Unreliable Public Water Supply and Coping Mechanisms of Low-Income Households in Delhi

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Abstract

India is reported to have the world's highest inhabitants without access to safe drinking water. Even in the capital city Delhi, although around 81% of the households have access to piped water supply system, it does not indicate reliability in water supply in terms of quantity or quality. Households adopt various coping mechanisms such as collecting, purchasing, storing, and treating of water to cope with the unreliable and irregular water supply. In this study a household survey was conducted to examine the coping mechanisms and the costs incurred by some low-income households, residing in the command area of the Chandrawal water treatment plant in Delhi. There have been numerous occasions leading to irregularity or disruption in water supply due to planned works, plant operational problems, or high levels of ammonia in the Yamuna River, the source of raw water to this plant. The quantitative and qualitative problems related to unreliable water supply were investigated. The results indicate that, on an average, the annual coping cost to the households is INR 6487 (US$ 93), which is approximately 2.52% of their annual income. Income seems to play a strong role in the choice of coping activities adopted by the households.

Keywords: Coping Cost, Household Production Function, Water Supply, Water Treatment Plant, Delhi

1. Introduction

Access to safe drinking water is a basic human right and a major concern across developing countries (Dattarao, 2012). Globally, around 800 million people lack access to water sources, while 1.8 billion people consume faecally contaminated drinking water (UNDP, 2016). The Sustainable Development Goal 6 aims at clean drinking water and sanitation. Universal access and regular supply of potable water is a big challenge in India. The Water Gap —Water Aid's State of the World's Water Report (2018)[1] — revealed that 163 million people in the country lacked access to clean water in proximity to their premises. The report also added that people who spend more than 30 minutes in travelling to procure water should also be considered as 'without access to clean water'. The report identified six major reasons for lack of access: lack of financing and political priority, institutions not capable enough for delivering and maintaining services, ineffective taxation and tariffs, location and land tenure, discrimination, and finally, disaster and displacement.

'Leaving no one Behind,' the report from the recent initiative of the joint collaboration between United Nations Educational, Scientific and Cultural Organisation (UNESCO), the SDGs, and the World Water Assessment Programme, stresses that water for all is "entirely achievable." It further highlights how improvements in the management of water resources and access to water supply and sanitation services form an integral part in addressing various social and economic inequities.[2] Burt et al. (2018) shared a concern that in Asia, countries like India are in the process of converting their intermittent systems to a 24×7 system, but it is subject to controversy. Critics believe that this conversion might be profitable for utility companies but may not be affordable by the poor. Also, non-revenue water further degrades system operations. The estimated losses from irregular urban water supply systems in India amount to US$2 billion a year.[3] The National Water Policy of India (2012) pointed out the skewed availability and distribution of water across and within different regions of the country. It also stated that intermittent and unreliable water supply system could cause social unrest (GoI, 2012).

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[1] https://washmatters.wateraid.org/publications/the-water-gap-state-of-the-worlds-water, accessed on 4th Dec 2018

[2] https://unesdoc.unesco.org/ark:/48223/pf0000367306 accessed on 6th July 2019

[3] https://www.thesourcemagazine.org/the-value-of-247-water/ accessed on 5th Dec 2018

Given this background, there is an urgent need to study various coping strategies that are adopted by a household and the associated monetary burden. Such a study can further facilitate the local administration to formulate policies or undertake institutional and infrastructural reforms that can efficiently provide clean water at an affordable cost. Thus, the present study proposes some policy guidelines in the context of Delhi, India.

1.1 Water stress and types of coping behaviour

Various water-related coping behaviors have been observed worldwide. Depending upon the degree of variability in well-being, the coping behaviors vary from collecting water from sources other than own piped connections to purchasing bottled water, investing in storage devices, treating water through filtration, boiling and using chemicals, pumping and drawing from wells, installation and maintenance of tube wells and bore wells, etc. (Harrington et al., 1989; Pattanayak et al., 2005; Misra, 2005; Misra and Goldar, 2008; Alam and Pattanayak, 2009; Baisa et al., 2008.; Jalan et al., 2009; Vasquez, 2012).

The coping behaviors related to water stress are different across developed and developing nations. Developed countries deal with the issue of water quality (Harrington et al., 1989; Laughland et al., 1993; Collins and Steinback, 1993), whereas developing nations deal with irregular and intermittent water supply along with poor water quality (Pattanayak et al., 2005; Misra and Goldar, 2008; Alam and Pattanayak, 2009; Jalan et al., 2009; Cook et al., 2016).

For quantifying the impacts and the costs associated with bad water supply, different valuation methods have been used by researchers such as cost of illness approach, health production function(Harrington et al., 1989; Alam and Pattanayak, 2009) or contingent valuation method (Pattanayak et al., 2005; Misra, 2005; Venkatchalam, 2012). Using the cost of illness method, Harrington et al. (1989) estimated that household incurred $485 to $1540 in 1984 as coping cost for procuring safe drinking water in the USA; the high cost was due to the majority of them purchasing bottled water. Pattanayak et al. (2005) listed five coping strategies by households in Nepal, i.e., collecting, treating, pumping, purchasing and storage, and estimated the monthly coping cost to be $2.94. In Bangladesh, the coping cost for households was estimated to be Tk.1,873(or $27.11) per year, and the monthly payment for improved services ranged from Tk. 64 to Tk. 97 depending on the economic status of the household (Alam and Pattanayak, 2009).

A study by Misra and Goldar (2008) estimated the monthly coping cost of households in Delhi to be INR 187 (on average) in the year 2005. Another study on urban India found 'awareness on water quality' to have a significant impact on peoples' coping cost and willingness to pay (Jalan, 2009). Regarding the irregularity in water supply in Delhi, Zerah (1998) had raised concern regarding water infrastructure by defining unreliability in terms of hours and timings of supply, water pressure, and supply breakdown. The study also estimated that a household in Delhi would spend yearly INR 2,000 approximately in case of unreliable water supply. By using contingent valuation method, Dutta et al. (2005) found that the households in Delhi slums willing to pay INR 295 per month for dual quality (separate provision for potable and non-potable) supply and INR 189 per month for single improved quality (as per WHO standards) of reliable supply.

Srinivasan et al. (2010) concluded that unreliability in supply of piped water in the city of Chennai led to the emergence of tanker markets. Similarly, Venkatchalam (2012) stressed that the informal water market in the city mostly caters to the low-income households, and the mean amount for improved water services ranged from INR 121 to INR 135 per month.
In developing countries, the time spent for water collection is a major contributor to the coping costs, but the magnitude varies across regions depending on the degree of water stress and the socio-economic characteristics of the households. An improved water source located in proximity is beneficial for the women and children of a household. This is because the household will have to spend less time for water collection and can utilise the travel time savings for some other productive purposes (Whittington and Cook, 2019).

Water service unpredictability may also wear out the relationship between individuals and the government as households who fail to rely upon regular services may be less likely to view government service providers as competent. They may perceive a direct linkage associated with political connection and better service delivery, which motivates them to rely more on intermediaries in resolving their issues from the point of approachability rather than the state itself (Kumar et al., 2018).

1.2 Water supply situation in Delhi

The National Capital Region of Delhi has a population of nearly 17 million with a decadal growth rate of 21.2% (Census of India, 2011). In addition, with water demand of 1040 million gallons per day (MGD) and a supply of 925 MGD, there exists a gap of 115 MGD (Economic Survey of Delhi, 2018). A study conducted by CSE (2018) states that 625,000 households (around 18% of total households) lack access to piped water; 461,000 of these households get water from tube wells and deep bore hand pumps, while the remaining 164,000 rely on other sources. Moreover, the Delhi Jal Board (DJB) lacks efficient infrastructure to meet the additional water demand, thereby posing severe water crisis. Aggravating the grave situation further, the city loses 40% of its water supply via leaking pipes or theft (Economic Survey of Delhi, 2018).

Given the limited option of perennial and non-perennial sources, the DJB projected that the water demand will increase further to 1380 MGD by 2021 and that there is an urgent need for alternative options. Currently, there are 12 water treatment plants (Economic survey, 2018) that cater to different parts of the capital. They draw raw water from sources according to their location, treat it, and supply the treated water to their respective command areas. However, the water supply gets disrupted in case of non-functioning of any one of these plants.

There have been occasions when there was irregularity in supply or the plant had been shut down or it does not work to its full capacity giving rise to water supply disruption. This paper investigates the households' choice of coping strategies, the coping costs suffered, and the health and other social outcomes of this unreliability. The material and methods section below describes the study area, study design, research methodology, and the formulas used for measuring the aggregate coping costs. This section is then followed by the empirical results, the discussion, and lastly, the conclusions of the study.

2. Material and Methods

2.1 Study Area

For the purpose of this study, two sites that fall under the command area of the Chandrawal Water Treatment Plant have been selected–old Chandrawal village and Malka Ganj. This plant is located in Civil Lines in the North Delhi district of the National Capital Territory of Delhi and its command area includes Civil Lines, Old Chandrawal village, Chandni Chowk, Kamla Nagar, Malka Ganj, Karol Bagh, Shadipur, among other areas. It also supplies in bulk to the New Delhi Municipal Corporation and Cantonment area. The rationale for selecting the two sites is the following:

Chandrawal water treatment plant is one of the oldest plants covering major areas of the city. The Chandrawal water treatment plant was built in 1936 with the expansion of its services taking place in the 1950's. According to a report by the Comptroller and Auditor General of India (CAG) on water management in Delhi, the existing facilities of the Chandrawal water treatment plant are not functioning efficiently, leading to a leakage of potable water carried by the pipelines (CAG, 2013). Since the water transmission and distribution system of the plant is quite old, over the years the pipes have become corroded and rusted. This affects the quantity as well as the quality of the potable water supplied by the pipes to the households. Locations at the further end of the distribution network of the plant are likely to be more affected by it than those closer to it. Therefore, we have selected two sites that will help us determine whether being closer to the plant has an impact on the water supply service that is received by the households. The old Chandrawal village is located less than 1 km away from the plant and Malka Ganj is located around 5 km away from the plant.

This plant supplies water to central core areas of Delhi with a population of 2.2 million (Government of Delhi, 2014). Its current installed capacity is 90 MGD and has a recycling plant of 8 MGD. Further, in 2014, a financial assistance was received from Japan International Cooperation Agency (JICA) to carry out the Delhi Water Supply Improvement Project of the Chandrawal water treatment plant. Through this, they aim to improve the existing facilities at the plant, replace old distribution pipes, and reduce non-revenue water in order to improve the water supply in the command area (Government of Delhi, 2014).

Over the years, there have been occasions when there was irregularity in supply or the plant had been temporarily shut down. Sometimes due to leakage in the main pipes, the water supply and pressure was affected.[4] In another incident, the water supply was interrupted due to planned works at the end of April 2017, a summer month in Delhi.[5] Mostly the supply gets disrupted when the plant is shut down due to the rise in ammonia levels in raw water from the river

[4]http://www.delhi.gov.in/wps/wcm/connect/5c05b4804f623314935bdfd87adfa114/PR_11122016_1.pdf?MOD=AJPERES&lmod=-1851283427, accessed on 22nd December 2018

[5]https://www.thehindu.com/news/cities/Delhi/chandrawal-treatment-plant-functional/article18363313.ece, accessed on 22nd December 2018

Yamuna. [6,7,8]At the beginning of 2018, the level of ammonia rose to 1.6 ppm, which was much higher than the limit of 0.5 ppm that the treatment plants are designed to treat.[9]

The situation becomes severe when Haryana, the neighbouring state that supplies water to Delhi, releases lesser quantity of water than the agreed quantity of 450 cusecs of water per day.[10] Such issues with the treatment plant lead to its failure to operate to its full capacity and affect its ability to produce and supply water. This further widens the existing water demand-supply gap, resulting in water crisis in the places that come under the command area of the treatment plant. In 2018, the irregularity in water supply lasted for at least half the year.[11] Given this background, one wonders how people would react to this situation even though they have piped water connection and are categorised to have access to safe drinking water.

2.2 Study design and data

We conducted a stratified random household survey to collect information regarding the socio-economic and demographic characteristics of the household, the water supply situation, the coping activities adopted and health impacts, etc. for the two study sites mentioned above. A total of 200 households (100 households from each site), selected via stratified random sampling, were surveyed. Since these areas included mostly unauthorised construction, we could not arrange a detailed census of the households from secondary sources. Based on their proximity to the main road, we selected 10 households from each side of the main road (20 in total) and then did the same from the interior roads. Later, this location information was used in the analysis.

2.3. Methodology

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[6]https://indianexpress.com/article/cities/delhi/city-faces-supply-crisis-as-high-ammonia-shuts-two-water-plants, accessed on 22[nd] 2018

[7]https://www.hindustantimes.com/delhi-news/35-40-lakh-to-be-hit-by-water-shortage-today-in-central-old-delhi/story-IkMid7UKHazlC7BfumRnOM.html, accessed on 22[nd] December 2018

[8]https://timesofindia.indiatimes.com/city/delhi/two-water-treatment-plants-shut-in-delhi-as-ammonia-levels-rise/articleshow/56559257.cms, accessed on 22[nd] December 2018

[9]https://timesofindia.indiatimes.com/city/delhi/no-water-for-2-days-in-many-parts/articleshow/62319315.cms, accessed on 22[nd] December 2018

[10]https://timesofindia.indiatimes.com/city/delhi/haryana-not-obeying-sc-order-on-yamuna-water/articleshow/63436512.cms, accessed on 22[nd] December 2018

[11]https://timesofindia.indiatimes.com/city/delhi/why-delhi-is-staring-at-a-water-crisis/articleshow/64228440.cms, accessed on 22[nd] December 2018

The coping cost, which reflects the households' coping mechanisms to deal with water or a resource stress, is derived from the utility maximisation condition under a household production function framework (Pattanayak et al., 2005; Pattanayak and Pfaff, 2009). Pattanayak et al. (2005) derived the willingness to pay of a utility maximising household from their quasi expenditure function. They proved that the willingness to pay for better water supply (both quantity and quality) consists of coping costs (extra time spent to collect water from different source, money spent on storage, purification, purchase of water etc.), cost of illness, opportunity costs of lost workdays and the psychological cost to the household when dealing with water stress. Bansal and Das (2019) broke down the household's water-related willingness to pay into its direct, indirect, subjective and objective components theoretically and explained why the coping costs differ from the willingness to pay. Studies showed coping cost to depend on various factors such as income, education, gender, occupation, geographical location, number of household members, etc. (Larson and Gnedenko, 1999; McConnell and Rosado, 2000; Pattanayak et al., 2005; Jalan et al., 2009). We attempted to use similar factors to find out the determinants of coping cost in our study.

We estimated the following reduced form of coping cost equation (Eq.1) in the study to determine the factors that significantly influence the water supply-related coping behavior of poor urban people located closely to the water treatment plant.

$$C_i = X_i{}' \beta + Z_i{}' \gamma + \varepsilon_i \qquad (1)$$

Here, C_i denotes the cost associated with a coping activity, and i is the i^{th} household. X is the vector of socio-economic and demographic variables, Z is the vector of water supply-related variables (whether having piped connection, perception about regularity of water supply, and whether households receive information prior to supply disruption), and ε is the error term. We estimated this model using different components of coping cost as well as total coping cost.

2.4. Description and calculation of the coping cost

The description and calculation of different components of the dependent variable, the coping cost, is discussed in this section.

2.4.1. Annual Collection Cost

This is the cost incurred by households for the time spent during water collection from different sources in a year. The total time taken by a household to collect water (including walking to the source, waiting, collecting and returning to the house) from different sources is added and divided by the total amount of water collected from the respective source. This gives the total time taken, in minutes, to collect water per litre by a household in a day when supply is unreliable. The values are then converted into hours taken to collect water in a year. The minimum wage rate for a worker is INR 536 per day in Delhi, according to the Ministry of Labour and Employment[12]. Assuming a person works for 8 hours in a day, the minimum hourly wage rate is INR 67[13]. Using this hourly wage rate, the annual collection cost for each household is obtained.

$$\begin{aligned}\textit{Annual collection cost} \\ &= \textit{Total Time (hours) taken to collect water per liter in a year} \\ &\times \textit{Minimum hourly wage rate}\end{aligned}$$

2.4.2. Annual Purchasing Cost

This is the cost incurred by the households for purchasing water jars (20 litres) and water bottles to meet needs during irregular supply. The total cost for purchasing is calculated by adding the expenditure on water jars and water bottles, taking into account the number of times such items are purchased in a year. The values are then turned into costs in a year.

$$\textit{Annual Purchasing Cost} = \textit{Water Jar Cost} + \textit{Water Bottle Cost}$$

2.4.3. Annual Storage Costs

This is the cost to households that have invested in storage devices like storage tanks, jerry cans, buckets and bottles. These one-time costs are annualised over the lifetime of the respective storage device using the formula for equivalent annual cost (Das, 2015).

$$\text{Equivalent annual cost} = \frac{\text{Purchase Price}}{\text{A(t, r)}} + \text{Annual maintainence cost}$$

where, $\mathrm{A(t, r)} = \frac{1 - \frac{1}{(1+r)^t}}{r}$, t is the expected lifetime of an asset (years) and r is the annual interest rate (%).

[12] https://clc.gov.in/clc/node/568, accessed on 24 January 2019

[13] As we are dealing with the urban poor in Delhi, we have taken the minimum wage rate instead of 50% of the wage rate, as has been done by others (Cook et al., (2016), Whittington and Cook (2019)).

For each storage device, a different expected lifetime is assumed. For storage tanks and jerry cans, a useful life of 10 years is assumed. Buckets and bottles have an expected life of 5 years and 3 years, respectively. An annual interest rate of 10% is considered for each storage device. The costs for each device to the household using the storage devices are added, and the total storage cost is obtained.

2.4.4. Annual Treatment Cost

These costs are incurred by those households who choose to invest in treatment devices such as Reverse Osmosis (RO) filter and candle filter. Like storage devices, these are one-time costs so these are annualised using the formula for equivalent annual cost (Das, 2015) as shown above. For each treatment device, a lifetime of 10 years is expected, and an interest rate of 10% is assumed.

2.4.5. Total Coping Costs

This is the total cost to the household for adopting one or more coping mechanism in a year. It is calculated by adding the costs associated with each coping activity, i.e., the annual collection cost, annual purchasing cost, annual storage cost, and annual treatment cost.

$$\begin{aligned}\text{Total annual coping costs} &\\ &= \text{Annual collection cost} + \text{Annual purchase costs} \\ &+ \text{Annual storage costs} + \text{Annual treatment costs}\end{aligned}$$

3. Results

3.1 Broad features of sample households

From the household survey data, information about the households' socio-economic and demographic characteristics, water supply situation, coping mechanisms and health status are inferred. Table 1 shows the summary statistics of such sample features. The average age of the respondent is around 36 years, and the average family size includes at least five members. On an average, the covered area of a house is 45 sq m, having at least one room. All the households had identification cards like Aadhaar and Voter ID cards. The mean expenditure on food, electricity and education on a monthly basis is INR 9492.30. Also, 67% of the households have toilet facility in their houses. Overall, 94% of the households are male-headed households, and the remaining 6% households are headed by females. However, the responses derived from the survey cover 51.5% females and nearly 49% male respondents.

Table 1: Socio-economic and demographic characteristics of the sample households

Variable	Mean (Std. Dev.)	Variable	Mean (Std. Dev.)
Age of respondent	35.95 (12.38)	No of men	1.68 (1.01)
Family size	5.23 (2.29)	No of women	1.82 (1.04)
Monthly expenditure (food +electricity + education) (INR)	9492.3 (4952.72)	No of children	1.77 (1.15)
	Percentage of households		Percentage of households
Gender of the respondent		Gender of the household head	
Female	51.5	Female	6
Male	48.5	Male	94
Highest education level		Income	
Primary	10.5	Below INR 50000	4
Secondary	26	Between INR 50000 to INR 100000	20
High school	29.5	Between INR 100000 to INR 200000	21
Bachelors and above	32.5	Between INR 200000 to INR 400000	29
Illiterate	1.5	Above INR 400000	28
Occupation of household head		Household ownership	
Own business	65	Renters	8
Government service	11	Owners	93
Daily wage	24		
Religion		Caste	
Hindu	71	General	17
Muslim	19	Scheduled Caste (SC)	49
Christian	6	Scheduled Tribes (ST)	18
Sikh	4	Other Backward Caste (OBC)	15

For most of the households, the highest educational qualification is Bachelor's degree and above, followed by high school. A small percentage of the households belong to the illiterate category. With respect to occupation, nearly 65% of the households have their own business, whereas 24% are daily wagers and 11% are government employees. Majority of the households are Hindus (71.5%), followed by Muslims (19%), Christians (5.5%) and Sikhs (4%).Households belonging to SC, ST, General and OBC are around 50%, 19%, 17% and 15%, respectively. Most of the households lie in the income category of INR 200000 to 400000, followed by a few, above INR 400000. Looking at the income categories by location, Chandrawal holds most of the lower income groups, whereas more of the higher income groups are concentrated in Malka Ganj (Table 2).

Table 2: Percentage of households in different income categories according to location

Income	Chandrawal (%)	Malka Ganj (%)
Less than INR 50000	3.50	0
Between INR 50000 to INR 100000	14.50	5
Between INR 100000 to INR 200000	10.50	10
Between INR 200000 to INR 400000	10	18.50
More than INR 400000	11.50	16.50

3.2 Water supply situation

In the sample, 85.5% have piped water connection to their households, whereas the remaining 14.5% rely on other sources such as public taps. In a day, on an average, the households receive water for 3 to 4 hours. Regarding quality of the water, nearly 50% of the households received unclean water, and 25% reported some smell in the water they receive. It was observed that proportionately more households on the main road perceived water to be cleaner as compared to other households (Table 3).

Table 3: Perception of water quality among households in according to location (%)

Location	Main Road		Not on Main Road	
	Clean	Unclean	Clean	Unclean
Chandrawal	5	5	17	23
Malka Ganj	6	4	13.5	26.5
Overall	11	9	30.5	49.5

The average water requirement for a household is roughly 95.4 Litres Per Capita Daily (LPCD), with a minimum of 30 LCPD and a maximum of 250 LCPD. Not all households were observed to be incurring a bill for water due to the '20 KL free water scheme'[14]. Around 20% of the households pay for water. The average water bill incurred is around INR 723.

With respect to the perception of households regarding regularity of water supply throughout the year, 75% households reported irregular supply for 2 to 3 days in a month. According to these households, this happens mostly during the months of January-February, May-June, and October. Around 54% of the households do not receive any information prior to water supply disruption, and the remaining 46% reported to have received information. Further, 24% of the households reported getting the information one day before any water supply problem. They received information from sources such as television (15%), newspaper (53%), SMS (10%), neighbour (9%), and announcement via mikes in their area (11%).

In the sample, only 44% of the households received supply from DJB tanker, whereas the remaining 56% do not get this benefit. Nearly 65% of households who receive water from tankers feel that the quantity given is not adequate to meet their needs. About 62.5% of the households have a water pump installed in their house that is used for an average of 37 minutes in a day. Households also incur costs associated with maintenance of the pump, which cost around INR 450, on average, in a year.

3.3 Household coping mechanisms to irregular supply

To deal with the problems relating to water quantity and quality, households engage in coping activities like collecting water from different sources, purchasing water cans and bottles, storing in containers, treating water using filters, and installing bore wells.

3.3.1 Water collection

Nearly 69% of the households reported that they engage in water collection from different sources to overcome the erratic supply. They go to sources like public taps, public latrines, neighbours, and religious places like temples and gurudwaras. The number of households going to different sources, time spent on collection and average quantity collected per house

[14]The Government of Delhi initiated this scheme in March 2015. Under this scheme, domestic consumers with functional meters receive up to 20 KL of free water per month. Only those households with monthly consumption beyond this level are required to pay the water bill, which includes the volumetric water charges, service charges and sewerage maintenance charge (Economic Survey of Delhi, 2018). Moreover, when there is a disruption in regular water supply, water is provided by tankers free of cost to the affected population.

household per day are shown in Table 4. The most commonly used sources are temples, followed by neighbours and public taps. Sources like public toilet and gurudwaras are less commonly used.

Table 4: Status of water collection from different sources as a coping activity

Collection Source	Number of households relying on the source	Average time taken for water collection in a day (minutes)[#]	Average quantity of water collected per household in a day (in litre) (Standard Deviation)
Public Tap	37	30.81	14.90 (-44.80)
Temple	41	36.46	18.55 (-37.48)
Public Toilet	11	28.64	4.25 (-18.33)
Neighbour	38	27.63	12.34 (-28.67)
Gurudwara	10	23.50	1.35 (-7.33)

[#] The time includes time for travelling to the source, waiting, collecting, and coming back to house.

The most time-consuming collection source seems to be temple, the average time taken being nearly 37 minutes and the least time taken is from gurudwara of around 24 minutes. The temple is also the collection source with the highest average quantity of water collected. It was found that the male members of the household collect water from sources such as temple, gurudwara, and neighbours, whereas the females usually collect water from public taps and public latrines.

3.3.2. Purchasing, Storing and Treating water

Unlike collection from different sources, which is a time-consuming activity, households also engage in coping activities like purchase, storing, etc. that involves monetary expenditure. In the sample, around 57% of the households reported purchasing water to meet their needs during irregular water supply. They purchase water jars[15] and water bottles[16] from private vendors. The frequency of purchase for each household is different and varies from one to two times a month or a few times even weekly, depending on how long they face problems. Majority of them purchase water jars of 20 litres costing between INR 35 to 50, and or water bottles of 10-12 litres costing INR 25.

[15] These are plastic bottled jars of 20 litres that are purchased
[16] These are smaller plastic bottles that are purchased

Nearly 96.5% of the households stored water in at least one container for future use. They reported using storage devices such as storage tanks, jerry cans[17], buckets, and plastic bottles. Out of all these households, 68.5% have invested an average of INR 4204 in a storage tank with the capacity ranging from 200 to 1000 litres. Buckets of 15 to 100 litres capacity, with an average cost of INR 237, are also used by 61% of the households. Jerry cans are used by 33.5% and plastic bottles are used by 7.5% of the households.

Households also reported using treatment devices such as candle filters or RO filters. Of the households that purchased these devices, nearly 35% purchased candle filters and more than 65% purchased RO filter. The average purchase and maintenance costs are higher for RO filter than for candle filter in a year. Table 5 shows the number of households engaged and the average cost of such coping activities.

Table 5: Average cost of coping activities like purchasing water, buying water storage and water treatment devices

Coping Activity[a]	**Number of households engaged in the activity**	**Average Cost (in INR) (Std. Dev.)**
Purchasing (59.5%)		
Water Jar	114	40 (3.73)
Water Bottle	6	25 (0)
Storage Device (96.5%)		
Store tank	137	4204.38 (1458.44)
Jerry can	71	403.52 (198.80)
Bucket	122	236.90 (80.07)
Bottle	18	65.56 (18.54)
Treatment Devices (70.5%)		
Candle filter	48	
Purchase cost		1295.83 (857.75)
Maintenance cost		651.04 (516.48)
RO	93	
Purchase cost		8717.20 (2437.60)
Maintenance cost		3988.17 (2186.12)

[a] Figures in parenthesis are the percentage of households engaged in the activity

[17] Jerry cans may be plastic or metal storage containers, with their capacity varying between1 litre, 5, 10 and 30 litres.

3.3.3 Bore wells

About 9% of the households, all from Malka Ganj, have installed bore wells. Very few households own a bore well individually. Some households, in a group of 4 to 5, have collectively invested in this and share its services.

3.3.4 Health information

Regarding health awareness, 89% of the households were aware of water-related illnesses like diarrhoea, jaundice, pneumonia, cholera, typhoid, malaria, and skin diseases. The respondents were asked whether they or any other member in their family experienced any of the water-related diseases in the last year for which they required treatment. Nearly 70% of households reported having at least one of these diseases. There were 53 cases of diarrhoea, 38 cases of jaundice, 34 cases of pneumonia, 8 cases of cholera, 46 cases of typhoid, 2 cases of malaria, and 25 cases of skin disease in the sample households in the previous year. For the households that experienced any of these diseases, they incurred costs for treatment too. They had direct costs in the form of out of pocket expenditures such as doctor fee, medicine cost and travel cost to clinic or hospital. They also incurred indirect costs in the form of wages lost due to illness. However, households were unable to report the exact treatment cost of different diseases, and it was difficult to attribute the health issues to water supply irregularity as the timings of water supply disruption and disease occurrences could not be matched with them. Hence, we do not include health cost in our coping cost analysis.

3.4 Average coping costs to households

The water collection time was converted to wage income lost and then was added to the other coping costs such as amount spent on purchase, storage, and water treatment. Onetime costs for storage and treatment were annualised before addition. Section 2.4 above shows the formula used for annualising the expenditures. We show these costs for different categories like income groups (Table 6), locations (Table7), whether information about water supply disruption is received (Table 8), and whether households have piped connection or not (Table 9).

Table 6 gives the annual average cost of coping activities according to income. The collection cost for lower income categories is much higher than that for higher income categories. Higher income categories bear higher average purchasing cost as more number of households engage in purchase as coping activity as compared to lower income ones.

Table 6: Annual average cost of coping activities in different income group (in INR)

Income	Mean Coping Costs (in INR) (Std. Dev.)				
	Collection	**Purchasing**	**Storage**	**Treatment**	**Total**
Less than INR 50000	459.43 (130.77)	480 (0)	156.25 (94.21)	-	1085.14 (687.41)
Between INR 50000 to INR 100000	573.80 (224.75)	480 (0)	247.76 (208.62)	1091.31 (1591.69)	2210.86 (1799.58)
Between INR 100000 to INR 200000	462.72 (195.78)	438 (95.56)	434.77 (240.62)	1668.07 (1561.9)	4166.46 (2720.79)
Between INR 200000 to INR 400000	450.52) (179.87)	532.34 (176.76)	620.07 (283.06)	4137.26 (2795.91)	7888.13 (4074.40)
More than INR 400000	469 (149.82)	546.82 (185.82)	788.43 (310.64)	5323.86 (2893.16)	10412.52 (4339.11)

Both average storage and treatment costs increase for a household falling in the higher income group. Households in the 'less than INR 50000' income category do not invest in any treatment devices, so they do not incur any costs associated with it. For these households, collection and purchasing form a major component of their total coping cost. For the rest of the income categories, treatment cost forms a major part of their total coping cost. Income seems to play an important role in determining what coping activity a household adopts. Higher the income, higher is the total coping cost for the households. This result is in line with literature (Pattanyak et al., 2005; Zerah, 2000; Cook et al., 2016).

Table 7: Annual average cost of coping activities according to location (in INR)

Coping Cost	**Malka Ganj**	**Chandrawal**	**Difference**
Collection	246.56 (27.89)	320.93 (29.76)	-74.37** (40.78)
Purchasing	314.40 (32.53)	302.40 (24.09)	12 (40.48)
Storage	742.79 (25.12)	320.60 (29.17)	422.18*** (38.49)
Treatment	3820.76 (340.32)	1621.34 (218.95)	2199.42*** (404.67)
Total coping cost	8868.02 (445.13)	4105.67 (376.67)	4762.35*** (583.11)

** - significance at 5%; *** - significance at 1%; Figures in parenthesis are standard errors

In Table 7 it can be seen that in Chandrawal, households bear a higher collection cost, whereas in Malka Ganj, there are higher purchasing, treatment, storage as well as total coping costs. The use of a two-sample t-test revealed significant cost differences in case of collection, storage, treatment and the total coping cost, but not in case of purchase.

Table 8: Average cost of coping activities without and with prior information about water supply disruption (in INR)

Coping Cost	**Without Information (N=111)**	**With Information (N=89)**	**Difference**
Collection	414.07 (22.96)	121.20 (26.19)	292.87*** (35.76)
Purchasing	187.57 (22.73)	459.10 (22.73)	-271.53*** (35.86)
Storage	398.30 (29.28)	698.06 (33.28)	-299.76*** (44.25)
Treatment	1790.45 (266.87)	3881.70 (315.06)	-2091.25*** (410.38)
Total coping cost	4718.48 (398.03)	8692.33 (477.50)	-3973.85*** (616.75)

*** - significant at 1%; Figures in the parentheses are standard errors

Table 8 shows average costs incurred by households according to coping activity and the total coping cost, depending on whether prior information is received about supply disruption. Average collection costs are found to be much higher for households that do not have the information beforehand. On the other hand, the average purchasing, storage and treatment costs are relatively higher when information is given in advance. The t-test revealed that there is a highly significant difference in the average costs between households that receive prior information and households that do not. This suggests that if households are given notice beforehand about any disruption in water supply, then it has a significant impact on their coping behaviour and they seem to indulge in different coping activities, and therefore, their coping costs are higher.

The average costs incurred by households according to coping activity and the total coping cost, depending on whether they have a piped water connection, are presented in Table 9. The average collection costs are higher for households that do not have a piped connection. Households that do have a piped connection have higher purchasing, storage and treatment costs. The t-test results show that average costs differ significantly between these two groups of households.

Table 9: Average cost of coping activities for households with and without piped water connection (in INR)

Coping Cost	With Pipe Connection	Without Pipe Connection	Difference
Collection	233.13 (20.21)	582.21 (47.74)	349.08*** (52.87)
Purchasing	355.08 (21.33)	33.10 (22.99)	-321.98*** (52.75)
Storage	605.59 (24.22)	95.98 (10.84)	-509.61*** (59.09)
Treatment	3179.23 (235.72)	19.41 (19.41)	-3159.82*** (573.64)
Total coping cost	7404.17 (346.97)	1077.82 (100.01)	-6326.35*** (845.29)

*** - significant at 1%; Figures in the parentheses are standard errors

4. Econometric Results

We estimate Equation 1 using different types of monetised coping costs as well as the total coping costs as dependent variable. Table 10 describes and defines the set of explanatory variables used in estimation of Equation1. It also shows the comparison category in case of dummy variables.

Table 10: Description of Independent variables

Variable	Description	Specification
Location	Location of household Chandrawal or Malka Ganj	Chandrawal = 1, Malka Ganj = 0
Main road	House located on main road or not	Main road = 1, Interior = 0
Male household head	Gender of the household head	Male = 1, Female = 0
Caste	Caste of the household General, SC, ST, OBC	General = 1, 0 SC = 1, 0 (Base Category) ST = 1,0 OBC = 1,0
Occupation	Occupation of the household head Own business, Government service, Daily wager	Own business = 1,0 , Government service = 1, 0, Daily wager = 1, 0 (Base Category)
Household size	Number of members in the household	Continuous variable
Children	Proportion of children	Continuous variable
Education	Highest level of education in the household Illiterate, Primary, Secondary, High school, Bachelors & above	Illiterate = 1, 0, Primary = 1, 0, Secondary = 1, 0, High school = 1, 0,

		Bachelors & above = 1, 0 (Base Category)
Income (in INR)	Range of income of a household	Less than INR 50000 = 1, 0 Between INR 50000 to INR 100000 = 1, 0 Between INR 100000 to INR 200000 = 1, 0 Between INR 200000 to INR 400000 = 1, 0 More than INR 400000 = 1,0 (Base Category)
Pipe connection	Whether household has piped water connection	Yes = 1, No = 0
Religion	Religion of the household Hindu, Muslim, Christian, Sikh	Hindu = 1,0, Muslim = 1, 0(Base Category) Christian = 1, 0, Sikh = 1,0
Regular water supply	Perception about regularity of water supply	Regular = 1, Irregular = 0
Information	Whether prior information about supply disruption is given	Yes = 1, No = 0
Collection	Whether household collects water from different sources	Yes = 1, No = 0
Storage	Whether household stores water	Yes = 1, No = 0
Quality	Perceived quality of water	Clean = 1, Unclean = 0
Proportion of sick children	Proportion of sick children to household size	Continuous variable

Table 11 presents the estimated ordinary least square coefficients of different models. Each of these models use the same set of explanatory variables and the dependent variables are indicated in the first row of the table.

Table 11: Estimated OLS coefficients of the determinants of different types of coping costs

Determinants	**Model 1 (Dep. var = Annual collection cost)**	**Model 2 (Dep. var = Annual purchasing cost)**	**Model 3 (Dep. var = Annual storage cost)**	**Model 4 (Dep. var = Annual treatment cost)**	**Model 5 (Dep. Var = Total coping cost)**
Location Chandrawal	-113.10** (50.07)	193.29*** (45.80)	-368.84*** (46.62)	-1153.30* (605.67)	-3326.67*** (724.72)
House on main road	-43.29 (34.71)	28.21 (46.74)	-60.93 (45.90)	-1017.51** (417.88)	-1427.34** (596.02)
Household head Male	-60.65 (45.14)	50.19 (73.91)	46.64 (45.71)	790.59** (378.78)	1077.96** (525.13)
Religion Hindu	-27.19 (40.72)	47.79 (42.49)	25.23 (34.33)	215.05 (420.09)	408.96 (528.27)
Religion Christian	-49.52 (52.73)	237.19** (116.91)	4.89 (85.71)	1260.19 (989.57)	1508.21 (1329.66)
Religion Sikh	29.82 (58.27)	411.76*** (112.66)	248.49 (191.64)	0.73 (1180.02)	1963.54 (2124.36)

Caste General	-78.19 (57.78)	44.31 (90.47)	-135.61 (83.19)	1380.71 (963.21)	539.71 (1293.23)
Caste ST	34.15 (53.84)	-13.31 (53.32)	-67.45* (35.68)	-1074.67* (562.34)	-1427.53** (636.84)
Caste OBC	-127.22*** (45.59)	184.79*** (53.17)	-36.78 (41.65)	1205.83* (614.81)	1061.93 (707.78)
Occupation Own business	10.09 (46.07)	-47.89 (44.95)	48.79 (30.79)	-107.19 (397.33)	167.79 (465.92)
Occupation Government service	14.60 (59.94)	-94.46 (67.29)	43.09 (62.06)	279.98 (871.34)	526.56 (1049.27)
Household size	23.89*** (8.19)	1.46 (5.95)	-7.89 (6.91)	-74.5 (68.89)	-104.92 (92.30)
Proportion of children in family	90.09 (76.26)	21.97 (102.42)	157.97** (79.47)	2358.01** (956.21)	3420.48*** (1230.31)
Highest level of education Primary	202.15*** (55.34)	17.21 (65.89)	-130.06** (52.79)	-1499.08*** (507.47)	-2142.29*** (705.84)
Highest level of education Secondary	209.63*** (42.61)	65.01 (47.13)	-89.03* (48.39)	-1651.56*** (557.42)	-1984.16*** (721.12)
Highest level of education High school	116.39*** (32.03)	67.09 (43.75)	-39.60 (50.43)	-1104.85** (511.01)	-1206.15* (706.81)
Highest level of education Illiterate	104.79 (86.30)	264.59 (175.44)	-53.59 (53.87)	-973.16* (549.91)	-1054.73 (788.58)
Income Less than INR 50000	184.16** (81.36)	-169.10** (80.78)	-306.75*** (62.35)	-2862.18*** (594.95)	-4777.74*** (839.46)
Income Between INR 50000 to 100000	313.66*** (58.49)	-207.22*** (67.59)	-324.28*** (55.31)	-3094.57*** (597.11)	-5042.23*** (783.01)
Income Between INR 100000 to 200000	148.29*** (40.24)	-137.54** (58.05)	-246.44*** (52.33)	-2603.65*** (522.66)	-4127.89*** (717.89)
Income Between INR 200000 to 400000	88.44*** (31.72)	48.13 (52.64)	-143.50*** (51.63)	-1297.35** (602.04)	-2041.43** (800.77)
Pipe connection	-112.47 (86.19)	237.68*** (65.34)	24.07 (40.03)	177.91 (411.38)	424.9 (536.06)
Regular water supply	13.15 (35.71)	2.22 (42.86)	21.85 (41.43)	-84.95 (389.92)	48.38 (566.31)
Information about water supply disruption	-117.58*** (29.57)	150.17*** (40.66)	150.48*** (34.76)	136.34 (405.72)	1120.14** (526.19)
Constant	192.44 (124.56)	-165.45 (136.58)	759.72 (100.15)	4339.61 (1164.89)	9005.17 (1488.81)
R^2	0.7031	0.5504	0.719	0.6084	0.7007
Number of Observations	200	200	200	200	200
RMS error	168.55	204.2	194.62	2041.9	2774.3

* - significance at 10%; ** - significance at 5%; *** - significance at 1%; Figures in parenthesis are standard errors

In Model 1, the variables having a significant and negative impact on collection cost are location of the household, caste –OBC, compared to Scheduled Caste (SC), and having prior information on water supply disruption. Whereas variables having positive and significant effect are household size, lower education levels compared to Bachelor’s degree and above, and low and medium-income level households compared to high-income group (income more than INR 400000). In Model 2, location of the household, i.e., Chandrawal, and religion, i.e., Christian and Sikh compared to Muslim, have a positive and significant impact on the annual purchasing cost. Households belonging to OBCs, in comparison to the SC caste, show significantly higher purchasing costs and so do households having a piped connection and having prior information about water supply disruption. In addition, households falling in the lowest income category, compared to the high-income group (income more than INR 400000), face a significant fall in the purchase costs.

On annual storage cost (Model 3), location of the household, Caste ST, compared to Caste SC, and all other income categories, compared to the high-income group (income more than INR 400000), have a significant and negative impact. Households having a higher proportion of children and prior information about supply irregularity show a significant and positive impact on the storage cost. Households with highest level of education being primary and secondary have significantly lower storage costs, compared to Bachelor’s degree and above. In case of Model 4, the location of household on the main road and caste ST, compared to caste SC, show a significant fall in the annual treatment cost. All the education categories, compared to Bachelor’s degree and above, and all the income categories compared to the high-income group show a negatively significant relation. Gender of the household head, proportion of children and caste OBC, compared to caste SC, leads to significant increase in the treatment cost.

In Model 5, the total coping cost from all the coping activities is the dependent variable. The results in Table 11 show that features like belonging to lower income categories compared to the highest income category and having highest education level as primary, secondary and high school have significant and negative effect on the total coping cost. ST caste, compared to SC caste, location of household, and house on the main road reduce the total coping cost. Receiving information about water supply disruption, household head being male and having higher proportion of children cause a significant increase in the total coping cost.

5. Discussion

The results from the OLS regression indicate that income plays a significant role in determining the household’s ability to engage in a coping activity and, therefore, coping costs. Households in higher income category have more financial costs as they cope with water supply problems by purchasing, storing, and treating water. Households in lower income categories cope by collecting water from various sources, which requires more effort and time. If a household belongs to a lower income bracket, it has a significantly higher collection cost than a household from a higher income one. This is in line with the finding of Pattanayak et al. (2005). In case of annual storage cost, if a household belongs to a lower income group, the reduction in annual storage cost is much more than the reduction for a household in a higher income group. This could be because households with low incomes are not able to spend more on storage devices and are, therefore, more vulnerable than households in higher income groups, during unreliable water supply. Income influencing a household's decision to spend on storage devices has also been found in literature (Zerah, 2000; Vásquez, 2012). The same result was found for the annual treatment cost. Therefore, the ability of a household to adopt a coping strategy is influenced by its financial position where time is saved by spending money.

The size of the household has a significant impact on the collection cost. This means there is increase in water requirement when there are more members in a household, and so more time is spent on collection of water. This increases the cost of water collection. This result is also found in a study by Cook et al. (2016). Further, if the proportion of children in a household increases by one unit then, on an average, the annual storage cost as well as the annual treatment cost for that household also increases. This indicates households are cautious about the effect of the quality of water on children's health. When the household head is a male, the annual treatment cost increases as compared to when the household head is female. This could be because the socio-economic position of female-headed households may not allow them to invest in water treatment devices.

The highest education level of a household plays a significant role. In comparison to the base category of Bachelor's degree and above, the households with education level of primary, secondary and high school probably have lower opportunity cost of time and accordingly spent more time in water collection and, thus, have a high collection cost. Households with the highest education levels being illiterate, primary, secondary and high school, experience a significant fall in the annual treatment cost. With higher level of education, the fall in treatment cost is lower. This indicates that educated households are more aware of the quality of water and its potential impact on health and, therefore, invest in treatment devices to cope. Pattanayak et al. (2005) also found a similar result in their study.

Receiving information about disruption or irregularity in water supply significantly impacts different coping costs and the total coping cost. If information is received, there is a significant reduction in the collection cost as households can prepare accordingly by other means. Prior information leads to a significant rise in purchasing cost as households prepare for irregular supply by purchasing water jars or bottles. Similarly, there is a significant rise in storage cost as households invest in storage tanks, buckets or other storage devices to store water. It can also be inferred that people who receive information are the educated and well of one's (newspaper and television were the source of information for most of the households) who have high opportunity cost of time and, therefore, prefer purchasing or storing water rather than collecting from different sources.

For households that have a piped connection, the purchasing and storage costs increase significantly because having a piped connection does not necessarily mean that the supply is regular. The results are similar to the findings of Burt and Ray (2014) in the context of Hubli-Dharwad where there is a co-existence of storage water by households despite the improvement in the formal network. Several interlinked factors like distrust between the consumer and the service providers, habits, valuing convenience above water quality and tap location also pursued them to resort to storage options. Further, a probit regression analysis reveals that income and education affect the likelihood of a household having a piped connection. Belonging to a lower income group and having lower education levels significantly reduce the probability of having a piped connection (detailed results are in Appendix Table A.1).

If a household belongs to OBC then, compared to the SC category, the annual collection cost falls. In case of purchasing and treatment costs, there is a significant increase for a household belonging to OBC. For households belonging to ST, in comparison to SC category, there are significant reductions in the annual storage, treatment and the total coping costs. This is similar to the result of Katuwal and Bohara (2011), where they found that caste of a household can impact the water treatment costs. The results also reveal that religion of a household leads to significant differences in the annual purchasing cost. This is found to be the case for non-Hindu households. This may be because there are no temples or gurudwaras or other collection sources nearby the households, and if their income position allows, they rely on purchasing water to meet their needs.

Location of the household, i.e., whether it is in Chandrawal or Malka Ganj, plays a significant role in determining annual collection, purchase, storage and total coping cost. If a household is in Chandrawal, then there is a significant decline in annual collection cost and an increase in annual purchase cost, compared to a household in Malka Ganj. This may happen because sources of collection are not available nearby and are forced to purchase water. There is also a significant fall in annual storage and treatment cost if the household is in Chandrawal. In Malka Ganj, all households invest in storage devices and almost all in treatment devices, where as in Chandrawal some households are unable to do so, perhaps because of their income position, and so they have lower storage and treatment costs. Overall, if a household is in Chandrawal, it bears lower total coping costs. We hypothesised that areas far from the water treatment plant would be worse off because of various supply related issues and the results support this, as the measures of coping costs for both the areas show. Though the components of the coping costs vary between Malka Ganj and Chandrawal, the total coping cost is higher for Malka Ganj, thus, proving our hypothesis "being far off from treatment plant will cause more water stress" to be true.

It has also been found that households on the main road perceive water quality to be better as compared to other households (see Table 3). Therefore, if a household is on the main road, then they would have significantly lower annual treatment cost as compared to a household not on the main road. This could also be because a house on the main road has better access to the marketplace or tankers.

With respect to the total coping cost in a year from all the coping activities, income is found to have a significant impact on it, as expected. Costs related to storage and treatment of water form a major part of the total coping costs. Households that belong to lower income groups do not invest in storage and treatment devices, so their total coping cost is lower than that of higher income groups. Gender of the household head and proportion of children in the family are found to have a significant impact on the annual total coping cost. For households whose highest education level is primary, secondary and high school, there is a significant fall in the total coping cost.

6. Conclusion

According to the Indian population Census of 2011, in Delhi, 81.30% of the households have piped supply system for water. However, access to piped water supply is not an indicator of reliable water supply in terms of quantity as well as quality. The risk of contamination is much high for intermittent water supply, and the opportunity cost of time for low-income households is relatively much higher than what a high-income household pays for house connections[18].

In this study, the aim has been to understand how low-income households cope in a situation of unreliable water supply and the additional costs they incur. The results show that a household's decision to adopt a coping mechanism is influenced by the socio-economic status of the household and prior information received about supply disruption. Therefore, regular monitoring of the functioning of water supply services and making the information available is important.

Under the existing water tariff policy in Delhi '20 KL free water scheme,' 100% subsidy is given to domestic consumers with monthly consumption below 20 KL. If a household consumes at least 20 KL every month, then the minimum amount the household pays in a year is around INR 3060[19]. Since this amount is based on the consumption level of the household, it must be paid irrespective of quantity or quality problems. In addition, households incur an average total coping cost of INR 6487 in a year. These costs are much higher than what a household would pay for the water bill and these accounts for approximately 2.52% of their annual income[20].

The tariffs were set for efficient water management. However, whether this scheme has been beneficial is questionable, as according to the Economic Survey of Delhi 2018, this scheme has affected the financial position of the DJB. Since the financial year 2015-16, DJB has been operating at a loss and during 2017-18, it recorded a deficit of INR 3990.10 crore (Budget Estimate). Also, there is no data available on consumption of water or loss on account of leakages due to either faulty meter or unmetered connection. Further, Delhi relies on Haryana for raw water supply, and any legal dispute affects the availability of water.

The existing tariff structure can be reformed to be more inclusive covering the operational and maintenance costs. A more equitable rate can be designed considering the quality of the service and targeting the poor and vulnerable sections of the society. Since the households have to bear the quantity and quality costs of water, they would be motivated to pay if the revenue from the

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[18] https://www.thesourcemagazine.org/the-value-of-247-water, accessed on 5th December 2018

[19] The amount is calculated based on the current water tariff rates of DJB for domestic consumers, http://www.delhi.gov.in/wps/wcm/connect/74fc0a8049fb1e4f84afcee4899821f2/Tariff+14.08.2015.pdf?MOD=AJPERES&lmod=-820044332&CACHEID=74fc0a8049fb1e4f84afcee4899821f2, accessed on 19th December 2018

[20] As we did not have the exact household level income, we took the mid values of the income categories and measured the average income approximately.

water bills is used for investment in improvement of the water infrastructure. Such as upgrading the water treatment capacity of the water treatment plants, fixing the old water distribution pipes or installing new ones so that sewage water does not contaminate the treated water and also prevent from distribution losses. It can also be used for development of an efficient monitoring system for the rising levels of ammonia in river Yamuna.

To phase out the problems associated with intermittent water supply, a multidimensional approach can be initiated by promoting awareness among stakeholders and addressing governance issues concerning autonomy of water utility. Introducing higher tariffs for 24-hour service, placing moratoriums on new connections, investing in hydraulic modification of the water distribution system, strict metering and reducing the component of non-revenue water (McIntosh, 2003, Source, 2016). A pre-requisite for success is that the public authorities, donors, and banks must also facilitate the utility companies to invest in water recovery. The technicians and engineers of water service providers using conventional techniques should be professionally well trained and equipped for higher capacity building of the sector.

Field-level evidence exists of a transition from intermittent to 24/7 in the context of a World Bank-supported Karnataka Urban Water Sector Improvement project implemented in 2005[21] in the area of Hubli, Dharwad, Belgaum, and Gulbarga. Since all these cities have similar water distribution network, it was possible to replace the broken network with new polyethylene pipes and install meters for all their customers. As a result, there was a 10% reduction in overall water consumed, while the revenue billed increased by a factor of 5. Thus, the revenue collected increased by a factor of almost 7.

The Sustainable Development Goal (SDG 6) targets that 'By 2030, achieve universal and equitable access to safe and affordable drinking water for all.' In order to achieve this, there is a need for a comprehensive and sustainable water policy for Delhi. Its purpose should not just be to enhance the water supply but also proper demand management of water resources. Importance should be given to reduce the loss of water during distribution and create more awareness among the public about judicious use of water. Policy decisions taken should aim at

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[21]WSP(2010): The Karnataka Urban Water Sector Improvement Project,24x7 Water Supply is Achievablehttps://www.wsp.org/sites/wsp/files/publications/WSP_Karnataka-water-supply.pdf accessed on 5th Dec, 2018

providing a reliable, affordable, and good quality supply of water and reduce the coping burden and vulnerability of poor households.

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Appendix

Table A.1.Probit estimates for having a pipe connection for water

Variable		**Marginal effect (dy/dx)**	**Standard Error**
Income	Less than INR 50000	-0.821***	0.155
	Between INR 50000 to 100000	-0.403***	0.106
	Between INR 100000 to 200000	-0.017	0.06
	More than INR 400000	All households have pipe connection	
Highest Level of Education	Illiterate	-0.447	0.42
	Primary	-0.288**	0.143
	Middle	-0.121*	0.068
	Bachelors and above	All households have pipe connection	

* - significance at 10%; ** - significance at 5%; *** - significance at 1%;

The results show that both income (compared to base category Between INR 200000 to 400000) and education level (compared to base category of High school) of a household can have a negative and significant impact on the likelihood of a household having a pipe connection.

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