include WFPs such as “out-door taps” are observed to have very low usage [32]. A study from 2015 looking at factors that influence what drinking water source families used in Punjab, cited “motor pumps” as being the safest drinking water option available outside of buying filtered drinking water [32]. Furthermore a study as recent as 2018 states that approximately 75% of Pakistani households across all socioeconomic status got their drinking water from their household water source, a departure from what was observed in this research [26]. Nearly 75% of the interviewees used water filtration plants to obtain drinking water.

It was also found that WFPs had an overwhelmingly positive reception among the interviewees. Water filtration plants were broadly understood to provide clean drinking water even though they are installed by numerous separate entities such as mosques, factories, NGOs and WASA Lahore. Individuals determined the cleanliness of water primarily by the source of the water, i.e. is it from a water filtration plant?. This is in contrast to determining if water is safe to drink based on physical parameters which are commonly used as a proxy for safety by poor residents in many developing countries [33].

The positive perception of WFPs might be partially driven by the exceedingly negative reception of piped water. The number of households using tap water as their main source of drinking water is lowest in Punjab at 18% [9]. This is significantly lower than Pakistan’s other provinces with Sindh at 41%, Khyber Pakhtunkhwa at 35%, and Baluchistan at 33% [23]. In some locales in Pakistan, “access to piped water seemed to worsen outcomes for stunting in children in certain age ranges” [18]. Thus, a significant distrust of piped water may contribute to the strikingly positive reception of WFPs among the urban poor in Lahore.

It is difficult to determine how the increase in the presence and use of water filtration plants relates to any trends in the awareness of the dangers of consuming contaminated water. Several interviewees noted that they were advised to use WFPs by doctors. Others noted that they learned to value using WFPs or otherwise treating their water by being in proximity to other people who also did so. The vast majority of the respondents stated a preference for obtaining drinking water from WFPs citing that they provided better water, though not all were able to use them. A 2018 study cites that knowledge of pollution and the need for clean water was driven mostly by newspapers and television; given that this study included all SES, newspapers and television likely captured the dominant source of information among higher income households [26]. Knowledge of the importance of clean drinking water was fairly high in the sample of individuals interviewed and stemmed primarily from word of mouth from doctors, family members, neighbors, and colleagues.

While individuals that were interviewed generally understood there was a link between unclean water and illness and further associated clean water with WFPs, if the plants were too far or there was some other hindrance to accessing WFPs, people would not utilize them. The simultaneous knowledge of best practices and the behavior of avoiding them when they are inconvenient is well documented and ultimately human [34].

While the positive reception of WFPs and the adoption of their use is certainly encouraging, studies showing evidence of high rates of contamination when water is collected from a central location are concerning [35]. Furthermore, water experts I spoke to in Lahore expressed concern that no additional chlorine is added to water after it is filtered in WFPs administered by WASA Lahore. Because activated carbon is used as part of the filtration process, chlorine is removed from the water and no chlorine residual remains when water is being dispensed to the public. This increases the chance that water may easily be recontaminated after it is collected. It is likely that WFPs are the cleanest source of water available to the urban poor but it is still likely that it is contaminated albeit not severe enough to cause illness.

6. Recommendations

6.1 Design, test, and implement water subsidies that include all domestic water users in Lahore. Implement tariffs that take advantage of the decentralized water infrastructure.

Lahore is a city with many self-enclosed water systems. Individual private housing communities typically provide their own water systems for their residents. WASA Lahore, which serves those outside of private housing societies, consists of numerous separate water systems which serve individual neighborhoods. This decentralized water infrastructure presents an opportunity for the implementation and evaluation of different water subsidy schemes.

The clientele of WASA Lahore excludes the wealthiest parts of society who are served by separate water infrastructure. In the water sector, where developed and developing countries alike utilize cross subsidies to remain financially viable and to ensure equity of water access; the existence of a water utility that is cut off from a large number of wealthier customers makes financial stability incredibly difficult. A singular water body which addresses water access for all residents would help to solve this problem. Such a water body is being proposed in the Punjab Water Act of 2019 which calls for the establishment of a Punjab Water Services Regulatory Authority that would oversee water use across the entire province. Ensuring that the newly established water authority is able to introduce or revise tariffs on water extraction from Lahore's aquifer would give it the ability to increase revenue, reduce exploitation of the aquifer, and move towards financial sustainability.

Volumetric tariffs are the standard for water utilities around the world and when designed and implemented carefully, allow for greater equity in access and cost for all. Notably, none of the water systems in Lahore include a substantial level of metering for water use which makes volumetric tariffs impossible. The introduction of metering should begin in wealthier neighborhoods and then grow towards middle and low income areas. This will be necessary to implement any meaningful volumetric subsidies which will allow for more equitable access to water.

6.2 Build and maintain an up-to-date inventory of the locations of all WFPs in Lahore and include their hours and cost (if any). Make this information easily accessible to the public and NGOs.

The research conducted strongly indicates that water filtration plants are broadly trusted by the urban poor. This is likely rooted in the reality that WFPs do provide the cleanest source of water that is accessible. These plants are the only source of water that make any attempt to address the very high levels of arsenic present in Lahore's water supply. WASA Lahore uses an adsorptive medium to remove arsenic, while others solve this problem with reverse osmosis technology; both address the presence of arsenic. While there is likely variation in water quality, and room for improvement in water provision; water filtration plants are widely lauded and provide the best option for potable water to Lahore’s urban poor population.

Water filtration plants have become fairly common in Lahore but the density of plants in different areas varies extensively. These disparities negatively affect many people's ability to access clean drinking water. Furthermore, less visible WFPs appear to be underutilized. Providing NGOs and other entities that install WFPs with data about where WFPs are already present can help them target areas where there is the most need. In a similar vein, individuals who utilize WFPs to obtain drinking water having greater knowledge of WFPs near them would ideally redistribute crowds at WFPs from more heavily trafficked areas to less heavily trafficked ones allowing for a more efficient use of the resource.

7. Conclusion

The experience of obtaining water for urban poor individuals in Lahore was found to be distinct based on the source of household water that was being utilized: a connection with the local water utility or a borewell installed inside one's home. Both of these sources came with distinct challenges. It was found that almost all individuals utilized large water storage tanks generally placed on the roofs of their homes to reserve water for use throughout the day. In addition to this, a third class of individuals, workers who were contracted from other parts of the country and brought to the city of Lahore to work lived in housing provided by the agencies that recruited them. The arrangements for water were handled by the agencies that employed them resulting in the individuals having little knowledge or concern over obtaining water. The water infrastructure that served the urban poor was found to be distinct from the infrastructure that served the wealthier class of Lahore. Separate parallel water supplies exist for private housing communities. These communities own their own bore wells and water infrastructure to serve their communities, separate from the local water utility. It is hypothesized that the level of infrastructural access: access to private water infrastructure, piped access from the local water utility, or being responsible for provision of your own infrastructure to obtain water (household borewells) might correlate with socioeconomic class. Given the high cost of electricity along with generally low flat rates for water access from the local water utility, it is likely much more expensive to access water from a borewell than the water utility. The cost of water access to individuals warrants greater exploration.

Most households were found to utilize separate sources of water for household tasks and for drinking water. The study revealed high utilization of water filtration plants among the urban poor with most interviewees using WFPs and the majority of those who didn't, indicating they want to but face obstacles in doing so. This finding may be influenced by bias in the sample of interviewees who were either individuals who worked in an industrial building that housed a university and many businesses. Water filtration plants were also vital for drinking water access at the workplace. It was found that water access in the workplace generally followed class and social boundaries with police officers, factory workers, security staff, and cleaning personnel being among those who were expected to make arrangements for drinking water for themselves. These people would obtain water from water filtration plants and bring it to the workplace. On the other hand, office workers generally had arrangements for drinking water made for them. While time in the workplace often accounts for a large portion of urban poor individual's lives, access to clean drinking water in the workplace has not been thoroughly studied.

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9. Appendix

Objective: Understanding water access and usage by urban poor households in Lahore

- Perception of water quality and water scarcity
- Challenges faced in accessing/utilizing filtration plant
- Challenges faced in getting clean water in general (What other options exist?)
- Reported/Estimated water consumption per person
- Reported/Estimated division of water for drinking and other purposes
- Where the burden of water collection lies in term of gender/ age (Children/ parents etc)
- Are water needs being met, if not what are the reasons why?
- Knowledge about water hygiene and health in general

Questions:

1. Number of people in the household
2. Between last night and this moment what are all the times you came in contact with water.
    a. Interaction with water in the restroom
    b. Interaction with water in the kitchen
    c. Chores related to water
3. Has the manner in which you interact with water been significantly different in the past? If so, how?
4. How do you get water at work?