DEVELOPMENT OF A WATER PRICING MODEL FOR DOMESTIC WATER USES IN DHAKA CITY USING IWRM FRAMEWORK

A Thesis by

Sumaia Kashem

Roll No. 1018282007

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Institute of Water and Flood Management
Bangladesh University of Engineering and Technology, Dhaka

....

Dr. Sazia Afreen — Member (External)
Executive Engineer, P & D (Sewer) Division
Dhaka Water Supply and Sewerage Authority,
WASA Bhaban (6th Floor), Kazi Nazrul Islam Avenue, Dhaka

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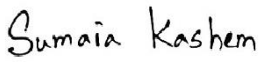
It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.



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Sumaia Kashem

Roll No. 1018282007

Dedicated

To

My Beloved Father

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Abstract

Groundwater is the principal water source in the megacity, Dhaka for all kinds of uses. It is supplied at Uniform Volumetric Charge which is comparatively lower than most other Asian cities, and this promotes higher water uses. Only the domestic abstraction in the city is about 2.0 Mm^3 of groundwater every day which has resulted in a drawdown of up to 80m with an annual decrease of 3.07m. Thus, the groundwater has become almost a free-access common pool resource due to its lower price, which in turn has led to a severe decline in this valuable environmental resource. On the other hand, while the rich enjoy tapped water in their houses, majority of the slum-dwellers rely on private vendors. The slum dwellers pay about 7-14 times higher price than the formal housing, and the total spending on water is about 12-15% of their monthly income. As a result, the slum people use 7.5-10 times less water in comparison with a middle-class household consumer in the Dhaka city and the insufficient water use leads to several inconsistencies in their livelihoods. The main burden of less consumption is generally imposed on women due to their responsibility to maintain the family. Thus, the total process does not follow the three principles (economic efficiency, environmental sustainability, and social equity) of Integrated Water Resource Management (IWRM). In this context, the study was taken to develop an efficient water pricing model based on IWRM framework for domestic water uses in this megacity as a long-term solution to the problems associated with the current water pricing system.

The broad objective of the study has been dissected in three steps: estimating domestic water usage for both formal and informal settlements, evaluating the current water pricing system based on the factors of water pricing as well as its impacts on livelihood and finally, developing a water pricing model integrating IWRM principles. Several field survey tools including questionnaire survey (sample size n=100), focus group discussions (n=4), key informant interview (n=5), in-depth interview (n=4), and pair-wise ranking (n=1) covered the collection of both the qualitative and quantitative data. The necessary secondary information for calculating the cost of externalities of groundwater exploitation has been collected from Dhaka Water Supply and Sewerage Authority (DWASA), Bangladesh Water Development Board (BWDB), Bangladesh Power Development Board (BPDB) and Department of Environment (DOE).

The findings reveal that the slum dwellers pay more than 17% higher price for buying the same amount of water (1000 liters) than the DWASA set price for domestic use. The price burden not only generates numerous endurances into the life of slum dwellers, but also stirs up the gender issue more threateningly. Less water consumption (11 times), water-shortage related disease sufferings (66%), and unhealthy sanitation (82%) are some notable evidences of price burden found in this study. It also validates that the slum women are in most vulnerable position due to this inequity prevailed in the Tejgaon area. Considering the improper water price practice, a new water pricing model is developed following an increasing block tariff strategy with the consumption limit of the first block as 50 lpcd. The suggested unit price of water considers that the consumption in the first block covers the unit extraction cost (BDT 15.18), while the volumetric rate in the second pricing block (BDT 25.37) includes the cost of resource degradation externalities for the high

consumption. The study considered four externalities relevant for the study area including two economic (increased energy consumption for the lifting of water in the wells, and damage cost for the dryness of the wells), and two environmental (carbon footprint of water and health externalities) and evaluated in monetary terms.

The price of the first and second block water is estimated to be about 5% and 75% higher than the existing price. Hence, DWASA can earn an additional revenue of BDT 9 billion to BDT 136 billion in a year from the first and second block water users in the Tejgaon residential area. In addition, domestic water use can be reduced up to 27% from the existing use which in turn can reduce the electricity use as well as greenhouse gas emission. Finally, on the equity perspective, the water bill can be reduced by about 67% if it is maintained in the first block which can contribute to cross-subsidy system. The proposed increasing block tariff model fulfills multiple objectives, such as groundwater conservation, cost recovery of water supply and deduction of price burden of water for the low-income people, and thus satisfies the three core principles of IWRM. Finally, the study offers a sort of methodology for pricing of water that may convey an appropriate conservation signal to the consumers which will be useful to the policy and decision-makers in devising an efficient water use plan for the present and future.

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ABBREVIATIONS AND ACRONYMS

BASA	Bangladesh Association for Social Advancement
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
BMDA	Barind Multipurpose Development Authority
BRAC	Bangladesh Rural Advancement Committee
BPDB	Bangladesh Power Development Board
BT	Block Tariff
BWDB	Bangladesh Water Development Board
CBO	Community Based Organization
CPCR	Community Program and Consumer Relation
CWASA	Chattogram Water Supply and Sewerage Authority
CWB	Channelized Water Body
DBT	Decreasing Block Tariff
DMA	District Metered Area
DNCC	Dhaka North City Corporation
DoE	Department of Environment
DPHE	Department of Public Health Engineering
DSK	Dustha Sasthya Kendra
DWASA	Dhaka Water Supply and Sewerage Authority
EFSA	European Food Safety Authority
FGD	Focus Group Discussion
GBM	Ganges-Brahmaputra-Meghna
GED	General Economic Division
GHG	Greenhouse Gas
GWL	Groundwater Level
GWP	Global Water Partnership
IBT	Increasing Block Tariff
IDI	In-depth Interview
IWM	Institute of Water Modeling
IWRM	Integrated Water Resources Management
IOM	International Organization for Migration

KII	Key Informant Interview
LGD	Local Government Division
LPCD	Liters per Capita per Day
MLD	Million Liters per Day
NRW	Non-Revenue Water
OECD	The Organization for Economic Cooperation and Development
OWB	Open Water Body
PRA	Participatory Rural Appraisal
RWASA	Rajshahi Water Supply and Sewerage Authority
SDG	Sustainable Development Goal
UNDP	United Nations Development Program
USAID	United States Agency for International Development
UVC	Uniform Volumetric Charge
WASA	Water Supply and Sewerage Authority
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1. Background and Present State of the Problem

Water is one of the most important resources for maintaining the needs of the dynamic environment. Unfortunately, water resources are diminishing despite their countless importance. Several human activities, such as unconscious use and pollution, are the underpinning factors of the decreasing state (Kılıç, 2020). According to the United Nations Development Program (UNDP), over 40% of people are affected by water shortages, which is expected to increase more as a consequence of climate change by 2050. Therefore, being vital for the continuation of life, access to safe water is highly emphasized in the list of sustainable development goals (SDGs) (UNDP, 2015). Integrated water resources management (IWRM) is marked several times as an effective approach to the management of water scarcity issue as well as acquiring sustainable development goals (Kumar et al., 2019; Meran, et al., 2021a; Rahaman and Varis, 2005; Sun et al., 2011; Videira et al., 2011). It is a process that encourages the coordinated development and management of water based on three core principles: economic efficiency (to provide the greatest benefit to the greatest number of consumers possible with the available water resources), social equity (ensuring equal access to an adequate quantity of water for marginalized and poorer user groups), and environmental sustainability (consideration of social and environmental costs for the sustainable functioning of resources) (GWP, 2004; Kasbohm et al., 2009).

Regarding the status of IWRM in Dhaka city, Dhaka Water Supply and Sewerage Authority (DWASA), is the autonomous organization that supplies potable water to residents of this megacity (DWASA, 2018). Due to the aggregated population growth as well as urbanization trends, the water demand of this megacity is increasing higher and higher. On the other hand, the continuous reduction of the rivers and other wetlands because of urbanization of the substantial population (Nahar et al., 2014) and polluted quality due to industrialization (Sarkar et al., 2019) make the city water supply depending on the groundwater. As a result, DWASA extracts higher share (up to 78%) of the water supply from groundwater to meet the water requirement in the city (DWASA, 2020).

In this city, water is supplied at subsidized Uniform Volumetric Charge which is comparatively lower than most other Asian cities (Arfanuzzaman and Rahman, 2017). The lower subsidized rate of water tariff encourages the unconscious and excessive use of water (Macian-Sorribes et al., 2015). Hardin (1968) pointed out the reason that whenever a product is free or undervalued, it promotes misuse rather than the efficiency of use. As evidence, despite being a more developed city, the domestic water use in Delhi is lower than that in Dhaka due to a higher price (Asim and Lohano, 2015). In Dhaka city, only the domestic abstraction results in about 2.0 Mm^3 of groundwater every day which has resulted in a drawdown of up to 80 m with an annual decrease of 3.07m (Chowdhury, 2018; GED, 2018). Thus, groundwater has become a free-access common pool resource due to its lower price which in turn leads to a severe decline in the valuable environmental resource.

As the stock is not unlimited, the dynamic inefficiency makes one of the most valuable resources, groundwater becoming scarcer day by day (Das et al., 2021). The declination of the groundwater has further negative implications (externalities) on the future water supply as well as the environment (Acharya and Barbier, 2000; Diwakara and Chandrakanth, 2007). A range of externalities, such as an increase in financial expenses of groundwater extraction, reduction in longevity of the well, damages to the aquifer, greenhouse gas emission and salinity intrusion, arise along with the depletion (Baniasadi et al., 2020; Diwakara and Chandrakanth, 2007). For full recovery of cost, externalities must be considered in the pricing of water (Bielsa and Cazcarro, 2015; Laila, 2008; Pulido-Velazquez, et al., 2013; Riegels et al., 2013). Unfortunately, the existing pricing policy disregards the associated costs of the groundwater externalities and is hinged on installation cost, and operation and maintenance (O and M) cost. Thus, the consumer receives all the benefits of groundwater without even paying the full cost (Das et al., 2021; Kemper et al., 2004). Additionally, while the rich enjoy tapped water in their houses, the majority of slum-dwellers rely on private vendors. The slum dwellers pay about 7-14 times higher price than formal housing which is about 12-15% of their monthly income (Rahaman and Ahmed, 2016). As a result, slum people use 7.5-10 times less water in comparison with a middle-class household consumer in Dhaka city (Nurul and Mohammod, 2014) where the main burden is generally imposed on women due to their responsibility to maintain the family. Thus, the total pricing process of this megacity is not maintaining the three principles of integrated water resource management although it is a critical concern for many countries. Water pricing, according to experts, is an approach that can significantly improve in the case of scarcity. This highly emphasizes the importance of designing an optimal tariff in accordance with IWRM so that it can be used to achieve economic, environmental and social goals (García-Rubio et al., 2015, Hek and Ramli, 2016). In this context, the study is taken to develop an efficient water pricing model incorporating the core principles of IWRM framework.

1.2. Objectives of the Study

The specific objectives of the study are as follows:

- To estimate water usage for domestic purposes in the selected area of Dhaka city;
- To identify and assess the current groundwater pricing systems in the study area; and
- To develop a use-specific groundwater pricing model using IWRM framework.

1.3. Scope of the Study

The main focus of the study is to assess the current water pricing system and revise its design in view of the three principles of IWRM framework. It refers to a sort of methodology of pricing of water that may convey an appropriate conservation signal to the consumers. The study emphasizes the domestic water usage of a small portion of Dhaka city for the estimation and calibration of the proposed pricing.

1.4. Importance of the Study

The development of a water pricing model based on IWRM framework is the most important outcome of this study. The study also provides a better understanding of how the disadvantaged slum people, particularly women, are suffering from the current groundwater pricing system and focuses on pro-poor water pricing for ensuring social equity for slum people. Finally, the findings convey a guideline for the reduction of overuse of groundwater which will be useful to policy and decision-makers in devising efficient water use for the present and future.

1.5. Limitations of the Study

Although the study has achieved its aim, still it has some limitations for some unavoidable reasons.

- Firstly, the study is limited to estimate the cost of groundwater externalities for a selected portion of Dhaka city due to time constraints.
- Secondly, the survey for primary data collection is conducted on a small size of population (sample size: 100) due to the pandemic situation. The result from the analysis would have been more representative if the sample size would have been larger.
- According to the DWASA Master Plan, DWASA attempts to move its water supply source from groundwater to surface water to the extent of 70% (DWASA, 2014; 2020). As the proposed pricing model is based on groundwater pricing, it will be valid till the implementation of the plan of DWASA.

1.6. Structure of the Thesis

The thesis is organized into six chapters including several sections and subsections in each chapter. Descriptions of the six chapters are given below:

CHAPTER ONE (this chapter) discusses the background of the study and the present state of the problem. It also underlines the objectives, scope, and limitations, and importance of the study.

CHAPTER TWO portrays a picture of the state of existing water resources in Dhaka city covering the availability, supply and uses. It also provides a detailed overview of water pricing scenarios across the world as well as Bangladesh and concludes with the role of IWRM on the design of water pricing.

CHAPTER THREE provides the description of the location, demography, climate, and present resources in the study area.

CHAPTER FOUR illustrates the framework (in detail) used to re-design the existing water pricing model. The types of data collected for this study and the methods used for collecting the data are also presented in this chapter.

CHAPTER FIVE displays the study findings derived from the comparative analysis of domestic water usage, the factors, and impacts of existing water prices of two different types of settlement. Finally, it incarnates the details of the proposed water pricing model and calibrates it with proper justifications.

CHAPTER SIX concludes the findings of the study and recommends directions for future research.

CHAPTER 2

LITERATURE REVIEW

2.1. Water Use and Availability

Dhaka, the capital of Bangladesh, is situated in the lower stream of the transboundary river basin: Ganges-Brahmaputra-Meghna (GBM). Despite its location, the city is still facing an enormous demand for water. The demand is getting higher and higher because of the changing pattern of the consumption of its rapidly increasing population. Coping up with the heavy industrialization and urbanization, surface water of the city gets contaminated which leads the city to depend on groundwater almost completely.

2.1.1. Multiple uses of water

Dhaka is the primate city of Bangladesh having a share of the national urban population of about 25% in 1981, 31% in 1991, 34% in 2001, and 37.3% in 2011 (BBS, 2011, 2015). One-tenth of the country's population and a third of the urban population live in Dhaka (Bird et al., 2018). Meanwhile, the volume of the population reaches up to 18.2 million and is anticipated to reach 27.37 million by 2030 (Swapan et al., 2017; United Nations, 2016). Due to this unprecedented population growth, the city is positioned as the eleventh largest megacity in the world (Swapan et al., 2017). The typical growth dynamics of any megacity demand for additional urban foundation, utilities, and services including water supply, strong waste management, sewerage, sanitation, transportation, and urban infrastructure which are producing higher water demand day by day (McDonald et al., 2014). Water is required for each fundamental convenience of urban advancement, for example, fulfilling domestic purpose, industrial purpose, commercial purpose, recreational purpose, sustenance of aquatic flora and fauna, and conservation of biodiversity. Moreover, being the capital of Bangladesh, this city is dominant in terms of economy, trade, commerce, and administration as well (Anwar, 2010). Therefore, the total water requisite for sufficient city supply amplifies along with the growth of urban population (Bradley, et al., 2002; Falkenmark and Widstrand, 1992; McDonald et al., 2011, 2014). Some of the prominent water uses are described below:

- Domestic water use: One of the foremost aims for the major cities is to satisfy basic demands for safe drinking water and sanitation (GED, 2018). Drinking, bathing, toileting, cooking, washing, cleaning and gardening etc. are basically domestic uses of water. To meet up the need of the extreme population in this city, only the domestic abstraction results in about 2.0 Mm^3 of groundwater every day here (GED, 2018). Anwar (2010) has claimed that the average water consumption for household activities is 105 to 204 lpcd (liter per capita per day) in Dhaka city. However, the average per capita water demand is also estimated at 150 lpcd by DWASA (DWASA, 2020).

- Industrial and commercial use: Due to the increase in population and demand for industrial products, greater Dhaka experiences rapid industrialization, and commercial activities. About 47% of industries (2179 in numbers) are located in Dhaka which is clustered in Tejgaon, Savar, Dhaka EPZ, Konabari-Kasimpur (Gazipur), Tongi, Hazaribagh, BSCIC Narayanganj, Shyampur, Fatullah, and DND (BBS, 2012). They need water for manufacturing, fabricating, processing, washing, cooling, sanitation needs within the manufacturing facility etc. Almost 0.35 km^3 is abstracted per year by 1000 private wells for industrial purposes in this city (Hossain and Bahauddin, 2013). The major industries in this city especially textile industries, metal factories, paper, dyeing and painting industries, and tanneries are highly reliant on the water environment. For instance, the washing and dying factories consume as much as 300 liters of water to produce only one kilogram of fabric (GWP, 2019). On the contrary, the estimated current water demand of the textile and leather sector of Dhaka is 4027 MLD (million liters per day) which is double of whole Dhaka's water demand. Considering the water demand same, only the textile sector will result in an additional water demand of over 6,750 MLD by 2030 which is equivalent to the annual water needs of 60 million people in Bangladesh (Sagris and Abbott, 2015). Water is also used in institutions such as offices, hotels, restaurants, hospitals, shopping complexes, business centers, office buildings, educational institutions, religious buildings, cultural halls, community centers, warehouses, and stores, etc. which can be termed as commercial use of water.

- Non-consumptive water use: Water is an imperative element of recreational opportunities and involvements which enrich urban life (Kakoyannis and Stankey, 2002). Besides, satisfying the recreational demand, a wetland contributes to the maintenance of the ecology of a city. Due to its location on a floodplain, Dhaka city is highly served by the lakes and other wetlands of it through groundwater recharging, flood management, and overall drainage system (Sultana and Chowdhury, 2013). For example, Hatirjheel and Dhanmondi Lake in Dhaka are used both as recreational spot and storm water management.

2.1.2. Available water resources

Dhaka was endowed with a significant amount of water resources. Unfortunately, the resources are on the verge of demolition nowadays due to unplanned urbanization and extreme population growth. However, the available water resources can be described under three broad categories:

- Surface water: Dhaka is located in the central region of the flat deltaic plain of the three major international rivers: the Ganges, the Brahmaputra, and the Meghna. The city is surrounded by several tributaries of these three major rivers such as Buriganga River in the south-west, Balu River in the east and Turag in the west and north, Shitalakhya River on the south-east. The three small rivers Turag, Balu, and Tongi Khal are mainly connected with the big perennial rivers Buriganga and Shitalakhya around Dhaka city. Besides the rivers, the city is blessed with a large number of water bodies consisting of khals, lakes, flood plain low-lying areas etc. The amount of total area fallen under surface water bodies was 2952 hectares in 1960 (Islam et al., 2014) which has reduced up to 886 hectares over the past 30 years (Habib et al., 2020) (shown in Figure 2.1). The gradual loss of the number of surface water bodies over years is also depicted in the study of Faridatul et al. (2019). They have embodied the transition of surface water area and its underlying factors in two cities, Dhaka and Hong Kong, using advanced geostatistical tools. Surface water bodies were the second most dominant land use in this city in 1989, but the dominance has been taken away by the impervious land gradually. In 2016, the surface water bodies were lowest in the position of dominant land use. The surface water area decreased up to 21.07% from 1989 to 2016 and the change is much observed in the central part of the city than the periphery.

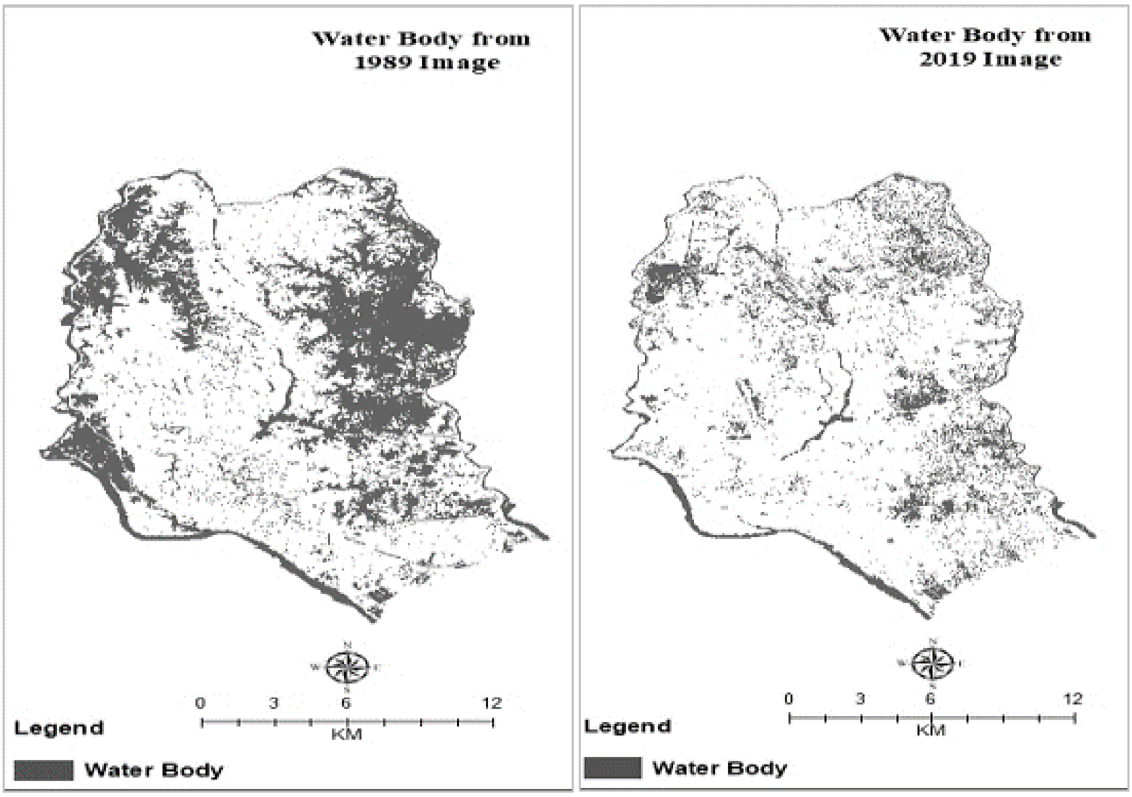

Figure 2.1: Water body map of DMP area (from 1989 to 2019)

Source: Habib et al. (2020)

Paul et al. (2019) has also tried to capture the reduction of surface water bodies and floodplains in Dhaka from 1967 to 2008 through geospatial analysis dividing it into two sections for more specified understanding. The sections were channelized water body (CWB) comprising the peripheral and inland channels and open water body (OWB) comprising the floodplains, lakes, ponds, etc. The study identified that a substantial portion of the well-defined network of channels of 1967 was entirely occupied or shrunken in 2008. The extent of CWB was reduced from 17.56 km^2 to 15.26 km^2 during this period indicating a decline of 15%. Contrarily, the changes of OWB exhibits 37.56% loss (from 81.33 km^2 to 50.78 km^2). The declination has much observed in low-lying floodplain areas in the northeastern and northwestern parts of the city including some of the most populated neighborhoods such as Uttara, Mirpur, Mohammadpur, and Bashundhara.

Besides the quantity, quality of water has become a critical issue in Dhaka (Haq, 2006; Chattapadhya and Islam, 2016; Hossain and Sultana, 2016; Hussain, 2018; Rahman et al., 2013; Sarkar et al., 2019). About 1.3 million m^3 of waste is being discharged into the rivers of the Dhaka watershed in a single day constituting 60% industrial waste and 40% domestic waste (GED, 2018). According to Rahman et al. (2013), the higher peripheral river water is highly contaminated with lead (Pb) for discharging into inland water, public sewer, and irrigated land. Although the concentration of other heavy metals (Cd, Cr, Ni, and Zn) is still well enough for discharge into inland water and public sewer, this exceeds the Bangladesh standard for drinking water. Sarkar et al. (2019) has also conducted a detailed review on the water quality of Dhaka city. He signified that the southern edge portion of the Buriganga River is almost biologically dead, while the Turag, Shitallakhya, and Balu rivers contain unfavorable water for sustenance of aquatic life. The color of the Buriganga, Turag, Shitalakkhya, Balu, and some other river water even becomes too dark to penetrate sunlight during the dry season. Moreover, a high level of organic pollution has been identified from the rivers of this city. For instance, the Buriganga has a lower level of DO (0.9-2.8 mg/l) and a higher level of COD (140-800 mg/l). He marked the discharge of untreated industrial and municipal wastes as the prime reason for this pollution.

- Groundwater: Groundwater is the major water resource in Dhaka city supplying about 98% water for industrial use and 78% of water for domestic and other commercial uses (DWASA, 2020; Sagris and Abbott, 2015). The city abstracts groundwater resources from fluvio-deltaic Pliocene Dupi Tila aquifer where the direct recharge is prevented by its soil characteristics (Akhter et al., 2009; Hasan et al., 1999). DWASA extracts water from the Dupi Tila aquifer within the city between 50 and 200 m below ground level generally. This extent of depth is now extended to 300-320 m facing problems in the main part of the Dupi Tila aquifer (Zahid et al., 2009).

Jerin and Ishtiaque (2015) have investigated the spatial distribution of the declination of groundwater in Dhaka city along with its causes. The findings of the study suggest that groundwater in Dhaka city has been disappearing at an alarming rate from 1990 to 2012. The central region is encountering the highest decline followed by the south-western region. The periphery zone, on the other hand, is in better shape due to the presence of rivers and wetland areas. They have indicated several causes behind this state of groundwater throughout the city such as high population density, the establishment of deep tube wells, and reduction of recharge capacity due to the rapid growth of urban structures. Mamoon et al. (2020) have also studied the spatial and temporal extent of groundwater level and examined the possible governing factors behind the continuous declination. They have also agreed with the previous study that the central region of the city has the higher declination, while the extent is lower in the periphery. During the 28-year study period (1990-2018), a significant change is observed for both the maximum depth (17m to 66m) and the minimum depth (2m to 16m). They have further explored that various factor have a positive relationship with massive declination, such as changes in rainfall distribution, diminution of water bodies, speedy change in land use pattern, and inconsistent extraction of groundwater due to the alarming growth of population.

Uddin et al. (2016) have abridged two main reasons for this depletion: hindrance in infiltration due to an increase in a built-up area and excessive extraction of groundwater. As shown in Figure 2.2, the rapid change in land-use pattern in Dhaka Metropolitan area has significantly reduced the area of natural 'infiltration galleries' which has resulted in a severe negative impact on groundwater recharge. The second point is also emphasized greatly in several literatures that large abstraction by water-wells has been triggering a substantial aquifer dewatering in this city (Akhter and Hossain, 2017; Arfanuzzaman and Rahman, 2017; Hoque, 2007; Roy and Zahid, 2021; Zahid et al., 2009).

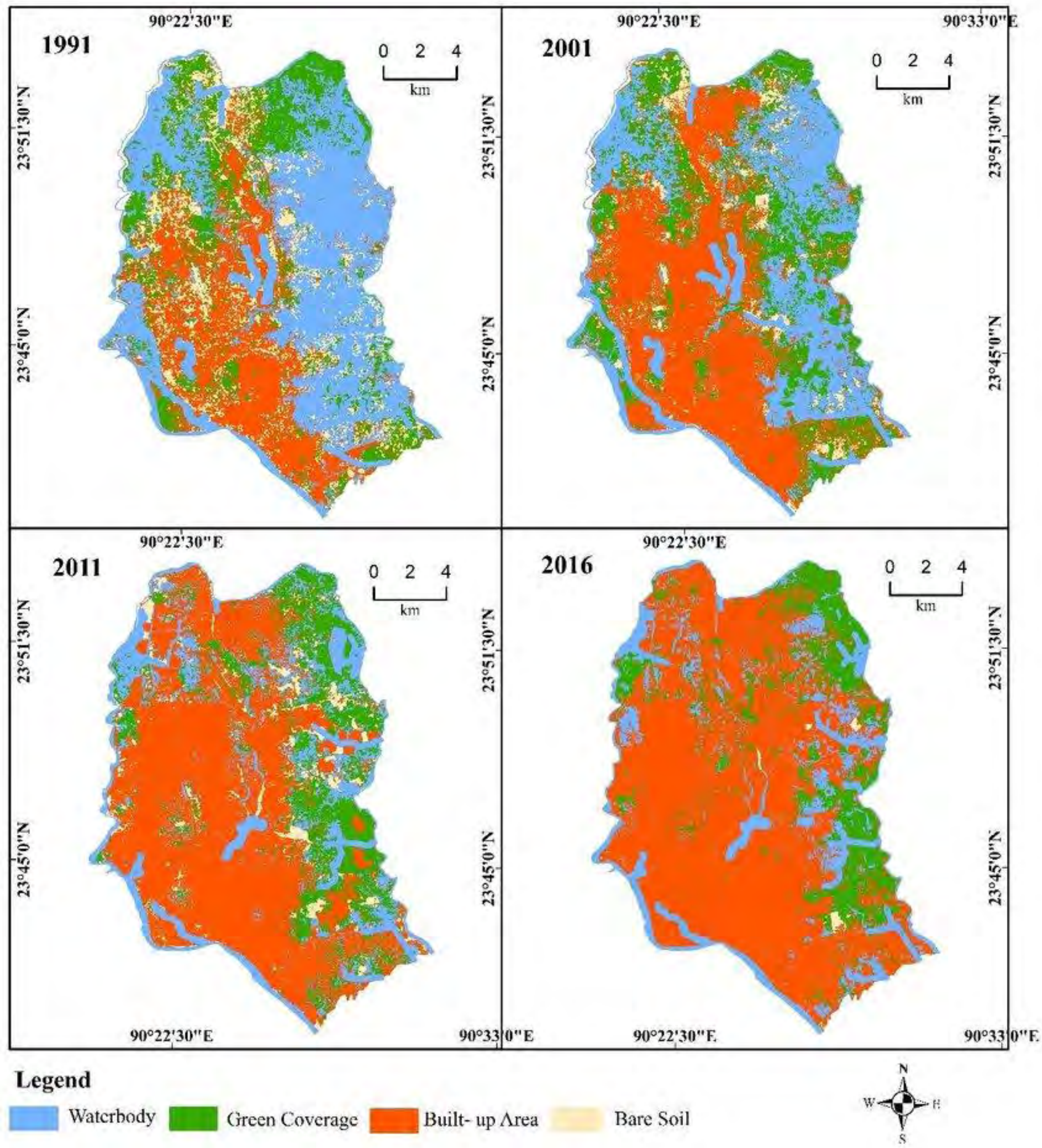

Figure 2.2: Land use change in DMP area (from 1991 to 2016)

Source: Enan and Ullah (2019)

The high population growth in the megacity and the consumption behavior have been marked as the reasons for this extraction extent. For instance, the water use is comparatively higher than other neighboring developed cities of Asia (Asim and Lohano, 2015; Quayyum and Rahman, 2008). Figure 2.3 represents a comparative picture of water consumption between different Asian cities. It is compared with eleven different cities among which four cities are from South Asian countries, five cities are from Southeast Asian countries and rest two cities are from East Asian countries. The South Asian cities are Kathmandu (Nepal), Gampaha (Sri Lanka), Karachi (Pakistan), and Delhi (India). Besides, the Southeast Asian cities are Kuala Lumpur (Malaysia), Manila (Philippines), Jakarta (Indonesia), Singapore (Singapore) and Bangkok (Thailand). Beijing (China) and Osaka (Japan) are the East Asian cities. The per capita water use of Dhaka (252 lpcd) is much higher than Delhi (110 lpcd), Gampaha (119 lpcd), Kathmandu (122 lpcd), Manila (131 lpcd), Jakarta (133 lpcd), Singapore (141 lpcd), Beijing (168 lpcd), Karachi (197 lpcd) and Bangkok (201 lpcd). However, only the city of Japan and Malaysia show the greater values with consumption of 263 liters and 268 liters per capita in a day respectively.

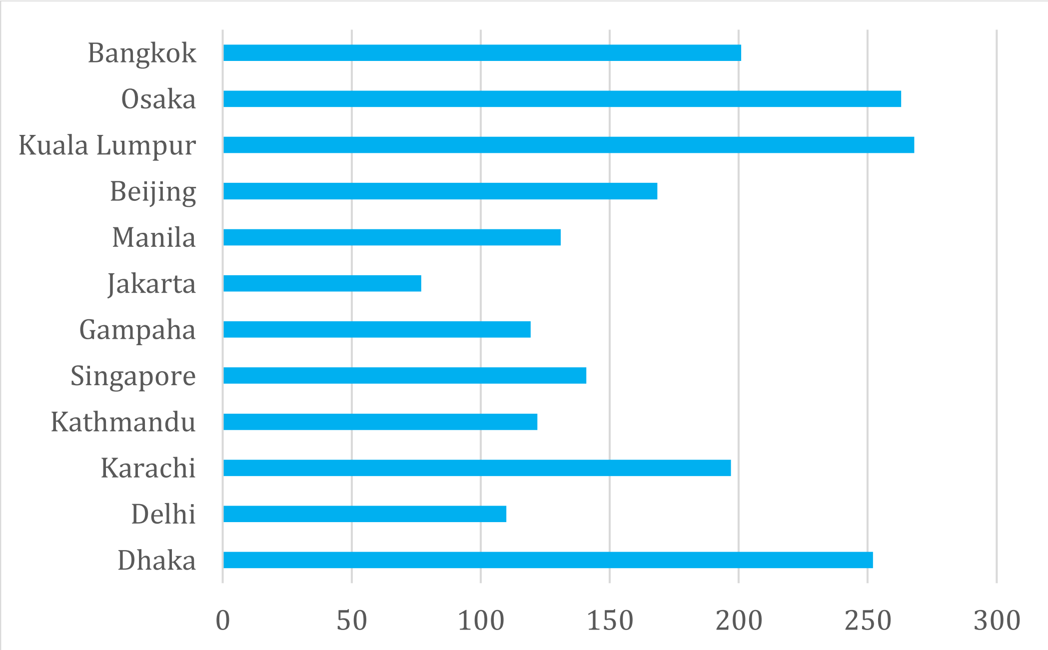

Figure 2.3: Per capita water use in different Asian cities

Source: Abedin and Rakib (2013), Lohano (2015) [Delhi and Karachi]; *Shrestha et al. (2016)* [Kathmandu]; *Public Utilities Board (2018)* [Singapore]; *Kausalya et al, (2020)* [Gampaha]; *McIntosh (2014*) [Jakarta and Bangkok]; *Bari et al. (2015)* [Kuala Lumpur]; *Manila Water Company Inc. (2018)* [Manila]; *CEIC database (2019)* [Beijing].

Only the domestic abstraction in the Dhaka city results in about 730 Mm^3 of groundwater every year which has exceeded the recharge extent of the aquifer. In the Dhaka Metropolis, the natural recharge rate is about 25% lower than the groundwater abstraction rate (Islam, 2017). As a result, the city is experiencing a drawdown of up to 80m with an annual decrease of 3.07m (Chowdhury, 2018; GED, 2018). In his study, Haque (2018) has provided a caution for the future water demand of Dhaka city. He revealed that the extent of groundwater declination has come to a point where it would not be feasible to dig more wells and increase the production rate. Rahman and Mamtaz (2018) have also agreed that the city will face a great scarcity of groundwater if the abstraction continues at this excessive rate. They have also specified that, due to the excessive depletion, many existing tube well yields will be lowered or perhaps go out of production, which might be disastrous.

- Rainwater: Chowdhury (2012) has marked rainwater as an important water resource in Dhaka city. The city experiences the Indian Ocean Monsoon and four metrological seasons: Pre-monsoon (March to May), Monsoon (June to September), Post-monsoon (October to November), and Dry (December to February) (IWM, 2005). The number of annual rainy days of this city varies from 95 to 144 where the monsoon period comprises the major percentage of the annual rainfall (> 80%). The annual rainfall of this city varies from 1169 mm to 3028 mm with an average of 2076 mm and a standard deviation of 389 (Ahammed et al., 2014). Shourav et al. (2016) has determined in their investigation that the yearly variation of rainfall is only 19.7% (during 1961-2010) demonstrating it as more or less reliable in this city. Though the annual average rainfall is abundant, the limitations of using rainwater are related to its storage. Due to the dominance of impervious areas, the groundwater cannot be recharged properly in this city (Chowdhury, 2012).

2.1.3. Present water supply system

Under Water Supply and Sewerage Ordinance-1963, Dhaka Water Supply and Sewerage Authority (DWASA) was entrusted with piped water supply in Dhaka Metropolitan Area, DND area, Narayanganj City Corporation in the South and Mirpur-Uttara in the North and adjacent area (Farok, 2017). The potable water distribution network has been installed in the whole area of the city and it covers the periphery of the city and its extension is going from Narayanganj to Tongi as well as the surrounding area of this city. Since then, the organization has been serving as the only public authority in Dhaka megacity having legal power for improvement, modernization, and expansion of water and its supply system (Haq, 2006). Moshfika (2021) illustrated the early history of water supply system of Dhaka city in her research. The first water supply system was introduced by the British in 1888 through Chandnighat plant which treats water from the Buriganga. Until the late 1960s, Dhaka's water supply was almost entirely relied on surface-water systems. Over time, the sources of water of the Buriganga River have become biologically and hydrologically dead because of ongoing water pollution caused by industrial and domestic sources. The traditional treatment plant, which solely employs lime and chlorine for treatment, is incapable of neutralizing the current contaminants in river water. So, in order to fulfill the city's ever-increasing demand, DWASA continued to develop deep-water pumps on a crisis basis, with no long-term strategy.

At present, DWASA is extracting groundwater by using a total of 887 deep tube wells. The rest 22% of water is supplied from surface water sources treating water of the river Shitallakhya and Buriganga through four water treatment plants. According to DWASA Annual Report (2018-2019), it serves more than 20 million people in this city covering about 360 km^2 area. It has provided 390642 connections to this city yet with about 3750 km supply line. The current production capacity of this organization is 2550 million MLD which has gradually increased since its inception in 1963 (Figure 2.4).

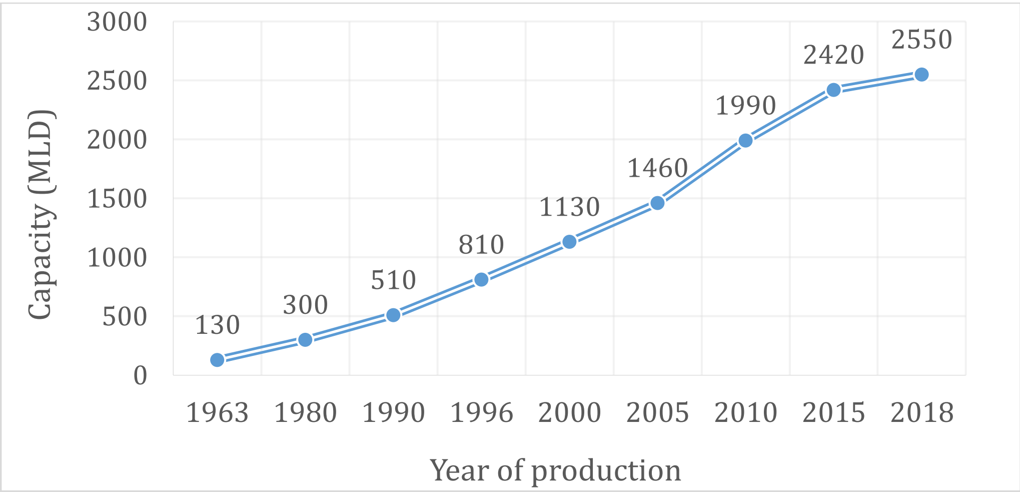

Figure 2.4: Time series of production capacity of DWASA

Source: DWASA (2020)

As already stated, due to the surface water contamination for high industrialization, DWASA started to extract water from underground sources (around 78% at present). So, an increase in production capacity indicates a higher dependency on groundwater. However, Dhaka WASA has 410 diesel-driven generators (including 42 mobile generators) which help maintain the abstraction of groundwater during the interruption of power supplies in summer (DWASA, 2020).

DWASA stated that these supply pipelines were constructed almost 144 years ago and became leaky causing 40-45% of non-revenue water. The water supply system of Dhaka WASA is now facing complexity in fulfilling the water demand of city dwellers due to water pressure, use of the suction pumps, plenty of unidentified leakages and illegal connections, poor water quality, and high system loss.

Considering non-revenue water (NRW) as a great challenge for Dhaka City, Farok (2017) has also calculated its percentage in his study. He defined NRW or system loss as consequences of pipeline leakage, illegal service connections, and theft of water. The percentage of system loss was about 50% in 2002-2003 which has reduced the revenue by about 27 crores. Through using of District Metered Area (DMA) unit, DWASA has managed to reduce the percentage of NRW to 27-29% from 50%. Still, nearly one-third of the water is lost on an average in Dhaka city which is creating obstacles in the way of water management.

A significant percentage of NRW consists of illegal connections and theft of water. Some politically powerful landowners maintain dual connection unlawfully and sell this water to the poorest people at a high rate. They collect water from the mainline without approval or often in contract with the corrupted person of the supply authority (Uddin and Baten, 2011). Still, a significant number of the more vulnerable low-income community (LIC) dwellers are dependent on the reserved tanks established by those middlemen having minimal or no access to water services (Nurul and Mohammod, 2014; Rahman and Ahmed, 2016). Surprisingly, the slum dwellers are paying about 12 times higher than the formal water supply (Nurul and Mohammod, 2014) which evidences the apparent unethical involvement of middlemen in the slums. However, DWASA has recently started giving connection to these settlements through supporting NGOs including Dustha Sasthya Kendra (DSK), Bangladesh Rural Advancement Committee (BRAC), and Bangladesh Association for Social Advancement (BASA) as well as Community Based Organizations (CBOs). For providing legal water services among the low-income communities of Dhaka city, DWASA created a new division named Community Program and Consumer Relation (CPCR) Division which was started on 30 November 2010. This division attempts to supply safe legal water services for slums. According to DWASA Annual Report (2018-2019), it has covered about 435 slums including the three largest low-income settlements named Korail, Bhasantek, and Sattola slum till 2019. The division is also working for supplying water to Kalapani, Beguntila, Kurmitola camp, Balurmath, Rajur bosti, Muktojodha Complex, Thirtynas camp, MCC Camp, Rahamat camp, Rabeda camp, Baganbari, Ersadnagar, Vangadewal, Godown bosti, Beder bosti etc. by the help of some local NGOs. As per the slum census, there are around 3399 slums in Dhaka city and the number of slum dwellers is around 643735 (BBS, 2014) which indicates that a significant number of LIC dwellers still have no or minimal access to water. The rest have to depend on illegal connections for meeting up their daily water demands (Nurul and Mohammod, 2014; Uddin and Baten, 2011).

2.1.4. Water scarcity

Freshwater scarcity is increasingly becoming a threat to the sustainable development of human society for the last few decades. The World Economic Forum has listed it as the largest global risk in terms of the potential impact on humanity in upcoming decades (Mekonnen and Hoekstra, 2016). To keep pace with the growing population and economic growth, water resources are depleting in many places that might give rise to spatial and temporal variations in water scarcity worldwide (Boretti and Rosa, 2019). Wada et al. (2015) have estimated that groundwater mining will rise about 1100 km^3 annually over the world. According to a USAID report (2009), over 2.8 billion people in the world are forecasted to live in either water-scarce or water-stressed regions by 2020 where over 1 billion people would lack access to improved water supply services (USAID, 2009). Boretti and Rosa (2019) have mentioned that the percentage of people will exceed half of the global population (57%) by 2050.

The access to water supply often becomes complex in developing countries (Khadse et al., 2011) to keep pace with its increasing standards of living and unbalanced population growth (Shams et al., 2016). Only domestic water use is anticipated to increase by 130% by 2050 in developing countries. Like other developing cities, Dhaka is also moving towards an inevitable water crisis gradually. The acute urbanization of Dhaka city due to its capital city-driven development strategies is attracting rural-urban migration, which have resulted in an unplanned horizontal and vertical expansion of the city leading to water stress and inadequate facilities for relevant infrastructures (Shams et al., 2016; Shams et al., 2014). Haque (2017) has estimated the future water demand in Dhaka city. Water consumption is showing an upward trend and is projected to reach 5105 MLD in 2035. Beyond 2035, there is likely to be around 50% increase in total demand by the year 2060. Hossain and Bahauddin (2013) have focused on the big gap between demand and supply of water for the water scarcity in this city. They mentioned some reasons for this gap, such as urbanization, lack of investment funds for constructing and maintaining water infrastructures, high public debts, inefficient resource allocation processes, inadequate management capacities, poor governance, inappropriate institutional frameworks, inadequate legal and regulatory regimes, and poor water management. Although DWASA has mentioned that it has been able to reduce the demand-supply gap to 0% from the year 2013 (DWASA, 2020), the consideration of NRW or unaccounted water still indicates that the amount of actual supply is lower than the present demand.

Moreover, quantity and quality degradation of surface water, greater costs for supplying water from distant rivers, and rapid groundwater depletion are all contributing to the difficulty in water supply in this city. Despite several scarcity-based adaption strategies such as managed aquifer recharge (India), rainwater harvesting (US, Taiwan) and grey water reuse (Australia, Germany, California, Brazil, Malaysia, Japan, China) have been able to achieve water security and to cope with the climate impacts in several developed and developing countries (Sheikh, 1993; Nolde, 2000, Ghisi and Ferreira, 2007; Basinger et al., 2010; Ismail et al., 2011; Juan et al., 2016, Moshfika, 2021), those are not still taken by Dhaka city (Ahsan, 2018). However, Khatun and Amin (2011) have mentioned some challenges in the way of greywater use in Dhaka city such as lack of human and financial resources, system energy demand, economic feasibility of the system, public perception and willingness, social and institutional acceptance, water right issues and political process, as well as absence of sufficient and consistent codes and guidelines.

2.2. Water Pricing in Relation to Water Supply

A water tariff refers to a set of prices, fees, and taxes used to evaluate water bills for consumers. The design of water tariffs is a very debatable topic that elicits a wide range of responses. Some people believe that water utilities should be supplied at zero price or at least heavily subsidized price when others believe that it should embody the scarcity value of the water and the expenses of providing it. Nowadays, water pricing has become an issue of great concern because of the risk of defective design of traditional supply systems.

2.2.1. Water pricing in the world

Currently piped water and sanitation services are heavily subsidized in low and middle-income countries (Andres et al., 2020). According to the global water intelligence database, the average price is less than 40 US cents per cubic meter of water in about half of the cities. In only 10% of the cities, the price is found doubled (>80 US cents). In most of the cities, price only includes the operation and maintenance costs of water services, or in many cases it is less. However, there is a bewildering miscellany of actual water tariff structures implemented by diverse water utilities, even within similar geographical conditions. The structures can be brought under two main categories: flat-rate charge (amount of consumed water has no bearing on the bill) and water use charge (water bill is dependent on the use) which are discussed below:

Flat-rate charge: A flat charge is usually the only feasible tariff structure when there is no water meter available to measure the water consumption (Meran et al., 2021b). Customers are charged a fee regardless of how much they use (Rios et al., 2018). The outlay function is L= R(w) (where L is the flat rate or lump sum and W is the expenditure) (Meran et al., 2021b). One of the basic advantages of this structure is the easy calculation of revenue or subsidies from the water sector. But this tariff structure is criticized for not reflecting the true value of water to the consumers (Oliver, 2009).

Although it is the most basic and oldest rate structure, still many developed countries (Canada, Mexico, New Zealand, and Norway) are practicing the structure (OECD, 2009). Renzetti and Dupont (2017) have reported that almost half of the total households of Canada were priced in flat rate tariff in 1999, which has reduced to 20% now due to advancement in the metering system. Among the 20%, the highest percentage of the population (84.2%) of Newfoundland and Labrador province use flat-rate tariffs. The second highest position is hold by Quebec province serving 67.9% of the population. This fee can either be constant or variable depending on the situation. For example, in Mexico, the fixed price per m^3 volume of water varies from zone to zone depending on the production and conveyance cost in the respective zone (Guerrero-Garcia-Rojas et al., 2015). While in Scotland and New Zealand, homeowners pay through municipal taxes which are based on property values instead of water use (Grafton et al., 2020). However, according to OECD (2010), the water rates do not fully reflect the cost of supply and are comparatively lower than the international standards.

Water use charge: The second option to design tariff is to charge customers based on how much water they use. In other words, a consumer's monthly water cost is determined by the amount of water consumed. A metered connection is a significant prerequisite of the charges. However, based on the differences in the charging formula, it can be divided into three main categories: uniform volumetric charge, increasing linear tariff, and block tariff. The particular characteristics regarding these categories are summarized below:

- **Uniform Volumetric Charge (UVC)** is a single part tariff where the unit charge is fixed irrespective of the quantity of use (Figure 2.5). It is one of the easiest pricing structures and currently in practice in most of the cities (Oklahoma City, Chicago, Memphis, Tennessee, Indianapolis, Indiana, Baltimore, Maryland, New York and, Dhaka). According to Singh et al. (2005), the mathematical formula of estimating water bill is:

$$Water\ bill = water\ use * uniform\ charge\ per\ unit$$

The precise formula used to set the uniform charge can differ from region to region (Ghimire et al., 2016). Oklahoma City's pricing system, for example, is made up of a base service price plus a fixed per-unit volume price. The base service rate is calculated based on the size of a household's meter. Every year, the unit uniform charge (price per 1000 gallons) rises by around 6%. On the other hand, in Hungary, the price consists of a fixed cost (to cover infrastructure maintenance) as well as a proportionate amount based on consumption (Vasa, 2009).

UVC is acceptable in many cities because of its easier implementation and estimation of billing (Babak, 2002). Singh et al. (2005) specified that this tariff structure can meet all the targets if it is set at marginal water costs. In practice, however, they are usually significantly lower than marginal costs, which does not provide the conservation signal to the customers and eventually leads to poor cost recovery.

- Under **Increasing Linear Tariff scheme,** the price that a consumer pays progressively increases with the amount of water used (Singh et al., 2005; Whittington, 2011). The rate structure provides a strong signal to customers that water is expensive enough. Every extra unit of water used is not only sold at a higher price, but all previous units are also sold at the last price. For instance, in Tunisia and Turkey, a family pays for its whole water consumption at the rate of the last block reached (Binet et al. 2014). However, Whittington (2011) has argued that the structure does not notify the customer about the short-run marginal cost of their further water use. This is because the utility's short-run marginal cost of providing water does not change significantly with the changes in household water usage. Moreover, the structure would be particularly inoperable in the case of large-volume industrial or commercial water users, as it may drive the price of increased water use far beyond the short-run marginal cost of supplying them with more water.

- The last category of water use charge is **Block Tariff (BT)**. Under a block tariff scheme, users pay different amounts depending on their consumption levels. Tariffs are organized in a step-by-step manner. The water charge is set per unit (e.g., m^3 or liters) of water consumed and is fixed until it exceeds the first block (a fixed quantity of water). As water usage grows, the tariff switches to the next block of consumption, and the process continues till the greatest block of consumption is not reached. Block tariffs are divided into two types: increasing and decreasing.

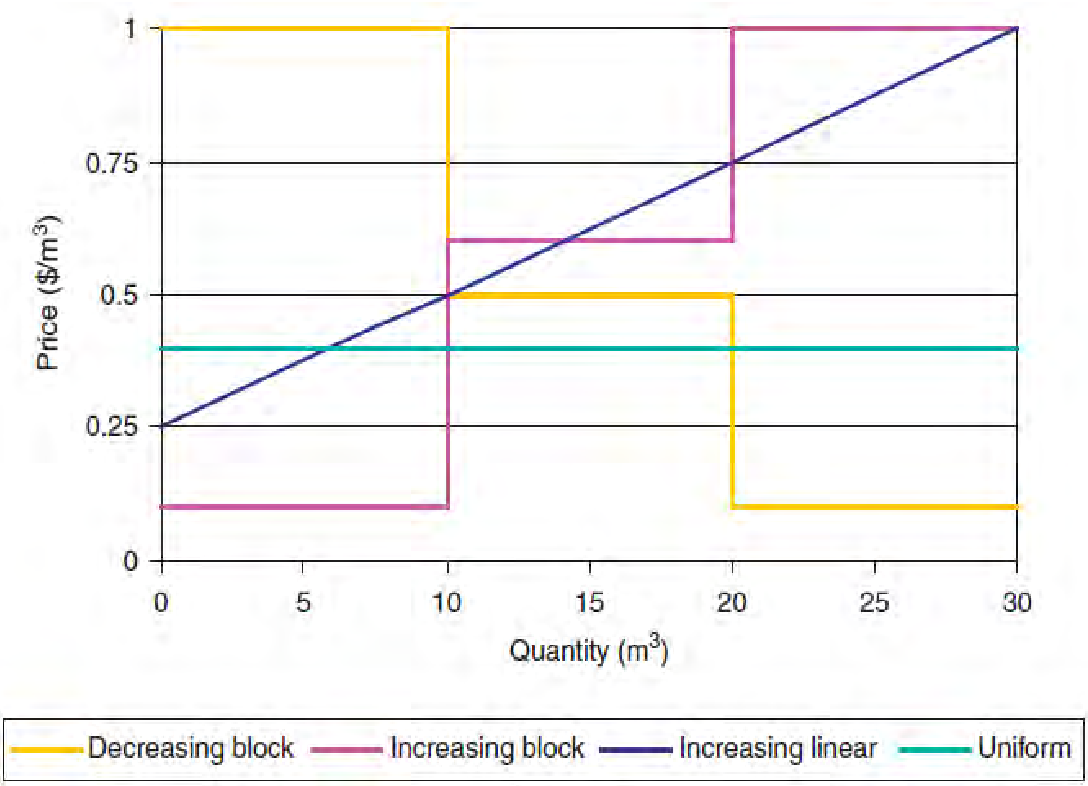

Figure 2.5: Category of tariff structures

Source: Whittington (2011)

Figure 2.5 illustrates that in **Increasing Block Tariff (IBT),** customers pay a lower volumetric unit price up to a certain quantity (first block), then pay a higher price for any additional water usage up to the second block's limit, and this process continues (Boland and Whittington, 2000; Shukla and Nayak, 2014). Many countries' water utilities and regulators are shifting to an IBT pricing structure (Dahan and Nisan, 2007). IBTs are mostly used in developing nations to support the poorer class (Boland and Whittington, 2000; Fuente et al., 2016). Hence, it has a common feature in that the first block price is intentionally set below cost regardless of the expenses. Barberán and Arbués (2009), García-Valiñas et al. (2010) and Martins et al. (2013) have debated in this topic that IBTs facilitate cost recovery while simultaneously penalizing extreme consumption and subsidizing basic uses for the poorer. The execution of IBT is also recommended (Huang et al., 2021) because of its conservation-oriented design and advancement of equity and efficient water use (Molinos-Senante and Donoso, 2016).

As an example, García-Rubio et al. (2015) detailed the existing tariff structure maintained in Spain which is a two-part tariff with increasing blocks. They have also mentioned the water demand impact of shifting from uniform rate pricing to increasing block rate water budgets. Three years after the change of the water budget pricing structure, demand was 17% lower than it would have been under a comparable uniform rate pricing structure. Besides encouraging efficient water use, IBT has seriously contributed to household equity.

An additional example can be drawn from the study of Gambhir and Tripathi (2016). They have reviewed the water pricing practice of Israel to compare it with Delhi. In Israel, over 70% of the country's water use has been set at increasing block rates, where each water user is highly obliged to have their own metering system. Prices are automatically updated in view of the elimination of subsidies, and the payment of water abstraction fees. The endeavor to water conservation has reduced about 26% per capita water consumption of Israel.

Despite the huge contribution of IBTs in cost recovery and efficient and equitable water use, it is discouraged by several policymakers. Nauges and Whittington (2017) have demonstrated the reason for the unpopularity of such tariffs. They require utilities to obtain (accurate) information on the size of the houses they serve and to keep this information up to date. This task is currently not administratively viable in the majority of low- and middle-income countries.

Decreasing Block Tariff (DBT), contrarily, offers two or more water prices, each of which relates to a customer's use inside a certain block. With each consecutive block, the price decreases to encourage higher water use (Boyer et al., 2012). Whittington (2011) demonstrated that the DBT structure was designed to reflect the fact of availability of plentiful raw water, on one hand, to encourage the industrial and development of settlements on the other. Irvin (2016) has surveyed water tariff structures of 2786 water systems across the seven states of the United States from 2013 to 2016. He has identified that decreasing block tariff structure accounts for 26% of total water supply systems where Wisconsin and Alabama states hold the highest position. However, according to Fuente et al. (2016), DBT has been losing its applicability over time. As the well-defined short-run marginal cost has become relatively high in some portions of the world which stimulating the concern in validating water conservation. Moreover, it often leads to a cheap price for large volumes of water which makes it politically uninviting.

2.2.2. Water pricing in Bangladesh

Despite being an important resource, groundwater is undervalued in Bangladesh. The current pricing only includes the cost of installation and O and M, but rarely the cost of externalities (Kemper et al., 2004). Qureshi et al. (2015) has argued that the Bangladesh government and several donor agencies even support the operation and maintenance of the water supply system. Thus, water is currently delivered at low and subsidized prices. They have also figured out that the water policy of this country favors growth above resource management. Increased groundwater accessibility meets the rising population's water needs in the short term, but it degrades the ecosystem in the long term. Excessive drawdown, groundwater level depletion, and other externalities result from widespread groundwater abstraction. Finally, they have concluded emphasizing the importance of alleviating groundwater pressure before the problem becomes unmanageable.

For the proper management of water resources, several policies are taken by the government. Table 2.1 demonstrates the progression of national policies regarding the water pricing issue in Bangladesh. The proposed pricing framework of the most recent policy ‘National Strategy for Water Supply and Sanitation in Bangladesh’ has not yet been adopted in Bangladesh (Qureshi et al., 2015). As a result, municipalities or water utility providers still possess the right to set their tariffs. Water Supply and Sewerage Authority (WASA) supplies water to a selected portion of Bangladesh such as Dhaka, Khulna, Chittagong, Rajshahi, Narayanganj etc. Department of Public Health Engineering (DPHE) is accountable for providing water supply services in areas that are not served by WASA (DPHE, 2015).

In general, water is priced following the uniform volumetric charge (UVC) scheme for the metered connections in Bangladesh. The unit charge of price varies from area to area depending on the cost of operation and maintenance of the water supply. For instance, the residents of Dhaka pay BDT 14.46 per unit (1000 liters) for domestic water consumption (DWASA, 2020), while the charge is BDT 12.40 in Chittagong (CWASA, 2021). On the other hand, having no metered connection, the water in Rajshahi, Naogaon, Natore, and Chapainawabganj are billed under a flat-rate tariff scheme where the base charge is determined by the diameter of the pump as well as the floor number of the building. In case of Rajshahi, the water bill varies from BDT 50 to BDT 275 for a 0.5-inch diameter pump which increases to the range of BDT 125 to BDT 690 for a 1-inch diameter pump depending on the floor number (RWASA, 2021).

However, narrowing down to Dhaka city, uniform volumetric charge is applied for the billing of water supplied by DWASA. The uniform charges vary according to connection categories such as domestic, commercial, community, and industrial (DWASA, 2020). The charge for domestic connections is almost three times lower than the industrial connections. It is also very lower in respect of other South Asian cities, such as Delhi, Kathmandu, and Jakarta (Asim and Lohano, 2015). In the context of low water price, the most recent policy regarding Dhaka city water supply, 'Water Supply Master Plan for Dhaka City' affirms that this lower and uniform rate tariff is not evenly affordable for the city dwellers because the annual family income ranges from BDT 200,000 to BDT 20,000,000. Hence, a three-block system is suggested to deal with the affordability issue.

Table 2.1: National policies regarding water pricing in Bangladesh

Serial	Name of policies	Information about water pricing	Citations
1.	National Policy for Safe Water Supply and Sanitation, 1998	• Has declared that water prices should represent its economic value, with the ultimate goal of covering the cost of supply for the assurance of feasible supply system. • Recommends that the shift from existing subscription levels to the new rate of payment should be gradual, with consideration for disadvantaged communities.	LGD, 1998
2.	National Water Policy, 1999	• Recognizes that reforms to the pricing system are essential. • Suggests a system of cost recovery in price to reflect the scarcity value of water.	LGD, 1999
3.	National Water Management Plan, 2001	• First mentions about IBT structure targeted to the full recovery of urban water supply and sanitation.	WARPO, 2001
4.	Sector Development Plan for Water Supply and Sanitation Sector in Bangladesh (FY 2011-25)	• Recovery of costs is regarded as fundamental to service improvement. • Recommends implementation of a pricing system that includes recovery of O and M cost in shortest possible time and capital cost in the gradual process as well as ensuring social justice.	LGD, 2011
5.	National Cost Sharing Strategy for Water Supply and Sanitation in Bangladesh	• Has set some guidelines about consumer category, base tariff, consumption blocks etc.	LGD, 2012
6.	National Strategy for Water Supply and Sanitation in Bangladesh	• Proposes progressive tariff (IBT) for piped water supply and sewerage systems with an inclusion of a lifeline tariff for the poor.	LGD, 2014

Figure 2.6 demonstrates the proposed pricing structure for this city. The first slab's pricing of 2014 was BDT 7.34 per 1000 liters of water. As per the WASA rule, the price intensifies by 5% annually to address inflation. As a result, the unit flat rate for 2015 is estimated to be BDT 8.09. The price of the third slab is recommended three times than the first block, and it is also the predicted initial water rate for commercial and industrial users in 2015. The plan also proclaims that the unit charge for each block will increase annually.

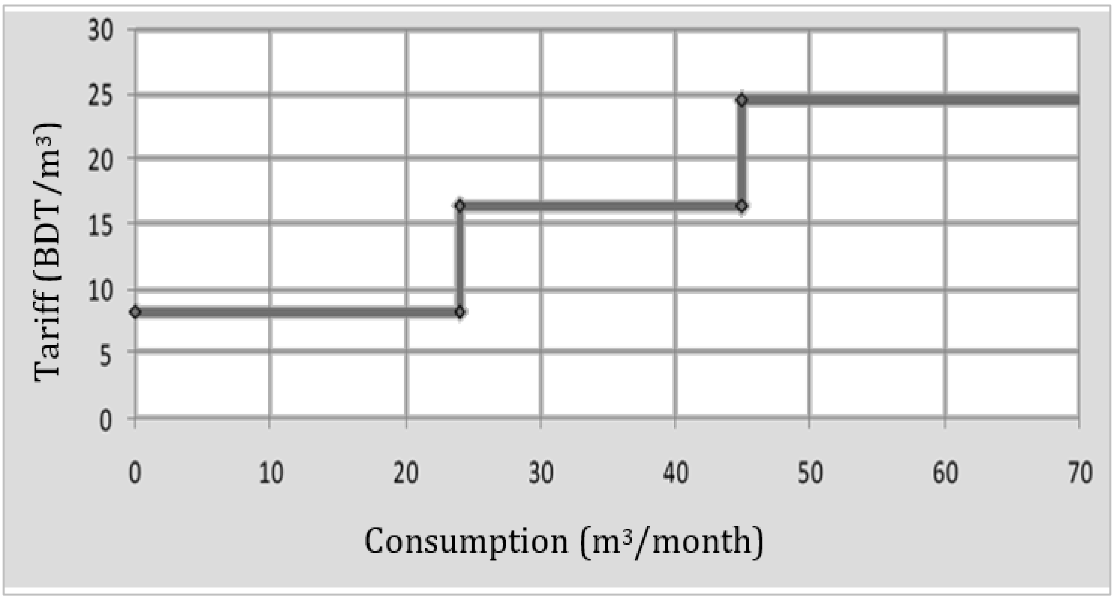

Figure 2.6: Recommended block tariff structure from 2015

Source: DWASA (2014)

Several researchers have suggested that cost of externalities must be considered in the pricing of water (Bielsa and Cazcarro, 2015; Laila, 2008; Pulido-Velazquez et al., 2013; Riegels et al., 2013). Nevertheless, the proposed pricing structure has not deliberated the cost of externalities which directs a necessity for the redesign of the proposed framework.

2.3. Role of IWRM in Water Pricing

IWRM, which stands for Integrated Water Resource Management, denotes a holistic approach to water resources management and governance. The four Dublin principles, proposed at the International Conference on Water and the Environment in Dublin in 1992, have underpinned the framework (Kasbohm et al., 2009). Later, GWP (2004) delineates it as "*a process which promotes the coordinated development and management of water, land and related resources to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems*". The concept can meet the goal of all actors, in a way that is appropriate for them (Figure 2.7). For instance, the maximization of aggregate welfare can be attained by the supporters of privatization under the 'efficiency' principles while NGOs working for improving people's livelihoods can employ the concept to promote social justice and equity. This framework, on the other hand, supports conservationists or green NGOs in their efforts to preserve the natural environment (Molle, 2008).

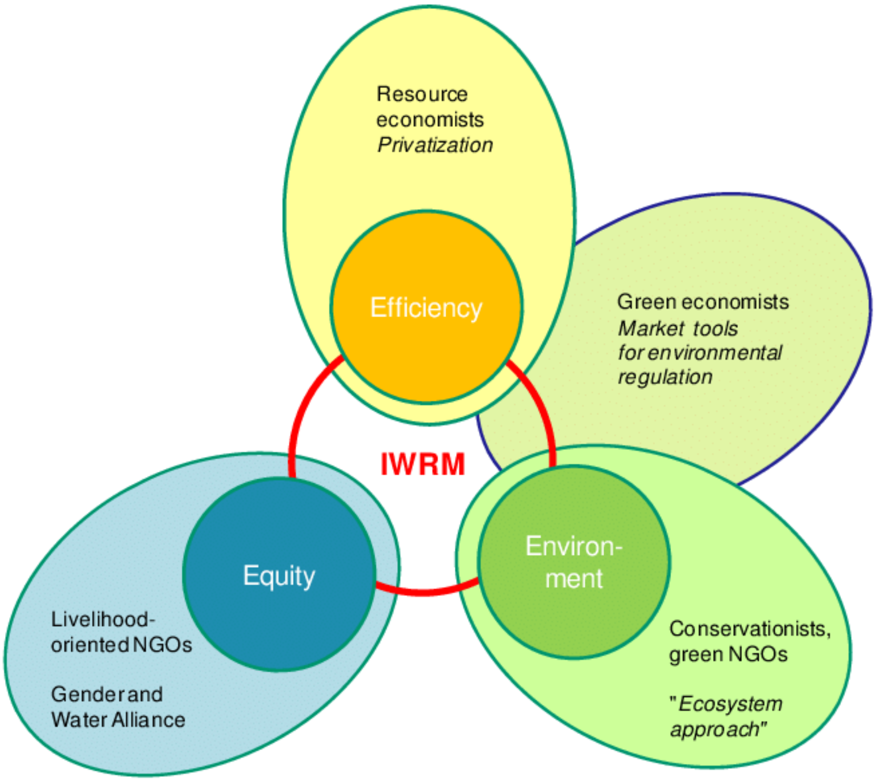

Figure 2.7: IWRM framework.

Source: Molle (2008)

This concept, therefore, has gained extensive acceptance as a framework for addressing complicated water resource management distresses effectively and sustainably (Kasbohm et al., 2009; Nowreen, 2010). Consequently, the concept of IWRM is now widely used in the implementation of overarching water policies and legislations that will employ basin management, the development of water rights, water pricing, and participation in decision-making (Benson et al., 2015; Giordano and Shah, 2014; Shevah, 2019; Smith and Clausen, 2015).

Water pricing is an overarching critical issue for accomplishing optimal water resource supply, ensuring security, and also for the proper management of this significant environmental resource (Dinar et al., 2015; Donoso, 2016; Laila, 2008; Mohayidin et al., 2009; Rios et al., 2018). Beecher and Kalmbach (2013) have discovered that the efficacy of these water pricing systems is contingent on the type of tariff and its monetary value. Therefore, determining a socially fair average water price according to the area characteristics (i.e. level of scarcity) is a requisite for water utilities and local communities (Kanakoudis et al., 2014; Singh et al., 2005; Tsitsifli et al., 2017) which directs the tariff to be designed by the principles of IWRM to meet the goal of sustainability and efficiency (Smith and Clausen, 2015). To determine the tariff structure in view of the IWRM framework, three key policy goals of this framework must be encountered (Kasbohm et al., 2009). Postel (1992) has named the three key principles of IWRM as three 'E's comprising Economic efficiency, Environmental integrity, and Equity which are discussed below:

- **Economic efficiency** is highly signified because of the non-renewable and finite characteristics of water resources. To attain this, recovery of the costs along with pricing following its economic value are prerequisites.
- The principle, **environmental integrity** refers to that the valuable environmental resource should be used in a viable way so that the future generation will be able to use it analogously as we do now.
- **Equity** denotes water as a basic need and right of all people in an area and therefore emphasizes the accessibility to adequate water for the poorer section.

Regarding the first principle, finding strategies to enhance water usage efficiency is one of the most critical concerns in integrated water resource management. Macian-Sorribes et al. (2015) have designated the implementation of scarcity-based pricing systems as one of the most promising alternatives. Many researchers also agree that incorporating IWRM in the pricing model eases the recovery of the full cost of any water supply project and thus aids in the design of scarcity-based pricing (Bielsa and Cazcarro, 2015; Meran et al., 2020; Koppen et al., 2016). Bielsa and Cazcarro (2015) have conducted an experimental study on whether the integration of IWRM principles brought success to water resource management in Spain or not. In their illustrations, they have designated that the total cost recovery should not only encompass the infrastructure construction, maintenance and management costs, but also the environmental costs. They have further mentioned that tariffs should have a special consideration for water use of poorer groups according to the European Commission. Albeit there is no trace identified that has included the costs of externalities into the final tariff in practice. The study has concluded that the gap between IWRM theory and practice has impeded the proper accomplishment of management plans in the area. Hossain and Bahauddin (2013) have also included an IWRM framework for solving the water issues of Dhaka city. In their proposed framework, they have highly emphasized incorporating the economic value of water into the pricing.

The second principle broadly highlights the conservation of scarce water resources for the future generation. The extensive and wasteful use of resources results in several negative impacts on the environment and leads the resources towards declination (Baniasadi et al., 2020; Diwakara and Chandrakanth, 2007). In this regard, several researchers have elucidated that cost of externalities should be taken into account while the pricing is set (Baniasadi et al., 2020; Bielsa and Cazcarro, 2015; Das et al., 2021; Laila, 2008; Pulido-Velazquez et al., 2013; Riegels et al., 2013). That consideration can assist in full cost recovery, on one hand, also provide water conservation incentive on the other.

Beside efficient resource use and environmental integrity, the IWRM framework has conveyed comprehensive significance in ensuring equitable access for poor marginal social groups (Benson et al., 2015). Molinos-Senante and Donoso (2016) have also emphasized equity as an important concern for designing a water price model. However, ensuring equity is often a challenging issue in designing a price model. In the cities, price is mostly set lower than the marginal cost of supply for safeguarding the basic needs of water for the residents (Grafton et al., 2020; United Nations, 2015).

For example, Spain attempts to provide discounts in water prices for poor-income families for ensuring equity (Calatrava et al., 2015). Albeit, the challenge arises because the provision of discounts and setting low price does not satisfy economic efficiency or generates water conservation incentive on one hand (Grafton et al., 2020; Molinos-Senante and Donoso, 2016), also it is often overlooked whether the needs of poor slum people are met or not on the other (Haque, 2019; Rahaman and Ahmed, 2016). For example, in absence of municipal water supply in the low-income communities often controlled by the power group results in high price burden charged by the private vendors. With the assistance of local powerful group, the vendors provide substandard services and make money taking the advantage of poor and water deprived people (Bayliss and Tukai, 2011; Rahaman and Ahmed, 2016; Sarker, 2020). Hence, to ensure the equitable water access fully in the society, it is highly necessary to bring the slum people under IWRM based pricing scheme.

As a corollary of all the above considerations, the future of the water resources of Dhaka is leading towards scarcity to keep pace with the growth of the urbanized population. Hence, it is high time to find a solution for the conservation of water resources for the future generation. Although IWRM is considered the best way for ensuring efficient use of water, its provision in the affordability range of the poorer group often collides with the other two principles of IWRM (Donoso, 2016) which directs a use-specific pricing system.

CHAPTER 03

STUDY AREA PROFILE

3.1. Introduction

The study attempts to re-develop the pricing model for the domestic urban water use of the capital city of Bangladesh, Dhaka. To meet the broad interest of this study, Tejgaon (which is located in the central part of the city), is selected as a study area. The combination of residential and slum areas has aided the study to have a better understanding of the whole domestic water use. As a result, based on the settlement category, the study area can be subdivided into two parts: formal settlement (represented by Tejgaon residential area) and informal settlement (represented by Tejgaon slum).

3.2. Location

3.2.1. Formal settlement

Tejgaon residential area is located in the focal point of Dhaka city with a large accumulation of old and high-rise residential buildings (Hossain et al., 2019). The area falls under zone-3 and zone-5 of Dhaka North City Corporation (DNCC) constituting ward no. 25 and 26. The location is marked in red color in Figure 3.1. The settlement is occupied an area of about 640 acres (BBS, 2013). Figure 3.2 represents the detailed map of the Tejgaon residential area.

3.2.2. Informal settlement

Tejgaon slum is chosen as a representative area of informal settlements. It is also recognized as Tejgaon railway slum because of its location alongside the railway line (marked in yellow color in Figure 3.1). The slum is located in ward no. 25 of DNCC area zone-3. The area under the Tejgaon slum is reduced to 4.9 acres presently due to ongoing construction work for Dhaka Elevated Expressway Project. However, the slum is an important emblem for assessing the impacts of water price because of its unusual water delivery process (Rahaman and Ahmed, 2016). Figure 3.3 represents the detailed map of Tejgaon slum.

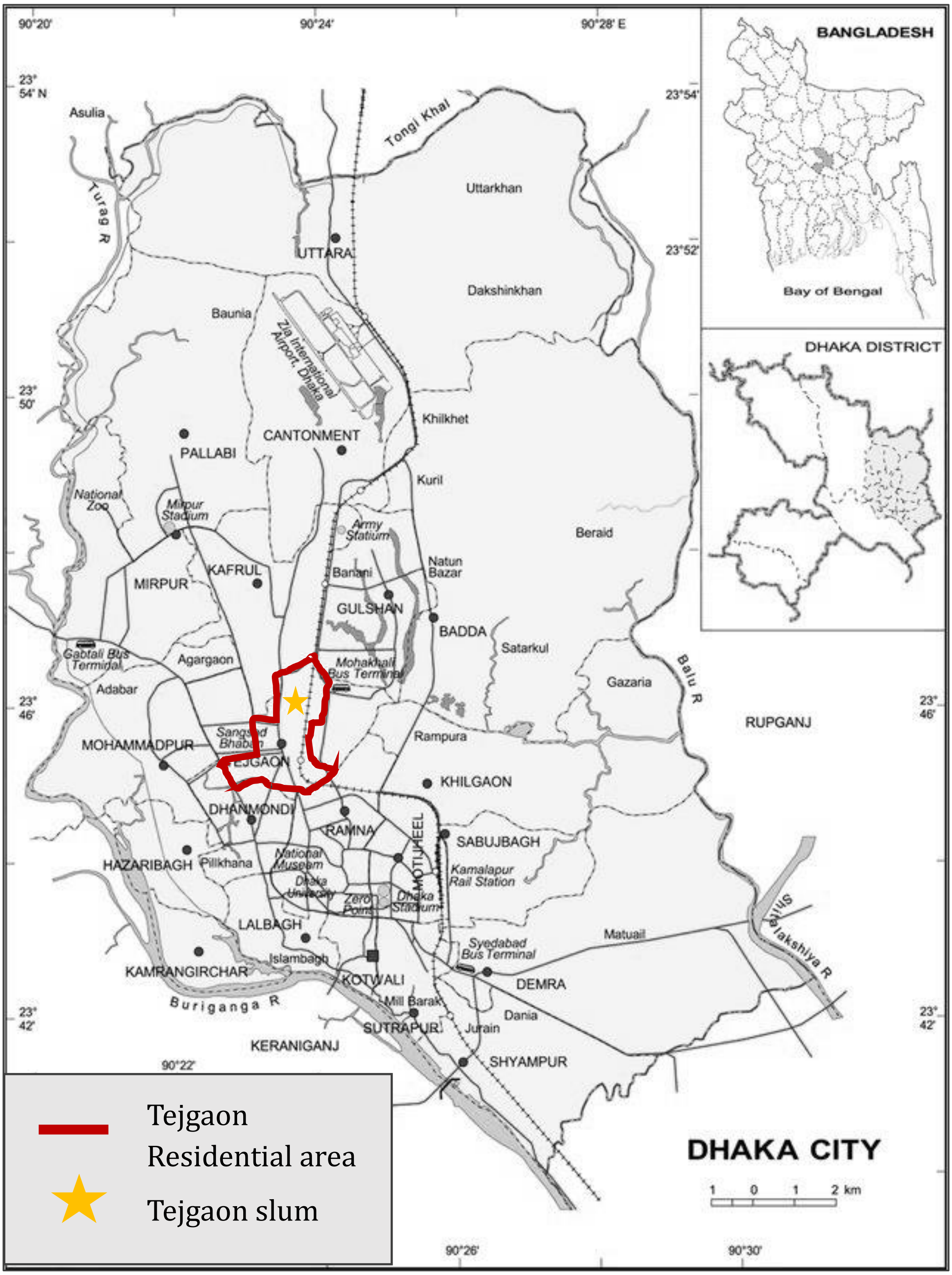

Figure 3.1: Location of the study area

Source: Swapan et al. (2017)

Figure 3.2: Map of the Tejgaon residential area

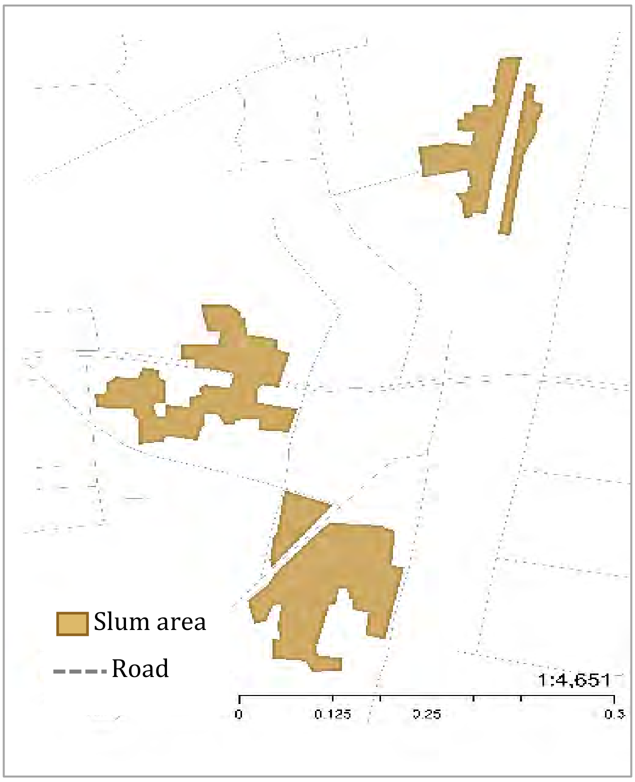

Figure 3.3: Map of the Tejgaon slum

3.3. Demography

3.3.1. Formal settlement

3.3.1.1. Population and Households

Tejgaon residential area has a total population of 0.13 million (BBS, 2013) which encompasses about 0.76% population of Dhaka city (Khalequzzaman et al., 2017). According to the district statistics report of Dhaka city, the population density of this area is found about 50000 people per square kilometers having about 26078 number households. Tejgaon residential area is observed as a haphazardly developed area with a large number of old buildings in some parts of this area (Roy et al., 2019).

However, the sex ratio (male: female) of this area is 137:100. Among the total population, male populations cover about 57.8% while the female population is 42.2%. The majority of the population residing in this area is Muslim (89%) while the Buddhist population is very negligible in the percentage of total population (291 in number). A similar pattern is observed between Hindu (6%) and Christian (5%) inhabitants (BBS, 2015).

3.3.1.2. Educational Status

The literacy rate of Dhaka city is reported to be 74.55% which is higher than the national literacy rate (Roy et al., 2019). The literacy rate of the Tejgaon residential area is estimated further 1.5% higher than Dhaka city. According to *Population and Housing Census, 2011*, the literacy rates of males and females are 79.98% and 74.33%, respectively (BBS, 2015).

3.3.1.3. Occupation and Livelihoods

In Tejgaon residential area, about 52.6% of inhabitants are employed among which the male inhabitants hold the major share (40%) (BBS, 2015). The inhabitants have mainly been involved in government or private service (50.19%), commerce (26.06%), transport and communication (3.90%), construction (1.64%), religious service (0.08%), rent and remittance (3.27%), non-agricultural laborer (0.91%), industry (2.28%) and others (11.10%) (Banglapedia, 2014).

3.3.2. Informal settlement

3.3.2.1. Population and Households

According to the *Census of Slum Areas and Floating Populations-2014* (BBS, 2015), the total population of Tejgaon railway slum is 2341, residing in 711 households. Among the total population, the sex ratio is 106:100 which shows a very little gap in the percentage of male (51%) and female inhabitants (49%). The religious status of the majority of the inhabitants is Muslim.

However, it should be noted that the slum is designated as a floating slum due to the higher frequency of eviction in the slum. As a result, the number of residents and households fluctuates throughout time (Rahaman and Ahmed, 2016). The present household number is identified as around 455 with an average household size of 4. The slum occupies an area of 4.9 acres. Hence the population is almost double (91782 people per square kilometers) than the formal residential area.

The living state of the slum residents is quite harsh because of their poor housing conditions and lack of basic utilities. Photo 3.1 delivers a portrayal of the housing condition of the Tejgaon slum.

Photo 3.1: Housing condition in the Tejgaon slum

The houses are typically built of substandard materials like tin and bamboo, and no gap is observed between the houses. The most common dimensions of the rooms are found as 7’×8’, 7’×9’ and 8’× 10’. About 93% of the residents live in a small single room in this slum.

3.3.2.2. Educational Status

The level of education is quite dissatisfactory in the study slum. Like Photo 3.2, only two schools are observed within the community. Among these, one school (named Khukumoni School) has been closed for 2 years which was run by a local charity foundation. Another school, named Urban Slum Anondo School, is run by an NGO named ‘Save the Children’ for a government project of providing primary education for poor children. The project is continuing since 2019 and is about to finish in 2021.

Photo 3.2: Community schools in the Tejgaon Slum (top: Khukumoni school, bottom: Urban Slum Anondo school).

About 67% of the total surveyed people have not even completed their primary education. Only 12% have completed secondary education and 21% primary education. The level of education, in most cases, is getting shrunk at the time of starting their secondary education. The low level of education is resulting in many social anarchies, such as dowry (reported by 62% respondents), early marriage (56%), domestic violence (74%), and child labor (41%).

3.3.2.3. Occupation and Livelihoods

Both the male and female residents of the Tejgaon slum are involved in income-generating activities. Male residents are mostly involved in nearby factories in Tejgaon industrial area (28%). Besides, they are also working as hawkers, rickshaw-pullers, shopkeepers, drivers, day laborers, and others. Contrarily, the women are earning their livelihood as domestic workers (35%), grocery and local vegetable sellers (28%) and garments workers (12%), and NGO activities (1%). Even though both males and females work in shops, there is a clear gender distinction observed in the study area. Male slum dwellers have a permanent shop where they sell their products, while female slum dwellers sell their products on temporary basis beside the railway line (shown in Photo 3.3). Photo 3.3 also exhibits the fact that children are also involved in income-generating activities.

Photo 3.3: Income-earning activities of the slum people (top: selling place of male, bottom: selling place of female)

Photo 3.3: Income-earning activities of the slum people (Continued)

Table 3.1 shows the income distribution of the slum residents. Their monthly income varies from BDT 2000 to BDT 12000 with an average of BDT 6440. Their income is comparatively lower than the formal city residents having an average monthly income of BDT 42140 which indicates their low affordability.

Table 3.1: Income distribution of the Tejgaon slum residents

Statistics		**HH income (BDT/month)**
Mean		6440
Std. Deviation		2141
Minimum		2000
Maximum		12000
Percentiles	25	5000
	50	6500
	75	8000

Although the impoverished people come to this capital city with a hope of better living, their low affordability often creates obstacles in the way of this hope. The slum dwellers have to spend a significant portion of their little income for accessing basic utilities. As a result, the rapid urbanization and city life cannot be defied by this poor affordability.

3.4. Climate

The Bangladesh Meteorological Department (BMD) is the responsible authority for collecting the meteorological data in this country. Among the 35 stations operating throughout Bangladesh, the station located at Agargaon, Dhaka is the closest to the study area and that is the best representative of the meteorological condition of the study area. Dhaka has a tropical monsoon climate characterized by hot summer and cold winter (Uddin, 2014). The city experiences three meteorological seasons: the dry winter season from (November to February), the hot summer season (March to May), and (iii) the rainy monsoon season (June to October) (Rahman and Lateh, 2017). Roughly 87.5% of yearly precipitation occurs in the monsoon season with its highest rainfall in the month of July. The city has an average annual precipitation of 1920 mm but the distribution is reported as uneven throughout the year (Hossain et al., 2018). On the other hand, the range of monthly average temperatures fluctuates between 25^0C and 31^0C with 42.6°C maximum (in March) and 6°C minimum (in December) temperatures (Pervin, 2015). Both the minimum and maximum temperatures are in increasing trend in the city due to the urban heat island effect (Shahid et al., 2015). Moreover, the relative humidity ranges from 59% to 86% in the study area.

3.5. State of Existing Water Resources

3.5.1. Surface water

Tejgaon is located at the south-central part of the Dhaka city (the location is marked in the red rectangle in Figure 3.4) where the amount of surface waterbodies is comparatively lower than the other parts (Mamoon et al., 2020). As shown in Figure 3.4, the percentage of increasing built-up area replacing the wetlands is also identified comparatively higher in this part of the city (Habib et al., 2020) which indicates a lack of surface waterbodies in the study area. Furthermore, the study area is located just beside the major industrial zone of Dhaka city which have impacted the nearby surface waterbodies in this part. Heavy metals such as cadmium, lead, chromium, mercury, zinc, arsenic, and in some circumstances copper and manganese are discharged with effluents and wastes by the chemical industries located around the study area (Hasan et al., 2019).

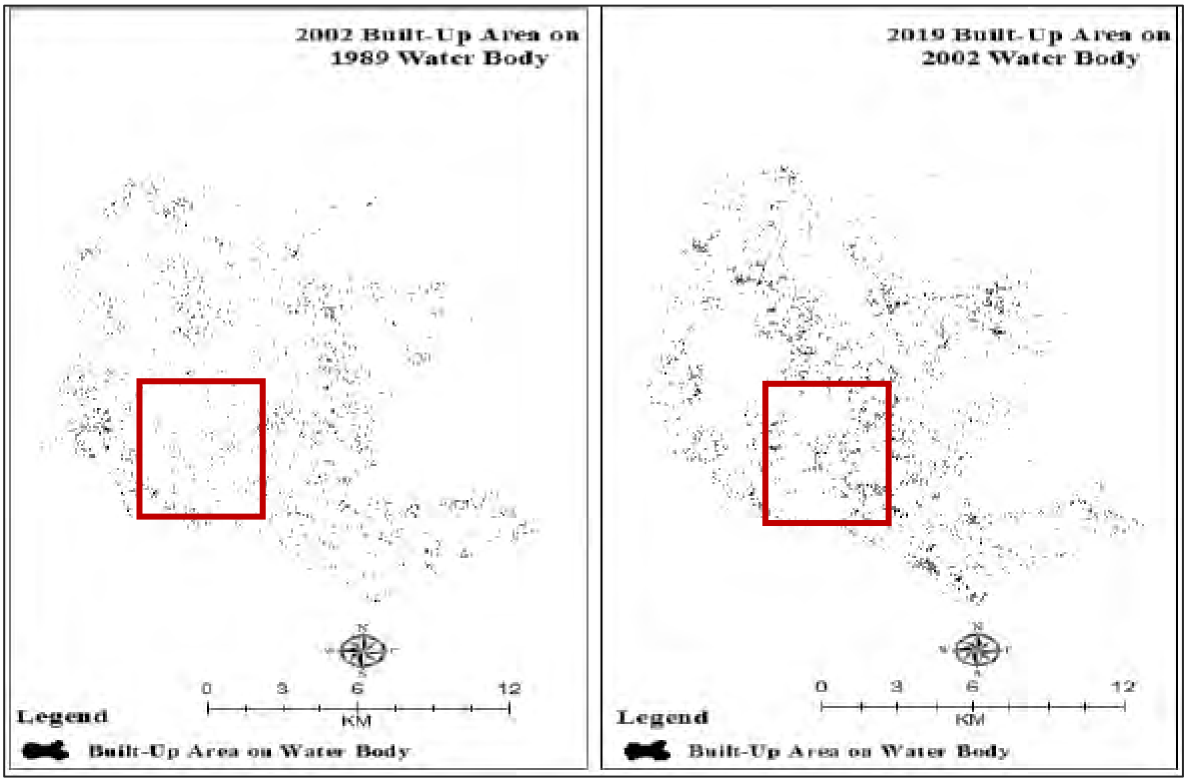

Figure 3.4: Built-up area on surface waterbodies in Dhaka

Source: Habib et al. (2020)

3.5.2. Groundwater

The GWL in the Greater Dhaka Area decreased considerably from 10 m to 30 m below the ground surface between 1985 and the beginning of 2000 (Islam et al., 2017). As a result of the reduction, a 'cone of depression' (a 'dried up' region beneath the ground surface) began to form within the metropolis. Over the previous few years, as the groundwater abstraction rates continued to surpass the natural recharge rates, the 'cone of depression' became deeper, reaching more than 70 m below the ground surface (Moshfika, 2021). The central part of Dhaka city is presently at high threat of environmental degradation with a declination up to 50-75 m (shown in Figure 3.5). The extreme drawdown of the groundwater table, therefore, is pushing the study area towards a critical state for future water supply.

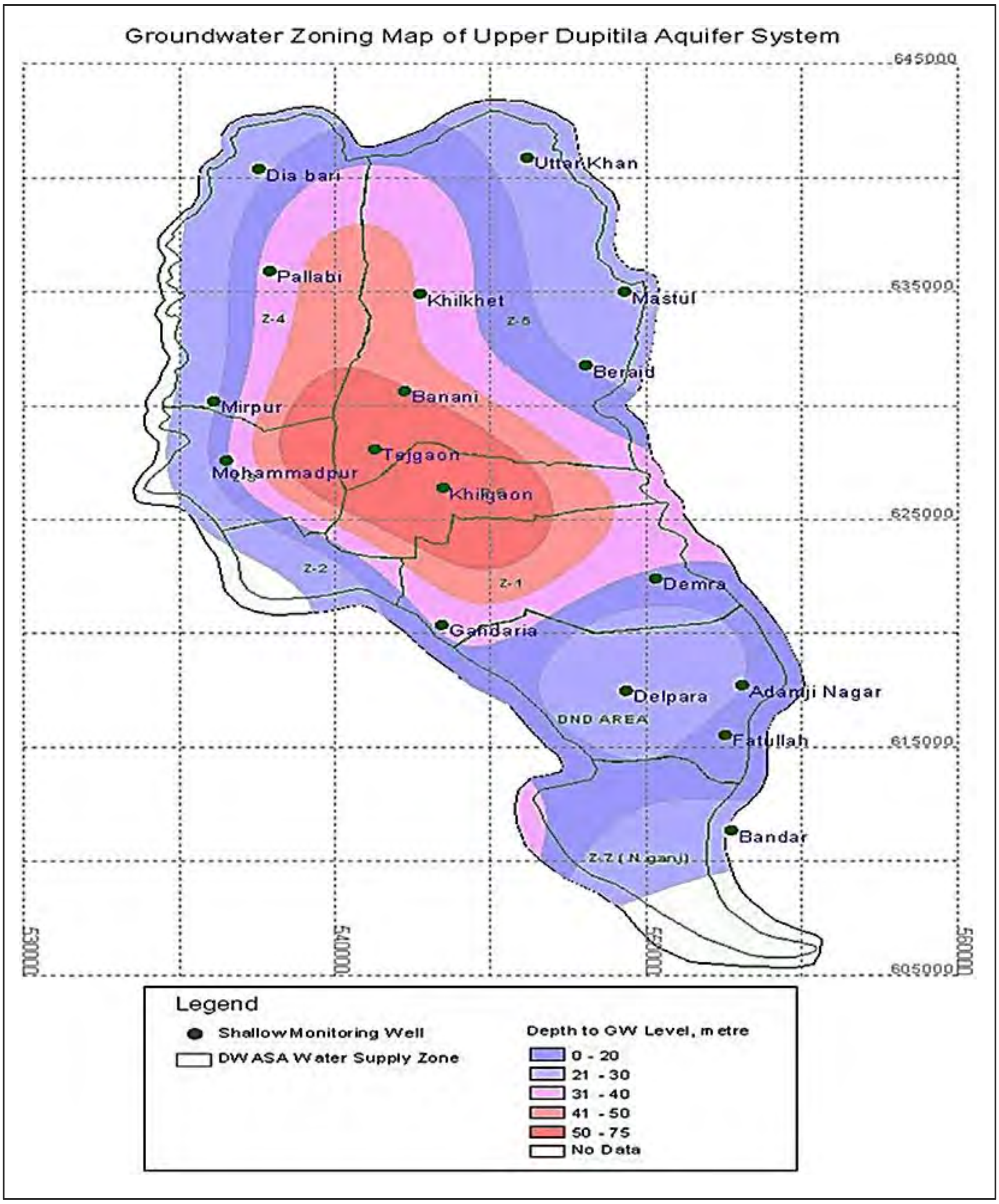

Figure 3.5: Groundwater depletion in Dhaka in 2010

Source: Arfanuzzaman and Rahman (2017)

Figure 3.6 represents detailed illustrations of the annual average groundwater level in this area. The analysis is based on the groundwater level (GWL) information of Tejgaon well (ID: GT2616005) collected from Bangladesh Water Development Board for the years (1990 to 2011). Because of low quality data, the water level data from 2012 to 2016 are not considered in the following analysis. Here, the trend shows a significant fall of 51m in the 20 years. The water table has declined at almost similar pattern in every 10 years. Moreover, every year the water table is declining 2-3m in this area and the declination rate has already reached 70m (Arfanuzzaman and Rahman, 2017).

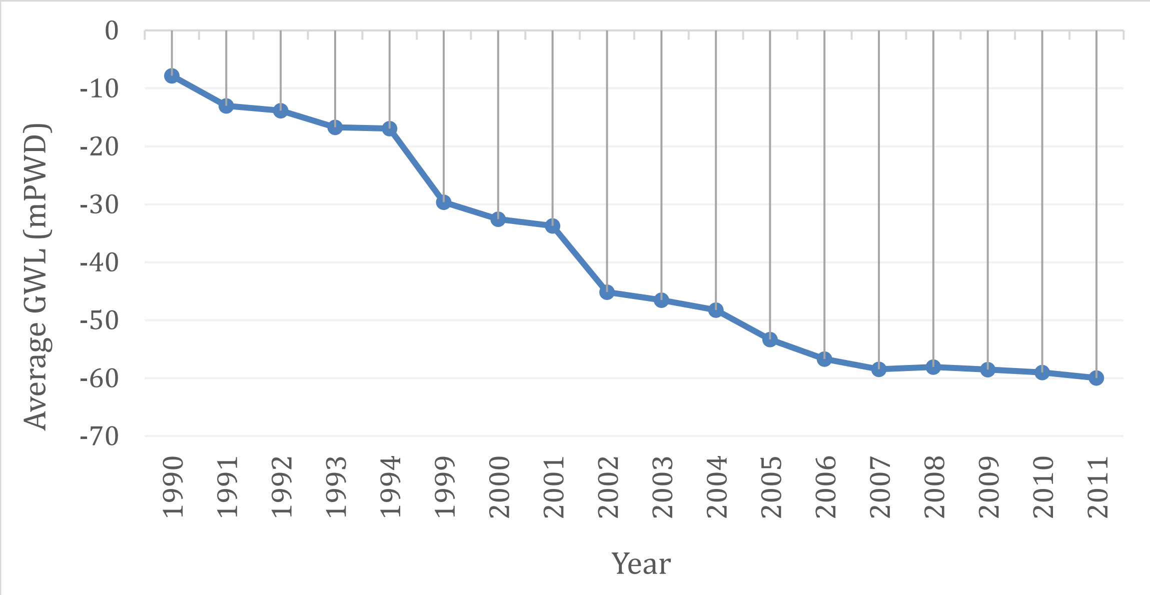

Figure 3.6: Annual average groundwater level at Tejgaon well (ID: GT2616005) of the study area

Source: BWDB (2020)

One of the key reasons behind the exploitation of the upper Dupi tila aquifer and the considerable fall in the water table is the maximum number of privately owned deep tube wells in the adjacent industrial zone (Chowdhury, 2012). Secondly, rising demand due to urbanization is also denoted as a major cause for groundwater depletion in this part (Mamoon et al., 2020). The unstable and critical condition of the groundwater resource in the study area demands an immediate action before it becomes too late.

CHAPTER FOUR

METHODOLOGY

4.1. Introduction

The entire study has been conducted in three steps. Firstly, domestic water usage is estimated for both formal and informal settlements. Secondly, the current water pricing system is evaluated on the basis of the factors of water pricing as well as its impacts on livelihood. Finally, a water pricing model is developed as a long-term solution for the existing negative impacts.

4.2. Conceptual Framework

As already stated, the overall objective of the study is to develop a domestic water pricing model by applying the core principles of IWRM as a long-term solution to the problems associated with the current water pricing system. In the backdrop of IWRM framework, the new water pricing model must meet the three goals such as economic, environmental, and equity (García-Rubio et al., 2015; Hek and Ramli, 2016; Kasbohm et al., 2009). Figure 4.1 shows how the three principles of IWRM can be integrated into the design of a water pricing model. Recovery of the cost with a reflection of its economic value is the first precondition for ensuring economic efficiency in the pricing system (Bielsa and Cazcarro, 2015; Hossain and Bahauddin, 2013; Meran et al., 2020; Koppen et al., 2016). Secondly, the consideration of environmental externalities into the water pricing reflects the high significance of water conservation for the future generation (Baniasadi et al., 2020; Bielsa and Cazcarro, 2015; Laila, 2008; Pulido-Velazquez et al., 2013; Riegels et al., 2013). Finally, the water pricing system should safeguard the accessibility to adequate water for the poorer section which can be achieved through a cross-subsidization process (the high-water users should pay for the low water users) (Benson et al., 2015; Molinos-Senante and Donoso, 2016).

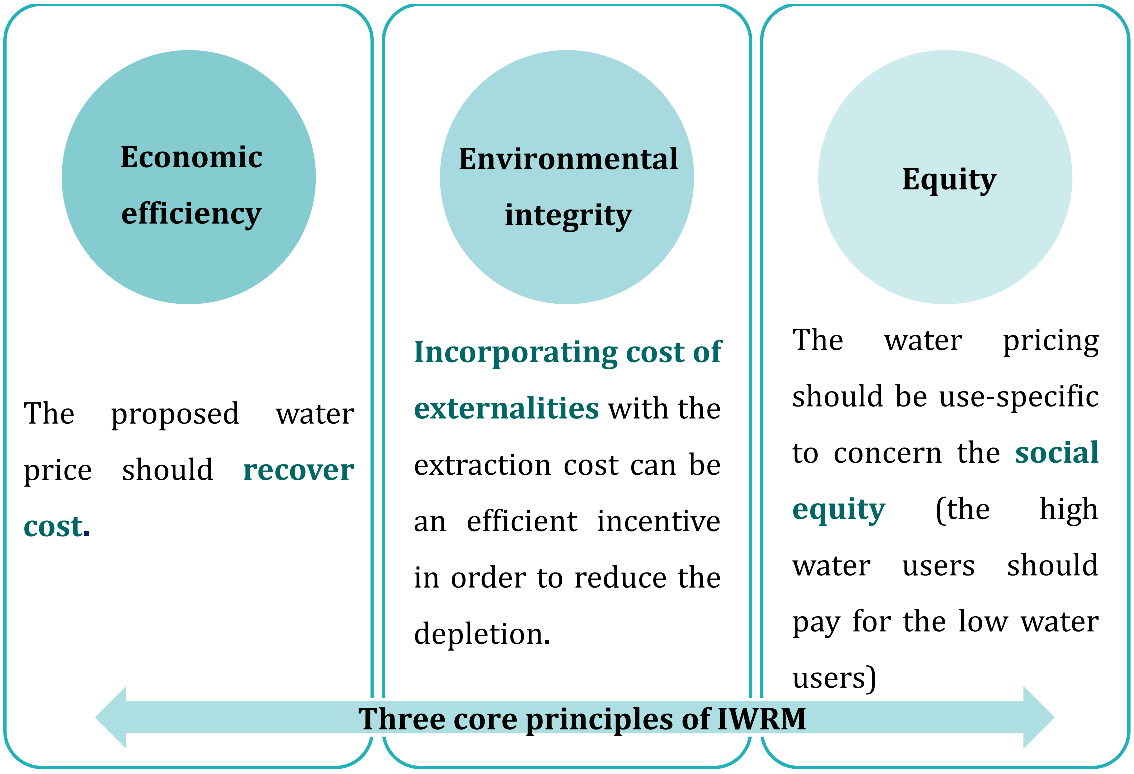

Figure 4.1: Framework of a water pricing model based on IWRM principles

Yet, the implementation of IWRM based water pricing system often becomes a challenge. The underpinning factor is that the last principle of this framework, equity, contradicts the other two principles (Donoso, 2016; Grafton et al., 2020). Provision of subsidized low price does not satisfy the cost recovery criteria (Grafton et al., 2020; Molinos-Senante and Donoso, 2016) on one hand, it reinforces the misuse of the valuable environmental resource and leads it to degradation on the other (Das et al., 2021; Macian-Sorribes et al., 2015). This conflicting issue, therefore, directs a use-specific water pricing system to successfully integrate IWRM principles. Based on the above arguments, the study attempts to develop a water pricing model which would assimilate three aspects: i) cost recovery, ii) affordability of water user and iii) amount of water use per capita to penalize the high-water users (Figure 4.2). Consideration of affordability of users as well as penalizing overuses of water can combinedly supplement the equity ethics of IWRM based water pricing. On the other hand, the reflection of the full economic cost would not only attain the economic efficiency of the water supply but also make the water users conscious about their uses (Das et al., 2021). The full economic cost can be subdivided into two broad parts: cost of extraction and cost of resource degradation externalities. The cost of externalities symbolizes the compensation of continuous degradation of resources to the environment. It is further subdivided into economic and environmental externalities which arise due to the declination of groundwater such as the cost of deepening wells and pumps, higher fuel cost, and greenhouse gas emission caused by greater use of energy (Baniasadi et al., 2020).

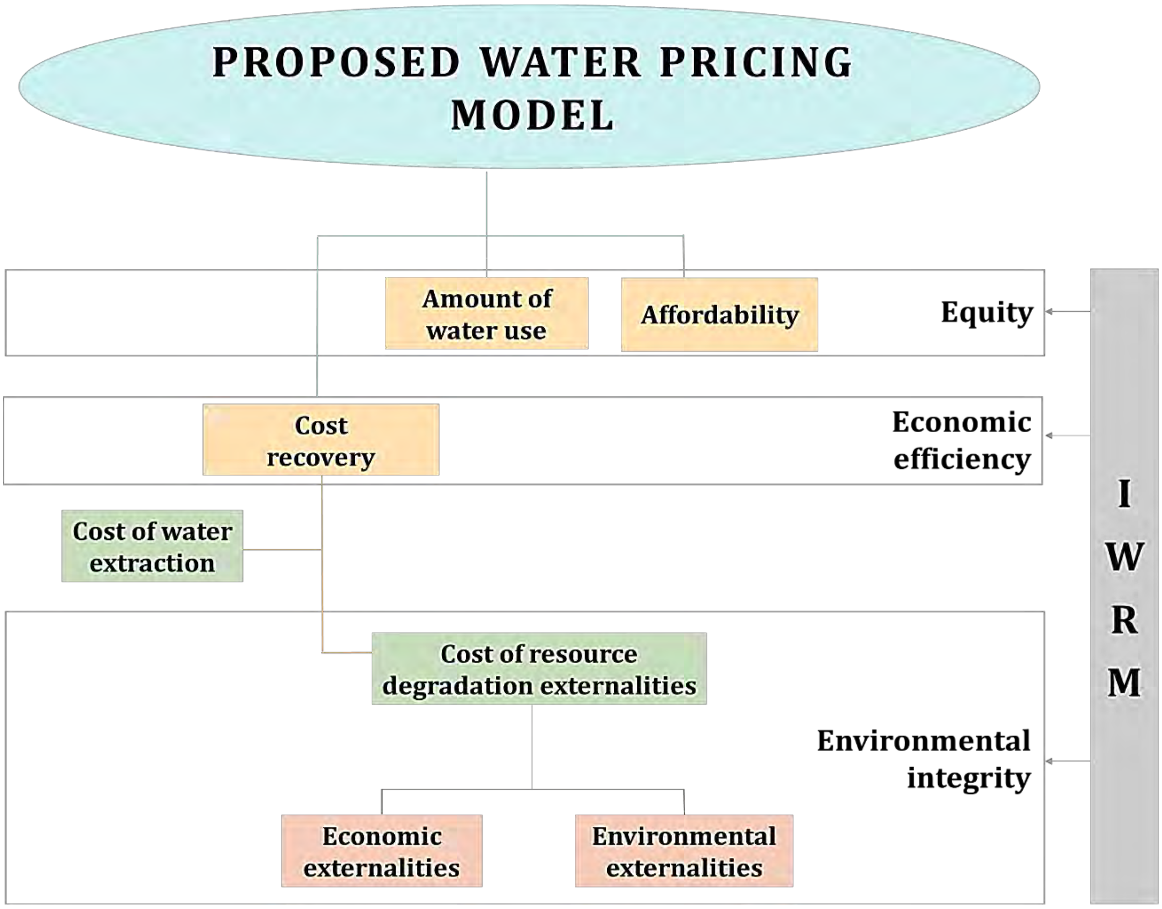

Figure 4.2: Conceptual framework of the proposed pricing model

As a result, the research investigation embraces three objectives. Firstly, estimation of domestic water usage has provided the basis of the amount of water used in both formal and informal settlements. The second step has evaluated the current water pricing system on the basis of the factors of water pricing as well as its impacts on the livelihood that provides a good understanding of the affordability of water users. Finally, an estimation of all the associated costs has been conducted to develop the new water pricing model based on IWRM.

4.3. Selection of the Study Area

As already stated, the Tejgaon area within Dhaka city is selected to meet the study interest. The rationale for selecting this study area is listed below:

- Tejgaon is considered critical for future water supply having the maximum drawdown of groundwater table (Chowdhury, 2012). It is also marked as a critical zone with a substantial risk of environmental degradation due to rapid groundwater exhaustion and declination up to 70m (Arfanuzzaman and Rahman, 2017). Hence, the area is selected to obtain a clear idea about the groundwater degradation externalities. Moreover, the greater extent of declination demands immediate conservation planning in these risky areas.
- Secondly, the study aims to evaluate the existing water pricing practices in both circumstances (with and without legal connections). Therefore, having the combination of both connections, the area would meet the research demand. The Tejgaon residential area represents the formal settlements with legal water connection and the Tejgaon slum symbolizes the informal communities with irregular water connection.
- Furthermore, the combination of residential and slum areas assists in gaining a better grasp of the overall domestic water use.

4.4. Data Collection

Both primary and secondary data were used for this analysis. Several field survey tools including questionnaire survey, focus group discussions (FGDs), key informant interviews (KIIs), in-depth interviews (IDIs), and pair-wise ranking covered the collection of both the qualitative and quantitative data. The rest quantitative data were collected from different secondary sources (published articles, national and international organizational reports, and from government and non-government websites). Table 4.1 represents a brief overview of objective-wise required data and their sources.

Table 4.1: Data required in this study and their sources

Objective	Parameter	Indicator	Data type	Data sources
Objective 1: To estimate water usage for domestic purposes in the selected area of Dhaka city	Water use of Tejgaon residential area	Monthly water use	Secondary	DWASA
		Number of apartments and families	Primary	Field observation survey
		Average HH size	Secondary	DWASA
	Water use of Tejgaon Slum	Daily water use	Primary	Questionnaire survey
		Household size		
Objective 2: To identify and assess the current groundwater pricing systems in the study area	Factors of Current GW Pricing System	Factors of pricing in residential area	Secondary	DWASA
			Primary	KII with DWASA officials
		Factors of pricing in slum area	Primary	KII with Water Suppliers
				IDI with slum dwellers
	Impacts of price on livelihood	Affordability and health	Primary	Questionnaire survey in both area
				KII with NGO school teacher
		Gendered impact	Primary	Questionnaire survey in both area
				Separate FGDs of men and women in the slum area
				IDI with slum dwellers

Table 4.1: Data required in this study and their sources (Continued)

Objective	Parameter	Indicator	Data type	Data sources
Objective 3: To develop a use-specific groundwater pricing model using IWRM framework.	Cost estimation of increased energy use	Groundwater level	Secondary	BWDB
		Energy consumption data for water production		DWASA
		No. of wells lifted within this area		DWASA
		Unit price of energy		BPDB
	Damaged Cost of dryness of well	Cost of constructing a new well	Secondary	DWASA
		No. of dried wells		
	Cost of greenhouse gas (GHG) emission by greater use of energy	Grid emission factor	Secondary	DOE
		Unit damage cost of GHG emission		World Bank
	Cost of health externalities	No. of affected people to water shortage diseases in slum	Primary	Questionnaire survey in slum area
		Treatment cost		

4.4.1. Primary data collection

Primary data were collected by two methods like semi-structured questionnaire survey and some participatory rural appraisal (PRA) techniques. FGDs, pair-wise ranking, semi-structured interviews with different key informants, and in-depth interviews are the PRA techniques used for the required data collection. Data collection was carried out from February to December, 2020.

4.4.1.1. Reconnaissance survey

Initially, field reconnaissance was taken to identify whether the study area is compatible with the research objectives or not. This step was conducted twice in the study area in order to gain a good understanding of the location, livelihoods of the local inhabitants, and water supply system. The data later helped in selecting suitable indicators for the study, performing surveys, setting up FGDs, as well as identifying individuals for KIIs, and in-depth interviews.

4.4.1.2. Pair-wise Ranking

Pair-wise ranking, a PRA ranking tool, aids in prioritizing people's concerns and needs. It refers to a structured method of uncovering the list of leading issues such as problems, possibilities, and needs (Narayanasamy, 2009). Considering this, the tool was used in the study to get the insights of slum dwellers about the most dominant water problems prevailing in that area. The technique was conducted with the help of public participation after the reconnaissance survey. The respondent group was made of eight people involving both male and female slum dwellers. The findings are outlined in Table 4.2.

High water price was rated as the most leading problem of the Tejgaon slum which indicated the suitability of the slum as a representative study area. However, a contradiction is observed between half of the women group with others. They opined that the distance of water collection point was the most dominant problem as they have to bear the water carrying responsibility. Thus, the slum dwellers put more emphasis on the water price and its collection rather than the quality of water.

Table 4.2: Pairwise ranking of water issues in the Tejgaon slum

Problem	**A**	**B**	**C**	**D**	**E**	Score	Rank
Water quality (A)		B	C	D	E	1	5th
High price (B)			B	B	B	5	1st
Distance from water collection points (C)				C	C	4	2nd
Separate sanitation cost (D)					D	3	3rd
Waterborne diseases (E)						2	4th

4.4.1.3. Questionnaire Survey

A semi-structured household questionnaire survey was conducted in the study area to explore the impact of water pricing as well as groundwater externalities. A set of questionnaires (Appendix A) were prepared before conducting the questionnaire survey which was also pre-tested during the reconnaissance visits to the study area. The total sample size for the household questionnaire survey was 100 (50 from each settlement). For selecting the survey respondents, a stratified random sampling method was applied. This sampling technique offers not only a highly representative sample of the population, but also a limited probability of human bias in case selection (Sharma, 2017). Both parts of the research area were segmented by the location into smaller stratum. As an example, the Tejgaon slum was divided into three strata: the south part, north part, and middle part of the slum. On the other hand, the data had been collected from five distinct areas falling under the Tejgaon residential area boundary (west Nakhalpara, east Tejturi bazar, Tejkunipara, west Razabazar, Saheenbag).

4.4.1.4. Focus Group Discussions

A Focus Group Discussion (FGD) refers to a data collection technique that is used to elicit participants' attitudes and perspectives, knowledge, and practices through a discussion among diverse people (Eeuwijk and Angehrn, 2017). Four FGDs were conducted in the study slum with men and women separately (two from each group). The unjointed FGDs were carried out to avoid swaying in their opinions that helped understand the gendered impact of water pricing more clearly. Each FGD group consisted of 8-10 members. The checklists to conduct FGDs were developed based on the objectives of the study. Photo 4.1 shows the view of an FGD with a women group in the slum.

Photo 4.1: View of an FGD with women group in the Tejgaon slum

4.4.1.5. Key Informant Interviews

KII is an important method for collecting information from the local expert people which reveals the how and why of a situation (USAID, 1996). Therefore, for attaining a knowledgeable insight of water pricing dynamics in this area, semi-structured interviews were conducted with five key informants: two executive engineers from DWASA, an NGO school teacher, and two water suppliers to the slum. It also shed light on how the externalities rises with the over-extraction of groundwater. Photo 4.2 shows a view of a KII.

Photo 4.2: View of a KII with DWASA officials

4.4.1.6. In-depth Interviews

Individual in-depth interviews are one of the most widely used data collection techniques of qualitative research that delivers a rich insight into surrounding social issues as well as their individual experiences in those issues (DiCicco-Bloom and Crabtree, 2006). Hence, the study used this interview method for pulling out the deep-rooted views of the slum dwellers about their experiences in the prevailing practices of water pricing. The interviews also helped understand the whole water distribution process clearly. Four individual in-depth interviews were conducted with male and female slum dwellers (two from each group) to distinguish the gender perceptions of how their livelihood is being impacted by the existing water pricing practice. The interviewees were selected from different occupations and ages. The male interviewees were day laborer (age: 36) and shopkeeper (age: 47). To identify gendered impact more clearly, the female interviewees were chosen on the basis of their employment status where one was garment worker (age: 27) and another was unemployed and totally dependent on her husband (age: 32).

4.4.2. <u>Secondary data collection</u>

In order to satisfy the interest of the study, it requires a number of secondary information including water consumption, groundwater level (GWL) data, current water pricing system, and externalities arisen from excess groundwater withdrawal. The information was collected during April and September 2020 from three diverse sources. Corresponding to Table 4.2, the city's water supply authority, DWASA contributed a major portion of secondary information required for the analysis. The rest of the data were collected from the Bangladesh Water Development Board (BWDB), Bangladesh Power Development Board (BPDB) and Department of Environment (DOE). The details are pointed out in the subsequent bullets:

- DWASA provided an electronic dataset of monthly water consumption for the year mid-2019 to mid-2020. The dataset includes the details of all connected holdings under the study area such as the address, account number, diameter of pump, water consumption, bill, and so on. Later, the required data for calculating average per capita water consumption and household water use were extracted from the dataset.

- The background information on factors of the current water pricing system was also collected from the DWASA annual report (2018-2019) and Dhaka water supply master plan (2014). The water rate of 2020 was also drawn from the DWASA website for fabricating a proper comparison of the impacts of water pricing between two settlements.
- Additionally, BWDB provided the GWL data during the period (1970-2016) for the Tejgaon groundwater well (ID: GT2616005) that is best suited to the study area.
- Furthermore, the related information about the groundwater externalities was obtained from DWASA. The information includes energy estimation for water production, the number of shifted and dried wells in the study area, cost of constructing new wells, etc. The unit price of electricity and the grid emission factor for electricity production were further drawn from BPDB and DOE websites, respectively.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1. Introduction

People, who get a continuous supply of water at a low price, often underrate the value of water, and make an impulsive use. On the contrary, the slum dwellers are being deprived of basic access to water because of high price and illegal medium of water supply. Contradicting with the theme of IWRM, the existing system needs renovation. In this chapter, a new pricing system is proposed focusing on the IWRM principles.

5.2. Domestic Water Use

Residential water use encompasses both the indoor (e.g., cooking, drinking, showering, laundry, toilets) and outdoor consumptions (e.g., garden irrigation, cleaning, swimming pool) at any residence. The consumption is highly contextual depending on a range of socio-economic factors and the behavior pattern of the residents. For instance, indoor consumption depends on family composition and income class while the drivers of outdoor consumption are social norms and affordability for luxury. Thus, the amount of water use is not indifferent in all households (Jorgensen et al., 2009).

5.2.1. Water use in formal settlements

The monthly water consumption data of each connected holdings of the Tejgaon residential area are collected from DWASA. The monthly household water use and daily per capita water use are calculated using the following formula (equations i and ii).

Monthly household water use= $\frac{Monthly\ consumption\ of\ 'X'building}{No.\ of\ families\ residing\ in\ 'X'building}$ ……………………… (i)

Per capita water use= $\frac{Monthly\ consumption\ of\ 'X'building}{No.\ of\ families\ residing\ in\ 'X'building * Average\ Household\ size * 30}$...... (ii)

where, $No. of\ families\ residing\ in\ 'X'\ building =$

$$(No. of\ apartments\ of\ 'X'building - No. of\ vacant\ apartments)$$

Here, the value of average household size of Dhaka Metropolitan area is mentioned 4.9 in Dhaka Water Supply Master Plan (DWASA, 2014). The additional information related to each building (no. of apartments and no. of vacant apartments) is collected from the field observation. Finally, both the equations are used separately for each month for the period mid-2019 to mid-2020 and are averaged. Table 5.1 displays the findings from the calculation.

Table 5.1: Descriptive statistics of the variables: per capita water use and household water use in the Tejgaon residential area.

Variables	**Household water use (m^3/month)**	**Per capita water use (L/day)**
Mean	30	202
Minimum	10	68
Maximum	85	578
1st quartile	15	142
Median	25	171
3rd quartile	32	216
Std. deviation	16	108

The findings reveal that a common Tejgaon family uses almost 30 m^3 of water in a month on average. Regarding the average per capita water use, a single resident uses around 202 liters of water, whereas one-fourth of the data indicates the consumption below 142 liters. The standard deviation (108 L) also indicates that the data points further away from the average having a great variation (Rumsey, 2011). The range of per capita water use varies from 68 liters to 578 liters where the 75th percentile is above 216 liters a day.

As seen in Figure 5.1, the water use normally varies between 100 liters to 300 liters except for the outliers. Here, the larger outlier values are indicated as green dots and the smaller values are indicated as red dots. It is observed that there are only two values below the 100 L/day line (68 L and 79 L). The households are being cross-checked due to the large differences. The households are situated at the ending point of East Nakhal Para bazar. Their incomes (< BDT 20000) are comparatively lower than the average income (BDT 42140) of the area and household condition (shown in Appendix B: Photo B1) is not also up to a reasonable standard.

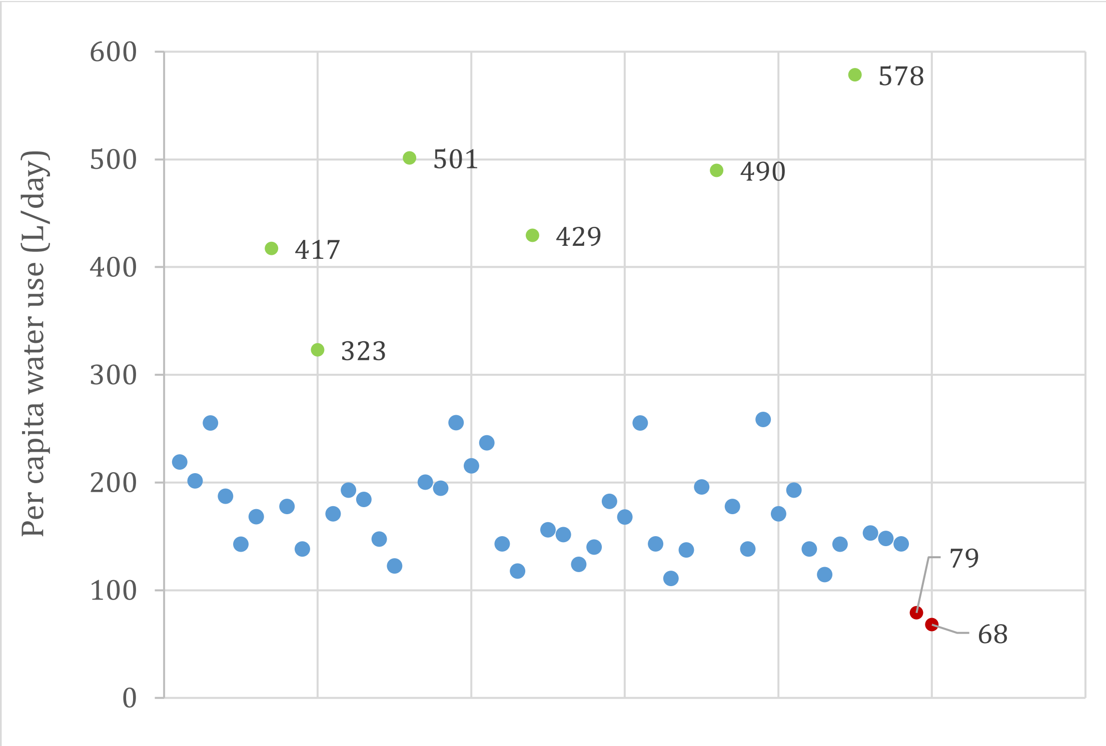

Figure 5.1: Scatter plot of per capita water use (L/day) in the Tejgaon residential area

5.2.2. <u>Water use in informal settlements</u>

A total of 50 people were surveyed from the Tejgaon slum to have a clear insight into the domestic water use of slum dwellers. The amount of water was measured according to the number of pitchers they used for water collection. The water use of the Tejgaon railway slum was identified as comparatively lower than the formal residential area. They are carrying water for drinking and other domestic purposes once a day averaging 10-15 liters per vessel and store it. Usually, they have to go to the collection points more than 3-5 times a day. As shown in Table 5.2, the monthly water use of a slum household is about 3 cubic meters on average. Although the maximum value of monthly water use (8m^3) is comparatively higher than the average (3m^3), 75% of the data are less than 5m^3. On the other hand, a slum resident uses an average of 18 liters of water to meet his/her daily demand. The range of per capita water use varies from 12 liters to 24 liters where about 75% of the data are below 20 liters per day.

Table 5.2: Descriptive statistics of the variables: per capita water use and household water use in the Tejgaon slum

Variables	**Per capita water use (L/day)**	**Household water use (m^3/month)**
Mean	18	3
Minimum	12	1
Maximum	24	8
1st quartile	15	2
Median	18	3
3rd quartile	20	5
Std. deviation	3	2

Their water use has been compared with the guidelines of domestic water quantity set by the World Health Organization (WHO) to check whether the standards are met or not (Table 5.3). WHO pointed out the requirements for water for promoting harmless health conditions through deriving a figure of an acceptable minimum to meet the needs mainly for consumption and basic hygiene (Howard and Bartram, 2003).

Table 5.3: Summary of the requirement for water service level to promote health

Service level	**Needs met**	**Level of health concern**
No access (quantity collected often below 5 lpcd)	• Consumption- cannot be assured • Hygiene – not possible	Very high
Basic access (average quantity unlikely to exceed 20 lpcd)	• Consumption – should be assured • Hygiene – handwashing and basic food hygiene is possible; laundry/ bathing is difficult to assure.	High
Intermediate access (average quantity about 50 lpcd)	• Consumption – assured • Hygiene – all basic personal and food hygiene is assured; laundry and bathing should also be assured	Low
Optimal access (average quantity 100 lpcd and above)	• Consumption – all needs met • Hygiene – all needs should be met	Very low

Source: Howard and Bartram (2003)

Table 5.3 illustrates a brief overview of the WHO domestic water standards focusing on the service level, needs to be met and level of health concern for respective service level. When comparing average per capita water consumption, the slum dwellers are still deprived of basic access to water (average water use per capita ≤20 liters) where the level of health concern is quite high. As a result, the residents of this slum face a significant health risk. It becomes tough to maintain proper sanitation and hygiene with this small quantity of water.

To understand the underlying influencing factor of water use, some demographic variables (no. of residents and household income) are verified through correlation analysis with per capita water consumption and monthly water use at a 10% significance level. Figure 5.2 demonstrates a positive relationship between the monthly consumption and the number of residents (where correlation coefficient, $r = 0.579$, $p \leq 0.01$). That indicates that the higher the number of residents in the household, the higher the monthly consumption tends to be.

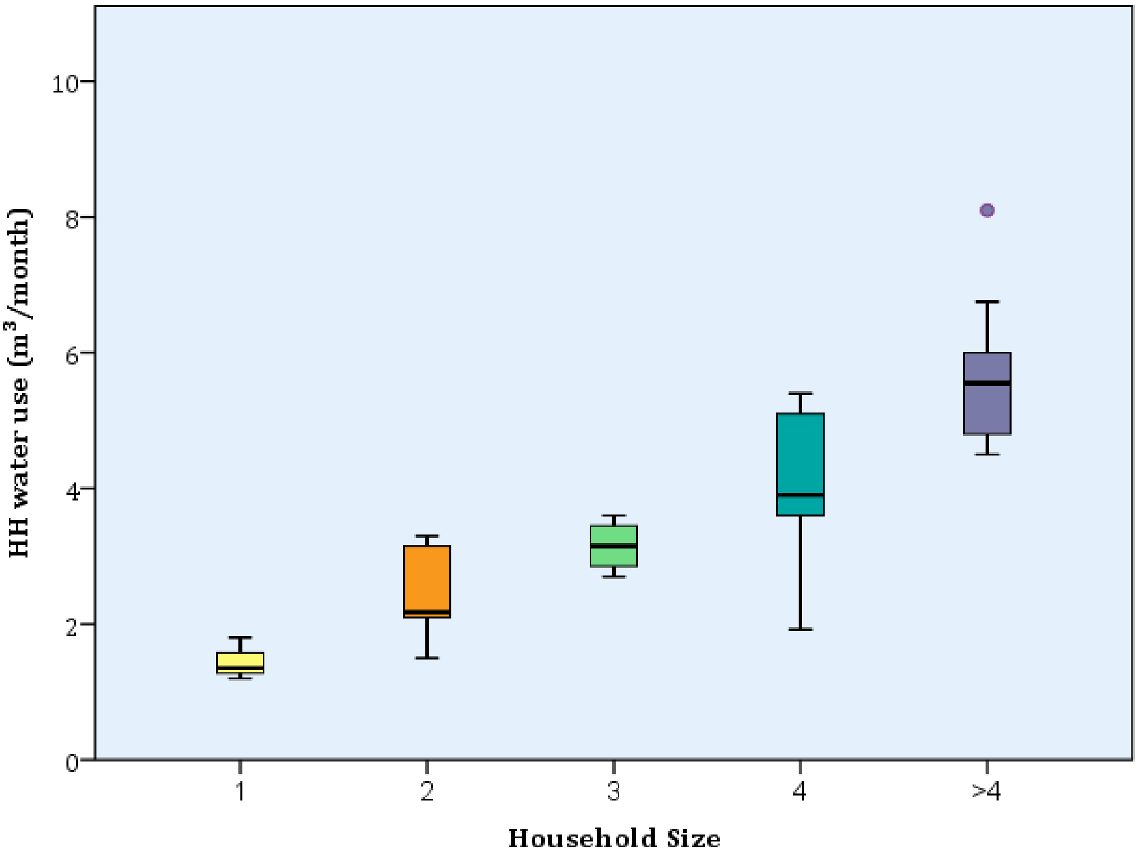

Figure 5.2: Relationship of household size with HH water use (m^3/month)

In contrast, a negative and significant correlation (where $r = -0.775$, $p \leq 0.01$) is observed in case of per capita water use (shown in Figure 5.3). That indicates the per capita consumption becomes lower with the increase of family members. Each resident gets a comparatively smaller amount of water to meet the demand of all family members within their small affordability.

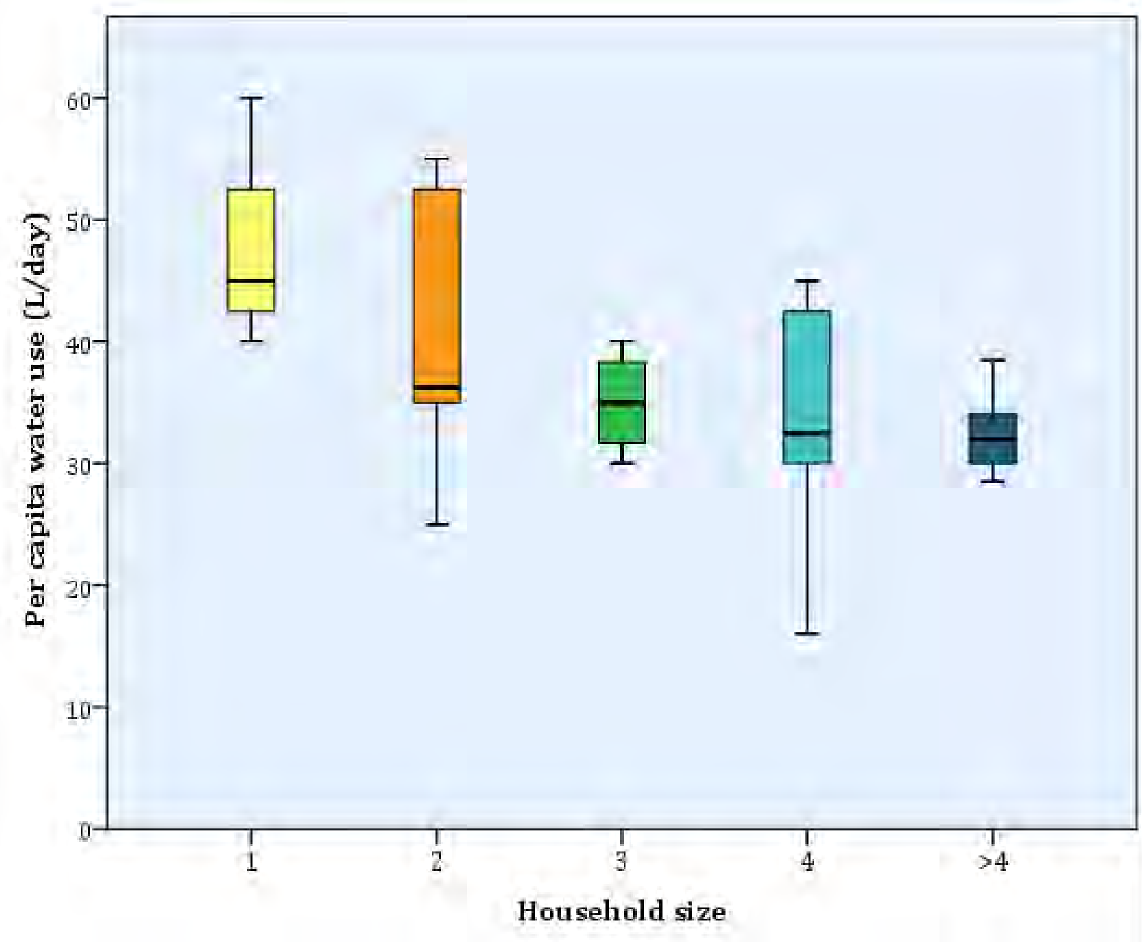

Figure 5.3: Relationship of household size with per capita water use (L/day)

As shown in Figure 5.4, the Boxplot shows a great difference in water consumption between Dhaka formal and slum settlements. The people of the Tejgaon residential area uses about 11 times more water than the slum dwellers in a day. In terms of per capita water use of slum dwellers, about three-fourths of the respondents use water below 20 liters. On the other hand, in Tejgaon residential area, the ratio of domestic water use is more than 200 lpcd for three-fourths of the respondents.

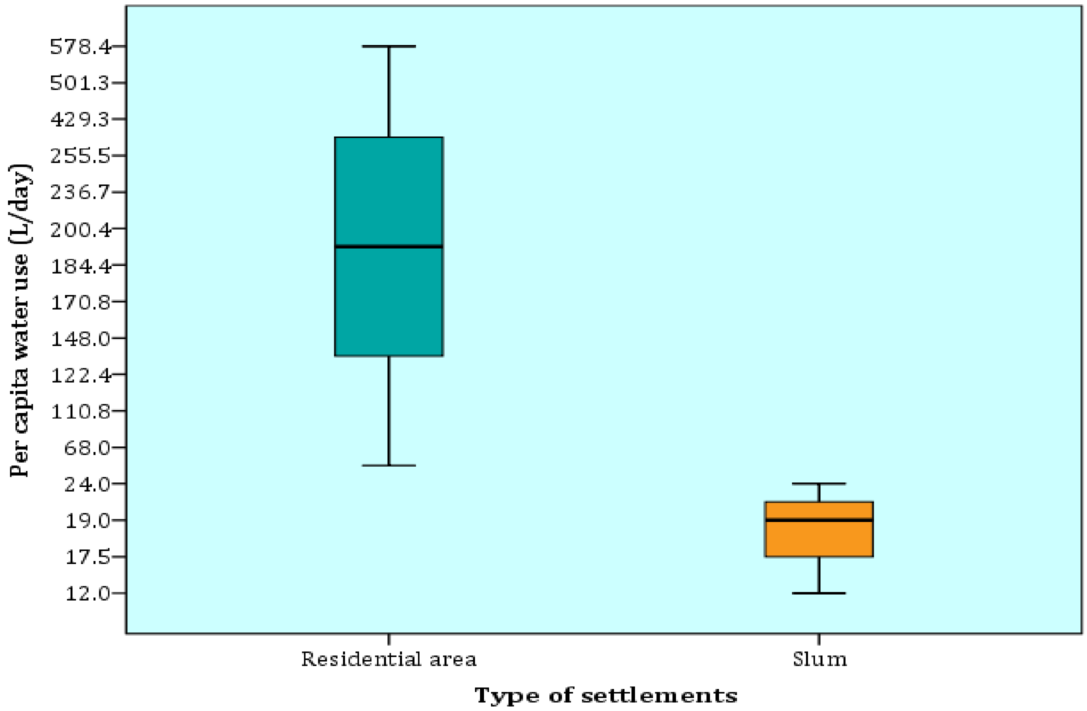

Figure 5.4: Settlement type-wise water use

5.3. Existing Water Supply System

Dhaka Water Supply and Sewerage Authority (DWASA) provides 24/7 continuous piped water supply to the whole city (DWASA, 2020). Being located under DNCC, the Tejgaon residential area falls under Zone 5 among the total 11 geographic zones of DWASA. Every household has a DWASA domestic water connection in this area. As a result, they pay the bill according to the price structure set by DWASA.

Although DWASA has started to provide water supply connections to low-income communities since 2010, the study slum is still excluded from this scheme. As a result, the water supply system of the slum reflects a completely different picture having no legal connection (shown in Figure 5.5). Despite its location at the heart of the city and close to DWASA head office, there are no water pumps or sources directly linked with households of the slum dwellers. A group of businessmen work as middlemen to provide water from DWASA to the slum unethically. They get water connections from DWASA to use for commercial or community purpose and sell it to the slum dwellers at a higher price for their profit. For conducting the water selling business, they establish reserve tanks, toilets, and sometimes bathing points in a specific place close to the households of the slum (Photo 5.1).

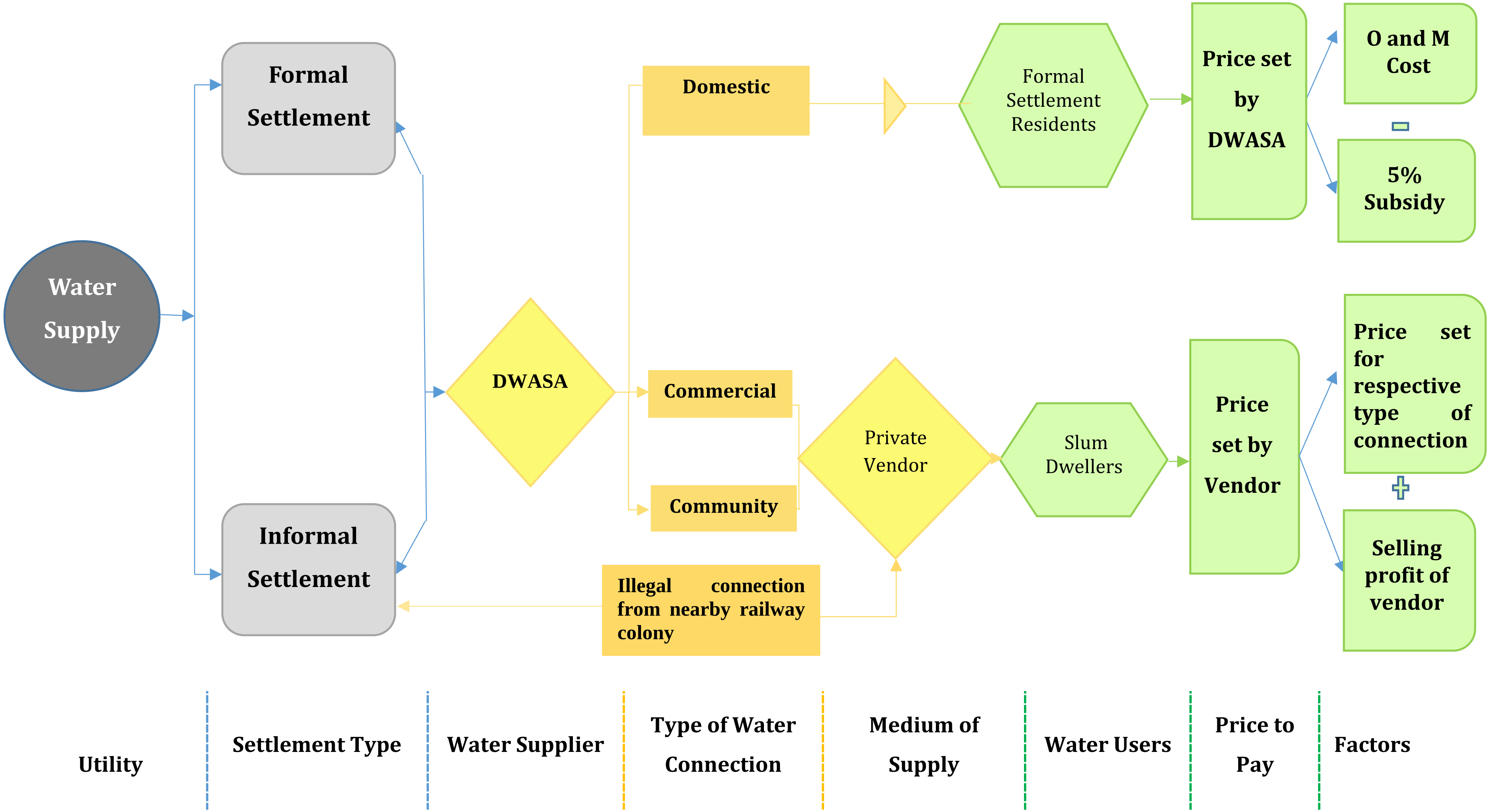

Figure 5.5: Water supply chain in the study area

Photo 5.1: Water supply points in the Tejgaon slum

There are seven reservoirs of water in the Tejgaon slum including different types of connections (Appendix B). Among these, one reservoir is permanently closed due to the ongoing construction work of the Dhaka Elevated Expressway. The water point was run by the nearby sports club named 'Tejgaon Khelaghor Krira Songho'. However, a field observation is used to identify the locations of the existing six water points which are shown in Figure 5.6.

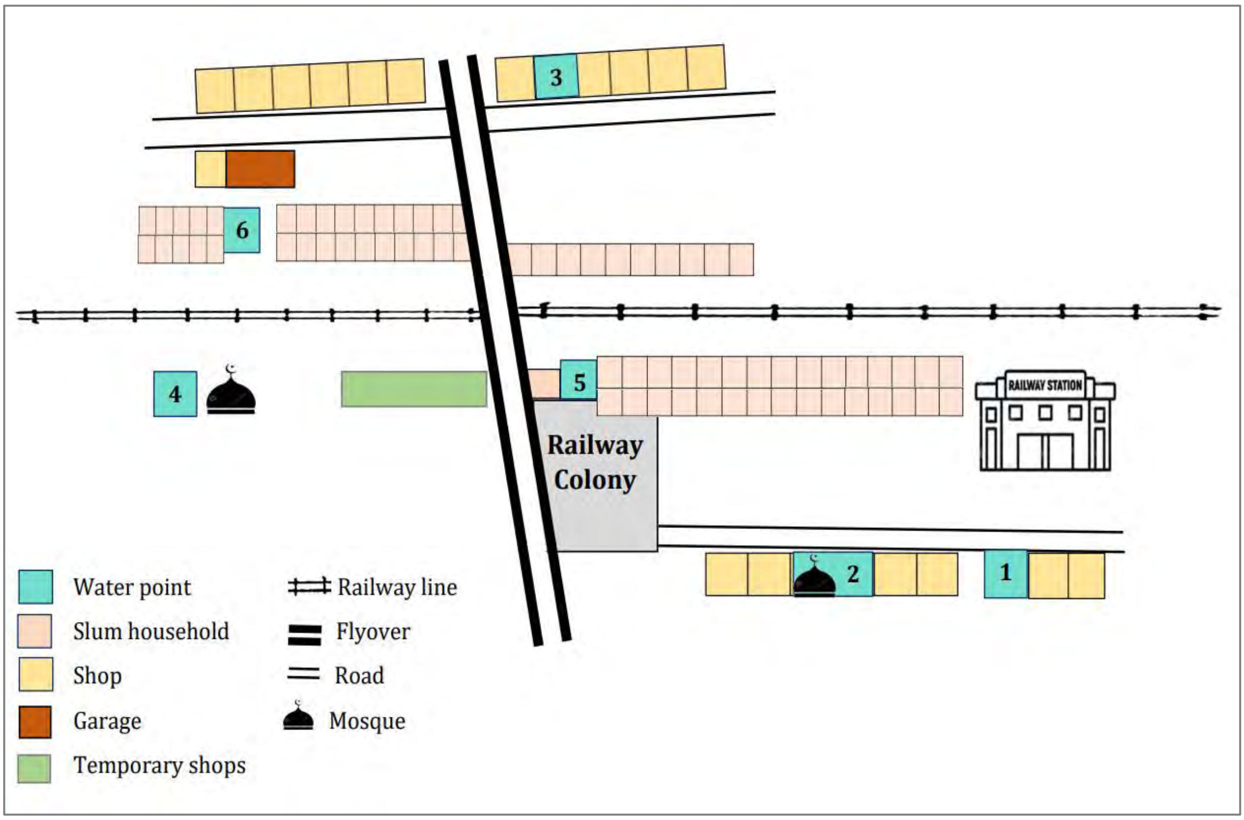

Figure 5.6: Locations of water points in the Tejgaon slum

Table 5.4 includes brief details of the existing water points of the slum focusing on the various aspects such as water connection type, location details and set-ups.

Table 5.4: A brief description of the water supply points in the Tejgaon slum

Serial no.	Connection type	Details	Set-up of water points
Water Point-1 (W.P.-1)	Commercial	It is a storehouse of fruits, located at the Tejgaon Railway Bazar, at the north side of the rail station outside the slum.	1 water reservoir (water is reserved in a big tank) 1 bathing point and 1 toilet
W. P.-2	Community	The water point is at the Railway Jame Mosque, located at the Railway Bazar outside the slum.	1 water reservoir (water is reserved in a big tank) 1 bathing point and 2 toilets
W.P.-3	Commercial	The water point is located at the Tejgaon Industrial Thana boundary which is on the south side of the railway station. It is the most distant water point from the slum.	1 water reservoir (brick structure) 1 bathing point and 2 toilets
W.P.-4	Private	This water point is surrounded by a nearby local hand tube well located at a community mosque (a little far away from the east endpoint of the slum).	1 hand tube well, People bath near the tube well and there is no toilet.
W.P.-5	Illegal connection from nearby railway colony	It is the only water point that is located in the middle of the slum (close to the flyover).	1 water reservoir (brick structure) 1 bathing point and 1 toilet (surrounded by tin-wall)
W.P.-6	Commercial	The point is located on the south side of the railway station. Water connection is taken from the nearby garage.	1 water reservoir (brick structure) 1 bathing point and 1 toilet

In Dhaka city, the role of NGOs in slum development services are more comprehensive in terms of access provision to public water and sanitation services. Unfortunately, no involvement of NGOs working in the water sector is found in this area. The whole illegal system is run through the assistance of goons. Hence, the slum dwellers collect water daily according to their needs and affordability from these reservoirs finding no other options. They have to pay separately for the use of the toilet and taking bath on a per-use basis.

5.4. Factors of Existing Water Price

The residents of Dhaka enjoy one of the lowest water tariffs in the world. The governing authority of water supply, DWASA is immensely supported by the government subsidy and other donor funding (Laila, 2008). As shown in Figure 5.6, the water tariff structure of DWASA is 5% subsidized operation and maintenance (O and M) cost regarding the water production and supply. Here, O and M cost includes all the associated costs incurred from the production of yearly volume of water to supply to the households (DWASA, 2014). According to the Management Information Report of DWASA (2007), it is an additive function of some variable costs which are listed in Table 5.5.

Table 5.5: Subdivision of operation and maintenance cost

Components of costs	**Average share of total cost (%)**
Power/ electricity	35-40
Administrative costs	18.90
Chemicals	1.66
Repairs and maintenance	7.73
Depreciations	18.46
Interest and bad debts	13.09

Source: Laila (2008)

Later, the breakdown of operating expenses is represented differently in Water Supply Master Plan for Dhaka City (2014). The major categories under operating expenses are (i) salary and wages, (ii) repair and maintenance, (iii) administrative, and (iv) depreciation. Firstly, the expenses of 'salary and wages' cover basic salary and wages, various allowances, and the pension which take up to 43% of the total cost of O and M costs. The expenses of overtime are added under 'salary and wages' in the 2008-2009 financial year. Secondly, the main costs incurred for water production such as power or electricity, chemical, and repair are counted in the 'repair and maintenance' category. This category takes up to 42% share of the total costs where power is 72%, chemical is 5% and repair works are 23%. However, if only the cost of groundwater production is taken into consideration, the major part of the cost is associated with the power to run the pumps (66%), followed by repair and maintenance (11%). Finally. the other costs of overall operating expenses are administrative and depreciation, which are estimated at 8% and 7% respectively, in the 2012-2013 financial year (DWASA, 2014).

In addition, Figure 5.7 points out a positive correlation between the operating expenses of DWASA and the no. of DTWs in operation. During the 2005 to 2019 time period, the extent of operating expenses of DWASA has increased almost 5 times which is also proportionate to the increase in the number of DTWs in operation (440 to 887).

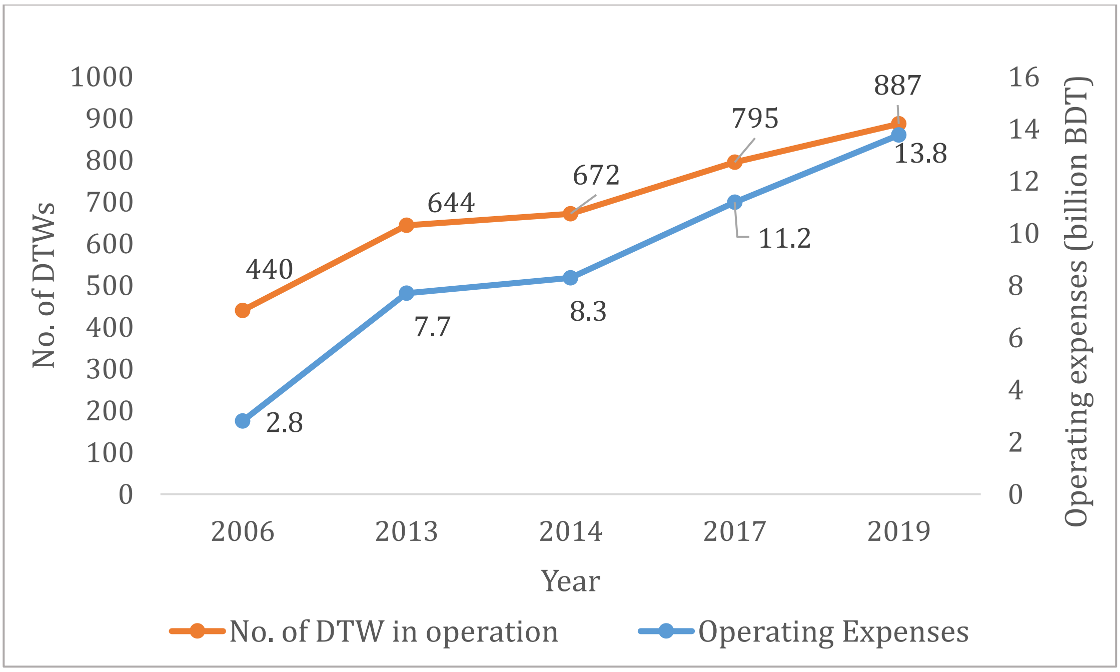

Figure 5.7: Relationship between operating expenses and no. of DTWs

The above-stated figure is based on the total operating expense for DWASA which includes expenses related to all the three types of services provided by DWASA, which are water, sewer, and drainage. There is still data or information deficiency and weakness in management and disclosure of information (Rahman and Islam, 2019). The breakdown for 'salary and wages' and 'administrative expenses' is not clearly found and therefore, the O and M costs for water services cannot be exhibited separately (DWASA, 2014).

However, Table 5.6 displays the DWASA established water tariff for different categories of water connection, such as domestic, community and industrial. The tariff has been fixed per 1000 liters of water consumption and is different according to the connection category. It is observed that the water tariff of domestic connection has increased almost 2 times from the 2016 to 2020 time period. The increase is comparatively lower (1.48%) in case of commercial, industrial or government categories.

Table 5.6: Tariff structure of DWASA (BDT/m^3)

Category	**Jul-15**	**Jul-16**	**Nov-16**	**Aug-17**	**Aug-18**	**Sep-19**	**Apr-20**
Domestic	8.09	8.49	10.00	10.50	11.02	11.57	14.46
Commercial	26.94	28.28	32.00	33.60	35.28	37.04	40
Industrial	26.94	28.28	32.00	33.60	35.28	37.04	40
Community	8.09	8.49	10.00	10.50	11.02	11.57	14.46
Government	26.94	28.28	32.00	33.60	35.28	37.04	40

Source: DWASA (2020)

Conversely, a huge price variation is observed in case of the Tejgaon slum. Figure 5.8 explains that the dwellers pay more than 17% higher price for buying the same amount of water (1000 liters) than the DWASA set price for domestic connection**.** Additionally, bathing and sanitation are charged separately for single use (BDT 10 and BDT 5 respectively). The underlying reason for this huge price gap is the involvement of local vendors in satisfying their business interests.

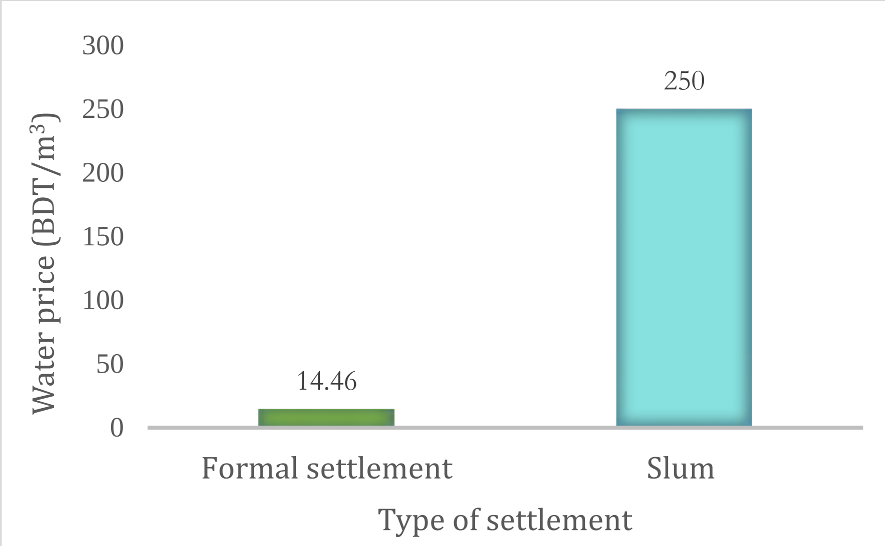

Figure 5.8: Water price variation in the study area

It is already stated that the private vendors get water through the legal water connection from the Dhaka water supply authority and sell it to the slum dwellers. As uniform volumetric pricing is used in the study area, there is no system of extra charges for higher water use. The consumers (vendors) pay proportionally to their water consumption despite their unusual higher water use. The water points located within the slum (W.P.-4, W.P.-5, and W.P.-6) have to provide a fixed percentage of profit as a commission to the goons who control the slum. The outside water points (W.P.-1, W.P.-2, and W.P.-3) are excluded from the money protracting by the goons. According to the survey findings, the percentage of commission holds about 20% of the profit. Although six water points are having different categories of water connections, the price of water is kept equal in all the six collection points. So, the amount of profit differs among the collection points. As shown in Table 5.7, the water points (W.P.-1, W.P.-3, and W.P.-6) hold the commercial connections of water which is charged BDT 40 per unit (1000 liters) water consumption. But the profit margin of W.P.-6 (BDT 160 per unit water sale) is comparatively lower because of the deducted percentage of commission the vendors need to provide for its location within the slum. On the other hand, W.P.-4 and W.P.-5 need not to pay any charges for their used water except the commission percentage for the location within the slum, while W.P.-2 pays a very negligible price (BDT 14.46) to DWASA because of having the community category connection and need not to pay additional commission to the goons.

Table 5.7: Breakdown of water price in the Tejgaon slum

Serial	Connection category	Unit price [slum dwellers pay] (BDT)	Unit price [vendors pay] (BDT)	Commission (%)	Profit per unit water sale (BDT)
W.P.-1	Commercial	250	40	0	210
W.P.-2	Community		14.46	0	235.54
W.P.-3	Commercial		40	0	210
W.P.-4	Private		0	20%	200
W.P.-5	Illegal connection from nearby rail colony		0	20%	200
W.P.-6	Commercial		40	20%	160

Furthermore, the total profit of any water points depends on some additional factors, such as the frequency of respective water point use, the distance of water points, and the restrictions on use of that points. Table 5.8 displays a rough evaluation of the ranking of the water point based on its total profit.

Table 5.8: Profit ranking of water points in the Tejgaon slum

Serial	Profit per unit water sale (BDT)	Ranking of distance	Ranking of frequency of use	Restrictions on use	Ranking of profit
W.P.-1	210	3	4	√	5
W.P.-2	236	2	5	√	4
W.P.-3	210	1 (max)	6 (min)	×	6
W.P.-4	200	5	3	×	2
W.P.-5	200	6 (min)	1 (max)	×	1
W.P.-6	160	4	2	×	3

Here, the distance of water points and the frequency of use at any particular point are ordered from 1 to 6 where 1 indicates the maximum and 6 stands for the minimum. The variable 'Restrictions on use' is symbolized by tick and cross marks (√= there is restrictions and ×= no restrictions). The findings reveal that the water point 5 (W.P.-5) has the highest profit because of its location which results in the highest preference to use that point. In addition, it is getting water from a leaked point of an adjacent railway colony for years and need not pay extra charges as the water bill. On the contrary, W.P.-3 has the lowest profit margin because of the highest distance (>2 km) from the slum and its location in a market in the Tejgaon industrial area market. Though it receives the same unit profit (BDT 210) as W.P.-1, the profit margin is different. Likewise, despite having higher profits for the sale of unit water, the total profit margin is comparatively low in W.P.-1 and W.P.-2 because of the restrictions upon the women to use that point. Women are considered impure and face religion barrier for accessing the water point (W.P.-2) located at the community mosque. W.P.-1 is also not accessible for women due to its location in the middle of the market and close to the mosque. Moreover, although W.P.-6 holds a higher water collection frequency than W.P.-4, its profit margin is lower because of its low unit profit (BDT 160). Hence, the profit margin of the water points is not constant rather varies depending on circumstances.

5.5. Assessment of Existing Water Price

The existing water price is assessed from a comparative breakdown between formal and informal settlements based on two surfaces; comparison with other South Asian cities and how it shapes their livelihood covering various socio-economic aspects, such as affordability, water use, health, and gender.

5.5.1. Comparison with South Asian cities

Existing water price of Dhaka city is compared with several neighboring megacities (except Gampaha city of Sri Lanka) within Asia region. Each city is represented by one (most used) utility provider and their tariff information has been mainly drawn from the websites of the responsible provider. For better understanding, the price of unit water (1m^3) is compared for each city. In terms of block pricing prevailing in any city, the price of mid-block has been considered. The comparative bar chart (Figure 5.9) represents that, the unit water price of the other neighboring cities ranges between USD 0.34 (Karachi) to USD 3.30 (Delhi), while it is only USD 0.17 in this Dhaka city. The water price is comparatively higher in Delhi, Singapore and Gampaha city due to inclusion of fixed service charges or water conservation taxes in price. In Dhaka city, neither any charge is added to the price nor is block pricing used to penalize the overuse of this valuable resource. On the other hand, unit water price of this city is about 2-20% lower than the other cities irrespective of the cities' level of development.

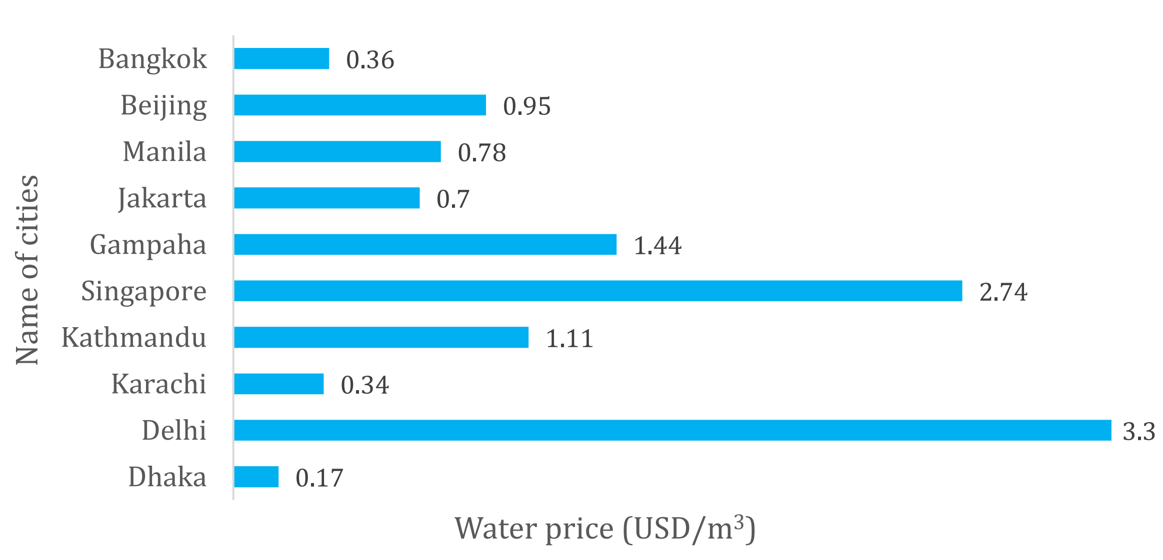

Figure 5.9: Water price in different Asian megacities

Source: DWASA (2020) [Dhaka]; *Delhi Jal Board (2015)* [Delhi]; *Karachi Water and Sewerage Board (2014)* [Karachi]; *Suwal et al. (2019)* [Kathmandu]; *Public Utilities Board (2018)* [Singapore]; *National Water Supply and Drainage Board of Sri Lanka, (2012)* [Gampaha]; *Arfanuzzaman and Rahman (2017)* [Jakarta]; *Manila Water Company Inc. (2018)* [Manila]; The International Benchmarking Network for Water and Sanitation Utilities Tariffs Database *(2016)* [Beijing] and *Metropolitan Water Authority (2010)* [Bangkok].

A negative correlation is also identified (Pearson correlation coefficient= -0.487, p=0.153 and Spearman correlation coefficient=- 0.612, p=0.060) between the water price and water use in the above countries. Figure 5.10 shows the water use is higher in Bangkok, Dhaka (representing Tejgaon residential area in Figure) and Karachi city due to the low price. On the other hand, water use in other countries are lower than the Dhaka city because of their higher price. For instance, the water price of Delhi is about 20% higher than Dhaka city which results into almost 50% less water consumption in this city. Therefore, water price has a significant impact on the amount of water used.

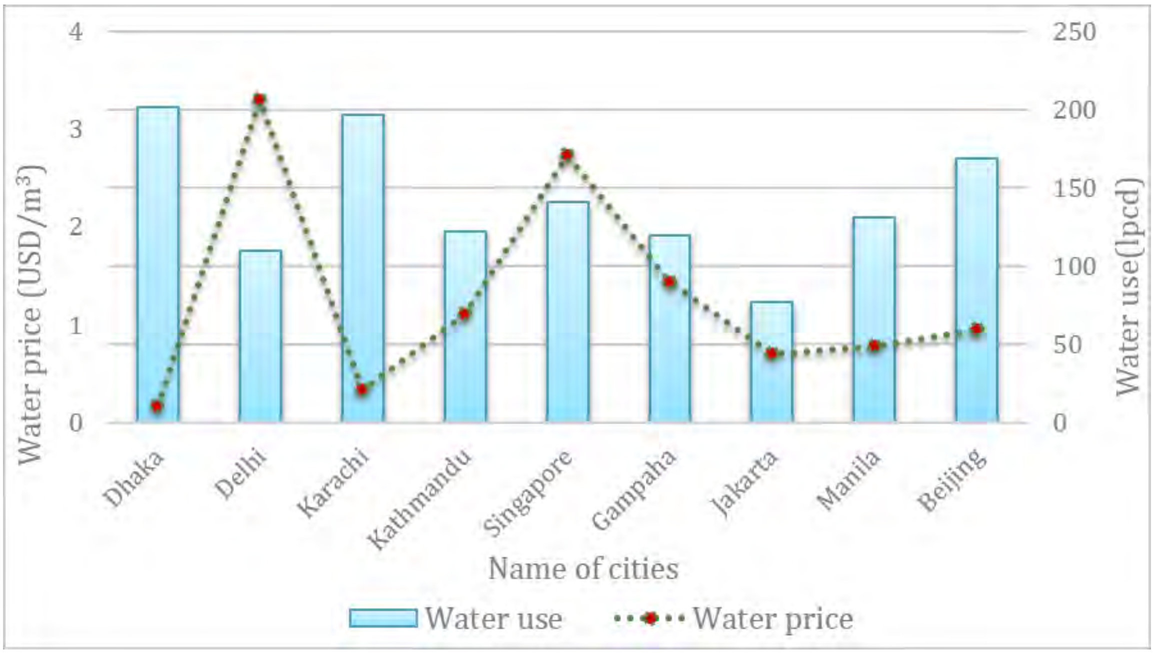

Figure 5.10: Relationship between water price and use

5.5.2. Impacts on livelihood

Being an everyday commodity for every person, not a single person can live without water. People, irrespective of their locations, spend a significant portion of their income for this basic utility. Depending on the price elasticity, the use of water is highly influenced by the collective factor of income and water price. The average income of the residents of Tejgaon is almost 7 times higher than the slum people. But the unit water price is low here. Thus, the slum people pay higher price with their lower income. A very negligible portion of the surveyed formal residents (8%) claim of high water price (Figure 5.11). Triangulation reveals that this opinion came from lower middle-class family. Here, triangulation refers to a process of cross checking the collected information to get a more detailed and balanced picture of the situation. However, they do not opine that the water price is not affordable rather indicate it as high. In direct contrast, nearly 90% of the slum respondents criticize the existing water price for not falling under their affordability range. The combination of high water price with low income forces the slum dwellers to spend about 8% of their monthly income for water on an average. Even in some cases, the expenditure range exceeds 14% of their monthly income while a formal residents pay only about 0.4% to 3% of their monthly income for water.

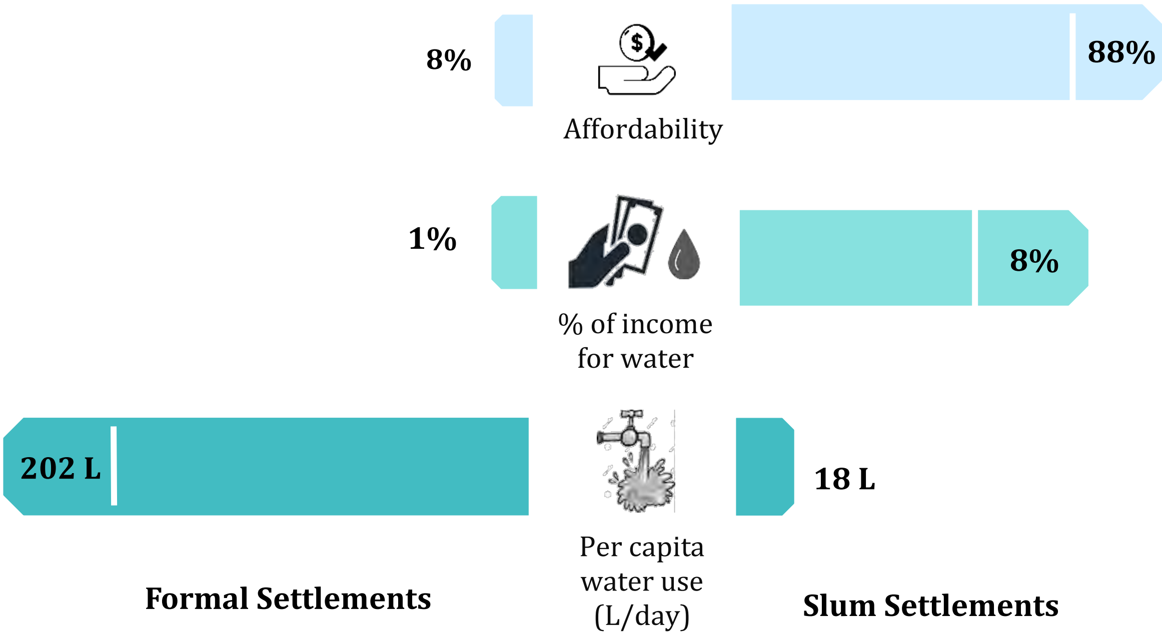

Figure 5.11: Economic impacts of water price

As per microeconomic theory, the magnitude of consumption is affected by the price due to elasticity of price. Therefore, when the price is high, consumption is low and it increases if the price is low. The study outcomes provide evidence in support of this theory which is noticed in the comparative water use between two settlements. Due to the irregular structure of price, the average daily domestic water use varies between a low range of 18 liters per person in slum to a high range of 202 liters per person in formal residential area. The theory is more transparently observed in the comparative picture of relationship between per capita income and water use in both settlements (shown in Figure 5.12). The per capita income is calculated from dividing the household monthly income by the household size.

It also presents a significant relationship between affordability and water use. The use does not vary too much with income when water is priced low and affordable. The average water use remains almost the same (within 150 liters to 200 liters) in all the three orders of income range. On the other hand, when water is priced high and beyond affordability, use is highly varied with income in slum**.** The water use of single slum dweller with a per capita income less than BDT 1000 per day lies under 12.5 liters in a day. When the income is in BDT 1001-2000 range, the average water use increases about 5 liters. The use even exceeds 20 liters in case of having income greater than BDT 2000 per capita. The underlying reason is that the slum dwellers are compromising their water need due to their low affordability. Therefore, a little increase in the income range increases their chance to fulfill the unsatisfied water demand.

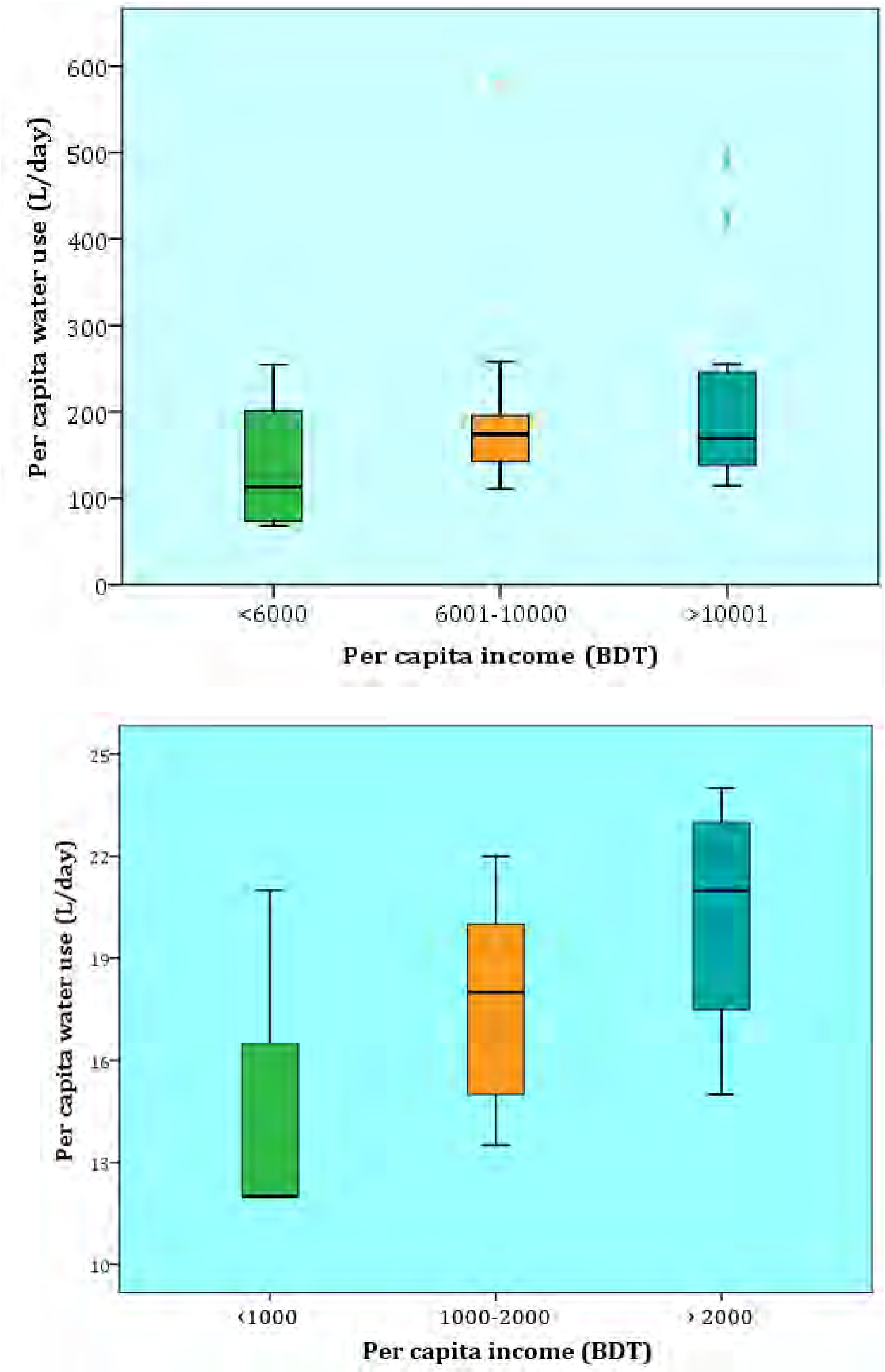

Figure 5.12: Relationship between per capita income and water use (top: the Tejgaon residential area, bottom: the Tejgaon slum)

This deprivation from the sufficient amount of water is also stirring up several inconsistencies in the livelihoods of slum people. About 64% of slum respondents claimed of not affording to consume sufficient drinking water while this percentage is totally zero in the residential area. Being a critical indicator to the development of a healthy human, the lack of access to sufficient amount of drinking water triggers the probability of various diseases, such as dehydration and diarrhea (Howard et al., 2020). Table 5.9 reveals the differences of drinking water consumption of the slum dwellers with the standard. The standard amount of drinking water used ranges from 2 to 5.3 liters, with slum dwellers consuming barely 1.2 liters on average. Thus, the slum dwellers still lack 1 to 4 liters from the standard quantity of consumption.

Table 5.9: Comparative picture of average drinking water consumption of slum dwellers with the standard.

References	Standard quantity (L)	Average consumption of drinking water in slum (L)	Gap with the standards (L)
White et al. (1972)	3	1.2	1.8
IOM (2005)	3.7 (Male)		2.5
	2.7 (Female)		1.5
EFSA (2010)	2.5 (Male)		1.3
	2 (Female)		0.8
WHO (2020)	5.3		4.1

Only 2% respondents of the residential area claimed of using less water for their sanitation due to their low affordability. Contrarily, the overpriced sanitation practice of the slum people adds numerous miseries to their life. As already stated that they have to pay per use basis for the community toilets and bathing points. BDT 5 and BDT 10 are charged respectively for one time use of toilet and bathing point. Despite paying their monthly water charges, a family of five members have to pay an additional BDT 1500 for taking bath every day in a month. Hence, bathing has become a luxury for slum dwellers. Figure 5.13 shows that more than 80% of the slum respondents do not take bath every day. They normally take bath at one- or two- day interval to reduce the extra burden of expenses. The interval even increases up to three to four days in the large families.

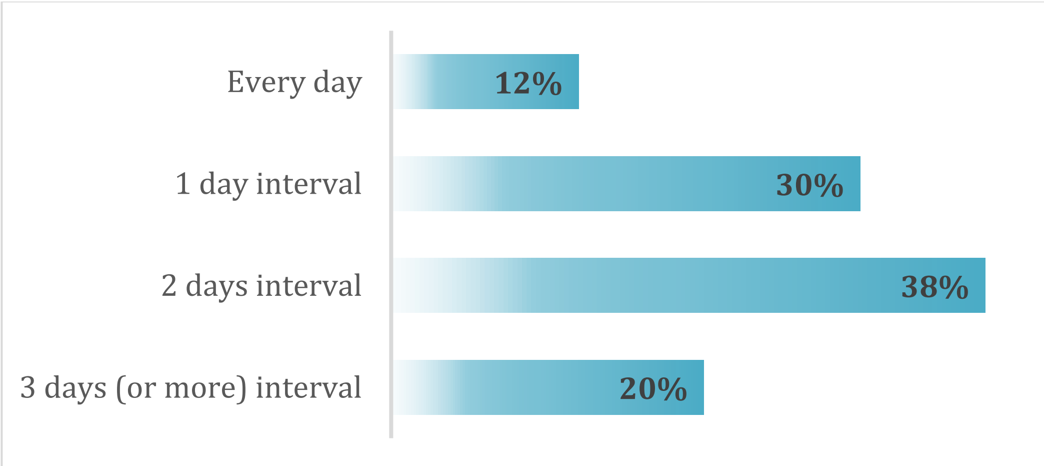

Figure 5.13: Bathing practice of the slum dwellers

Although there are two toilets within the slum and five toilets outside the slum, the slum residents, especially the children, have to defecate in the open place beside the railway line. The reason of open defecation is highly related to the cost of sanitation rather than the insufficient number of toilets. If a person uses the toilets at least 3 times a day, he has to pay BDT 450 per month. The excessive cost, therefore, results in an unhygienic and unclean sanitation practice in the slum family (shown in Photo 5.2).

Photo 5.2: Sanitation practices in the Tejgaon slum.

Additionally, the patriarchal society as well as the water managing responsibility of women forces the women to compromise their sanitation hygiene in most of the families. In 80% of the households, at least one woman completes her defecating and urinating at home and dump those garbages beside the railway truck (Photo 5.3). Nearly 60% of the female respondents have claimed that the stoppage of menstruation cycle (through uterus removal surgery, hysterectomy) gives relief to their husbands because it saves the additional cost for maintaining menstruation hygiene. Thus, the health and hygiene of a woman are being troubled by the cost of water.

Photo 5.3: Sanitation practice of the slum women

The insufficient water consumption of the slum residents leads to the larger percentage of affected people in various diseases compared to the formal residents. About 66% of the slum respondents complained of suffering from water shortage related illness, such as itching, urine problem, constipation, and diarrhea on regular basis (Figure 5.14). Among them, 24% of the respondents or their family members suffer from more than one disease. The slum dwellers have emphasized on the urine infection (18%) and constipation (10%) as the most frequent diseases. They also suffer from itching (8%) and diarrhea (6%).

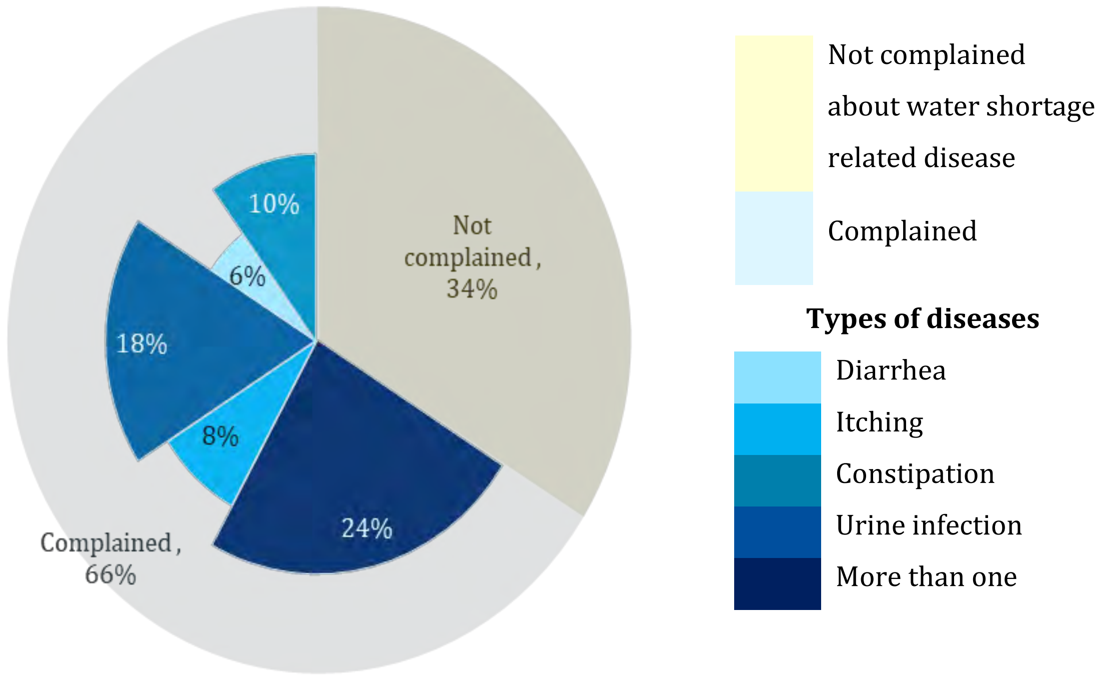

Figure 5.14: Status of water shortage related diseases in the Tejgaon slum

To sum up, the amount of water use is being determined by the price of water as well as the affordability of the user. Because of the low affordability, the necessity of water is being compromised by the slum dwellers. Since the society is mostly patriarchal and women are held responsible for water management at the household levels, their needs are threatened of becoming secondary in dire crisis scenarios.

5.6. Development of New Pricing Model

Capital, operational, and maintenance costs have dominated the decision making in water resource projects, with very little regard paid to environmental costs. If sustainable water systems are to be constructed, such factors must be incorporated into decision making (Shrestha et al., 2011).

5.6.1. Development of pricing block

The pricing model is proposed following an increasing block tariff strategy. The suggested unit price of the water considers that consumption in the first block covers the unit extraction cost, while the volumetric rate in the second pricing block includes cost of resource degradation externalities for the high consumption. WHO (2003) defined standard domestic consumption quantity as 50 lpcd because it can assure hygiene with a low risk of health concern for a person. Hence the consumption limit of first block is considered 50 lpcd in the proposed pricing model (shown in equation iii and iv).

*If Q≤ 50 lpcd, P (Q) = EC*Q* .... (iii)

*If Q> 50 lpcd, P (Q) = MP*Q* .... (iv)

Here, Q= Quantity of water usage by a household

The unit extraction cost of groundwater (EC) and modified price of the groundwater (MP) can be estimated using equation (v) and (vi) respectively.

EC= *Current price + Subsidized amount of price* .... (v)

MP= $EC + Cost\ of\ Externalities$

$= EC + (Cost\ of\ Economic\ Externalities + Cost\ of\ Environmental\ Externalities)$

.... (vi)

Considering the proposed pricing model, the new water rate will make water services more affordable to the poorest households. On the other hand, as water price rises with water use, excessive water consumption can be penalized severely.

5.6.2. Monetary valuation of economic externalities

Over-extraction of groundwater resources results into a drop in water level. In case of the long-term declines in groundwater levels, wells go dry and wells are deepened or replaced at substantial cost (Gailey et al., 2019). Therefore, the main economic externality comprises the increased financial expenses of groundwater extraction including both the capital and operational costs, particularly energy consumption for pumping a certain volume of water (Baniasadi et al., 2020, Bierkens and Wada, 2019, Manning and Suter, 2019)

5.6.2.1. Increased Energy Consumption and Energy Cost

It requires a significant amount of energy to abstract water from a reservoir or well into a distribution system. In the DWASA groundwater wells, the source of energy is electricity (DWASA, 2014). The increase in depth of the water level has a direct impact on the amount of energy consumption as well as operating expenses. It requires more energy to extract the same amount of water from comparatively lower depth. Hence, the first externality of over-extraction is an increase of pumping costs (Gailey et al., 2019).

The level of energy (E) required to raise one liter of water at height of one meter is equal to (Shahidasht, 2008):

$$E\ (KWH) = m \times g \times h \times v \times 2.78 \times 10^{-7} \quad \text{……………… (vii)}$$

In equation (vii), m is the plain water density (which is equal to 1000 kg/m^3), g is the acceleration of gravity in meters per second squared ($g=9.8ms^{-2}$), h is water height in meters, and v is the volume of water extracted in liters (or cubic meters).

DWASA wells extracted about 1035915 m^3 water in a month on an average in this area. On that basis the value of volume of water (v) is 1438.77 m^3/hour. If the volume of water is considered the same over the time period, the increase in energy due to groundwater depletion, (E_i) can be calculated with reference to the changes in height of the level of groundwater in the study area (Baniasadi et al., 2020). Therefore, the equation of increased energy will be:

$$E_i\ (KWH) = m \times g \times \Delta h \times v \times 2.78 \times 10^{-7} \quad \text{……………… (viii)}$$

The changes in water level height (Δh) can be measured using equation (ix).

Δh= Average height of groundwater level in 2020 - Average height of groundwater level in 1996. ……………… (ix)

As shown in Figure 5.15, the average static groundwater level has been changed from 22.4 meters to 81.2 meters during the study time period (1996 – 2020). Hence, the change in height (Δh) is estimated as 58.8 meters with an annual declination of 2.45 m. The static water level data has been collected from BWDB for the year 1996 to 2012. The rest of the data (2014-2020) has been forecasted on the basis of previous BWDB data using excel formula.

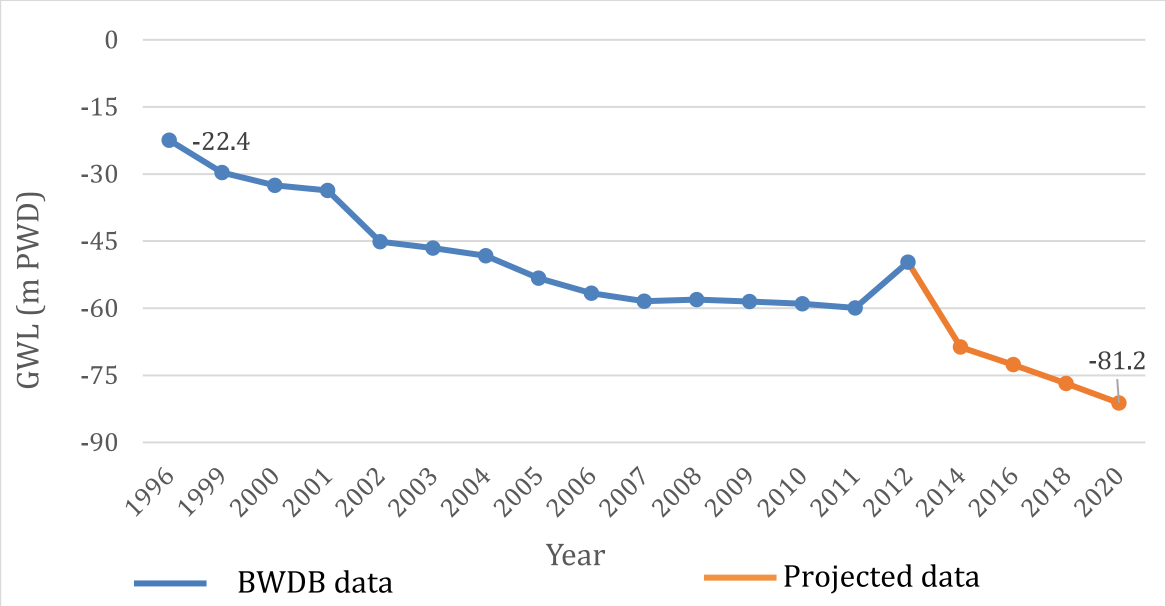

Figure 5.15: Changes in static groundwater level in the study area

Finally, the increased annual energy consumption (2.7×10^7 KWH) has been converted into monetary value by multiplying with the unit electricity price. Energy prices for electricity (for the general category of medium voltage) peak load, medium load and low load are respectively, BDT 10.56, BDT 8.45, and BDT 7.61 (these amounts were, respectively, equal to 0.12, 0.10 and 0.09 dollars according to the period's exchange rate) for each kilowatt hour (BPDB, 2020). The average energy price (equal to BDT 8.87 for each kilowatt hour) is considered for the calculation of externality cost. Finally, the total increased energy cost is calculated multiplying by number of wells (n=14) lifted to the lower depth.

5.6.2.2. Damaged Cost of Dryness of Well

Negative externalities in groundwater over-extraction are also leading to premature well failure, and reduced life of wells and eventually the drying of some wells (Diwakara and Chandrakanth, 2007). Due to the cost of construction and exploitation of these wells, the drying of wells causes a huge loss to the authority. These costs can be calculated directly by market prices method (Baniasadi et al., 2020). The total amount of damage caused by the dryness of wells can be obtained using the equation (x):

Damaged cost for dryness of well, $C_w.dry = N_{dry} * C_{con}$ ……………… (x)

In the above equation, $C_{W}.dry$ is the total damage caused by the dryness of wells, N_{dry} is the number of dried wells during the study time period (1996-2020) and, C_{con} indicates the cost of construction of a new well in the study area.

According to the DWASA estimation, the average number of dried well per year is 0.5 for the selected six years (2018-2020 and 1996-1998) in the study area. On that basis, the total number of dried wells (N.dry) should be 12 throughout the course of 24 years. Due to the lack of all year's data, the study assumes 10% margin of error in computing the total number of wells dried. Finally, the study estimated the number of dried wells as 11 (actual value) using the following formula:

$$Percent\ error = \left|\frac{actual\ value - estimated\ value}{actual\ value}\right| \times 100 \qquad \text{……………… (xi)}$$

Moreover, the average cost of constructing a new well in this area is BDT 1.5 crores.

5.6.3. Monetary valuation of environmental externalities

A reduction in the levels of aquifers is followed by many environmental problems, such as loss of plant and animal diversity, water quality degradation (salinity), loss of vegetation and, consequently, soil erosion and an increase in the potential of flooding, damage to the human health, the storage potential and hydrological characteristics of the aquifer, and greenhouse gas emissions caused by greater consumption of energy (Baniasadi et al., 2016; Baniasadi et al., 2020; Diwakara and Chandrakanth, 2007). Among these, the study considered two significant externalities appropriate for the study area: carbon footprint of water (greenhouse gas emissions caused by greater consumption of energy) and health externalities (damage to the human health).

5.6.3.1. Cost of Carbon Footprint of Water

Although Bangladesh contributes 0.56% of the global CO_2 emissions, it is now counted within the list of most affected countries by climate change due to its extreme fossil fuel consumption (Hasan and Chongbo, 2020). The country emitted about 0.2 million metric tons of greenhouse gases in 2016 and the emission percentage is in an increasing state over the years (Ahmed and Khondker, 2018).

Energy sector (electricity generation) is indicated as the highest contributor (48%) of greenhouse gases emission in this country (Sarkar et al., 2015).

As a major user of energy, groundwater extraction contributes to a significant percentage of greenhouse gasses generation which not only causes environmental threat (Almasoud and Gandayh, 2015) but also fuels the climate change (Hasan and Chongbo, 2020). Therefore, the environmental damage costs of greenhouse gases (emitted by each additional KWH electricity production for groundwater over-extraction) should be incorporated to evaluate the environmental externalities. In this context, the study has attempted to integrate cost of carbon footprint of water into full economic cost calculation. However, the carbon footprint is the measure of the total quantity of greenhouse gasses, expressed as carbon dioxide equivalents (CO_2e), that directly and indirectly results due to an activity or is accumulated over the life stages of a project (Shrestha et al., 2011). The total value of carbon footprint of water is obtained from the following equation:

$$Cost\ of\ carbon\ footprint\ of\ water = Cc * Emw * GEF \qquad \text{…………….. (xii)}$$

where, Cc = Unit damage cost of CO_2e emission

Emw= Level of increased consumption of electricity in the wells in the area (MWH);

GEF= Grid Emission Factor = Amount of CO_2e produced per MWH electricity production

The damage cost of carbon emission has been estimated by several organizations. Although there is no fixed calculation for Bangladesh, it normally varies considerably from $1 to $130 per ton CO_2e, with the vast majority set between $5 and $30 across the world (World Bank, 2016). Hence, for the calculation of total cost of carbon footprint of water, the study considered the median value (Cc= US $17.5) of the most used range as unit damage cost. In addition, the method of calculating the increased consumption of electricity during the time period (1996-2020) was introduced in the "*Increased energy consumption and energy cost*" section. Moreover, Department of Environment has estimated the grid emission factor of Bangladesh is 0.67ton CO_2/MWH (DOE, 2013).

5.6.3.2. Cost of Health Externalities

As it is already illustrated, the impoverished slum dwellers cannot even fulfill their basic need for water due to the higher price, while the formal residents are using much more than the optimal accessibility of water. The inadequate water use is causing a great hamper to the health of the slum dwellers. As shown in Figure 5.3, several water shortage-related illnesses such as itchiness, urinary problems, constipation, and diarrhea affect more than half of the slum dwellers regularly and burdening them with extra treatment costs. Therefore, in this study, the treatment cost for water shortage related diseases has been considered as health externalities of the current water pricing. It is calculated using the following formula:

$$The\ treatment\ cost\ for\ water\ shortage\ related\ diseases = N_{\mathrm{ap}} \times \mathrm{C_t} \qquad \text{.........(xiii)}$$

where,

N_{ap}= Average no. of affected people to water shortage related diseases in the slum

C_t= Average yearly treatment cost per person (BDT)

The cost estimation of health externalities is mainly based on the primary data collected from the Tejgaon slum. The average number of affected people to water shortage diseases in the slum (N_{ap}) has been estimated by multiplying the total population in the Tejgaon slum with the average percentage of the population suffering from water shortage related diseases. In order to estimate the yearly treatment cost, the average monthly expenses spent for the water shortage related diseases are multiplied by 12. According to the survey findings, about 66% of the population in the Tejgaon slum suffer from water shortage related diseases. They spend on average BDT 210 in a month for the treatment of one person for these types of diseases.

5.6.4. Estimation of new water price

As previously indicated, the water price of the first block includes the subsidized portion of the existing water price. In Dhaka, DWASA provides water at a 5% subsidy on the unit water price set by the government or other donor agencies. If the subsidy is not deducted, the unit water price will be the same as the unit extraction of water

(BDT 15.18). Therefore, the unit price of the 1st block will be BDT 15.18. On the other hand, the water price of the second block is the summation of extraction cost and externalities cost. The study measured the cost of groundwater externalities for the Tejgaon residential area only. Figure 5.16 presents the cost of externalities in the study area.

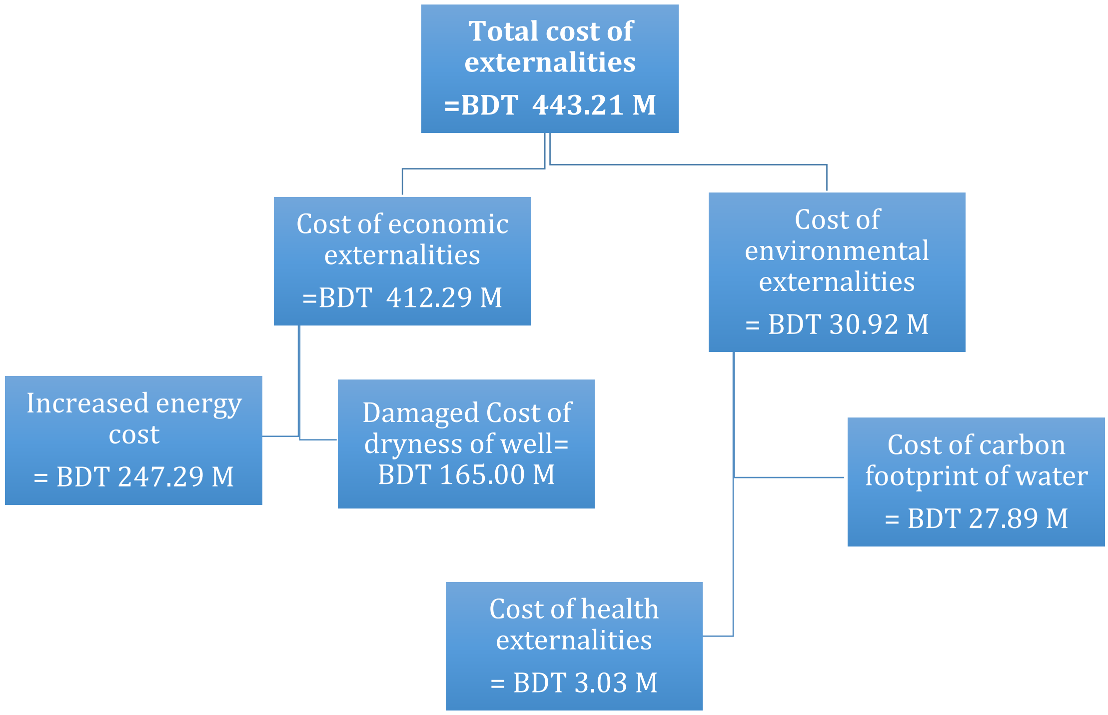

Figure 5.16: Cost of externalities in the study area.

The following equation is used to convert the cost of externalities into an annual uniform cost using the uniform series capital recovery factor formula (Fraser and Jewkes, 2012):

$$Annual\ uniform\ cost, A = P\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \quad \text{.........(xiv)}$$

Here, P is the total present value of cost of externalities, i is the interest rate, and n is the economic useful life of each well. The value of interest rate has been drawn from the website of the Central Bank of Bangladesh. The average interest rate on bank loan of all state owned commercial banks (SCBs) of this country is 9% for industrial category (Bangladesh Bank, 2021). Moreover, the average economic useful life of groundwater wells is 6 years in the region. Table 5.10 represents the annualized uniform cost of the externalities.

Table 5.10: Annualized cost of externalities in the study area.

Type of externalities	Annualized uniform cost (million BDT)
Increased energy cost	55
Damaged cost of dryness of well	37
Cost of carbon footprint of water	6
Cost of health externalities	1
Total	99

For determining the unit price increment, the total cost of externalities is further divided by the total amount of water drawn from groundwater (liters/year). In the study area, every year DWASA produce 12.43 billion liters of water on an average. As DWASA extracts 78% water from the groundwater, hence the total amount of water extracted from groundwater in the study area is considered to be 9.69 billion liters. Thus, the cost of externalities for 1000 liters of water production is calculated as BDT 10.19. Table 5.11 shows the estimated price of the proposed pricing model.

Table 5.11: Development of pricing block

Block	Price	Subdivision of price	Monetary value	Increase in price
1st block (Q≤50 lpcd)	Unit extraction cost of groundwater (EC)	Current price= BDT 14.46	BDT 15.18	5%
		Subsidized amount of price= BDT 0.72		
2nd block (Q>50 lpcd)	Full economic cost	EC= BDT 15.18	BDT 25.37	75%
		Cost of Externalities= BDT 10.19		

As the cost of externalities changes over time, the water price should be monitored on regular basis.

5.7. Validation of the Proposed Pricing Model

The two-tiered pricing of urban water supply like the proposed pricing model has a high probability of achieving the efficiency, fairness, and sustainability goals to direct the pathway of IWRM (Pulido-Velazquez and Ward, 2017). To be more detailed, in this section, the proposed pricing model has been validated in terms of three main IWRM principles to assess if it meets the key-theme of IWRM or not.

From an economic point of view, recovery of the costs (with a reflection of its economic value) is the first precondition for ensuring economic efficiency in the pricing system of any non-renewable resources. In the proposed model, the 1st block price deducts the subsidized amount from the existing price and directs to the cost recovery even for the low water consumers. The 2nd block price, on the other hand, incorporates the cost of groundwater exploitation externalities in order to notify the high water consumers about the true economic value of water.

Moreover, the increment in price brings about a great revenue for the DWASA organization. DWASA can earn an additional BDT 10 billion in a year for the first block water users in the study area while the amount is 135 billion for the 2nd block. As shown in Table 5.12, the amount of earned income is much greater when it is estimated for Dhaka city. To calculate the city's earned income, the total amount of yearly water usage is multiplied by the proposed price.

Table 5.12: Estimation of income for the proposed water pricing model

Area	**Income from present price (Billion BDT)**	**Income from proposed price (Billion BDT)**	
		1st block	2nd block
Tejgaon residential area	180	190	315
Dhaka	13460	14130	23615

At present, DWASA earn about BDT 13460 billion in a year which can be increased about 5% to 75% implementing the first and second block price respectively. The subsidized amount is provided by the government and international donors which can be covered by the additional revenue obtained from the 1st block price. The rest of the revenue can be used for the development of surface water supply system, such as water purification, and constructing supply line from distant rivers.

From environmental point of view, water pricing is a valuable strategy for incentivizing water consumption reduction, that in turn, assists in the conservation of valuable environmental resource, groundwater. The proposed water rate, thus, directs to a good demand management policy since it reduces water usage to a great extent. According to DWASA master plan (DWASA, 2014), in Dhaka city, the water demand-price sensitivity in 2012 was estimated as 3% that indicates, a 1 Taka rise in price will decrease 3% per capita daily consumption. However, price sensitivity is projected to decline over time due to the changes in additional factors such as increase in household income as well as less options to cut the demand. DWASA estimated that the price sensitivity will decrease by 0.5 percent every five years effective from 2015. As a result, the sensitivity in 2020 would be 2.5%. The increase in price due to the implementation of the new pricing model described in the study is BDT 0.72 and 10.91 for the 1st and 2nd blocks respectively. If the sensitivity factor is considered, the rise in water price will have a significant influence on reducing overall water demand in the city (shown in Figure 5.17). Due to the small increment in price the water use reduces about 2% (for the 1st block) to 27% (for the 2nd block).

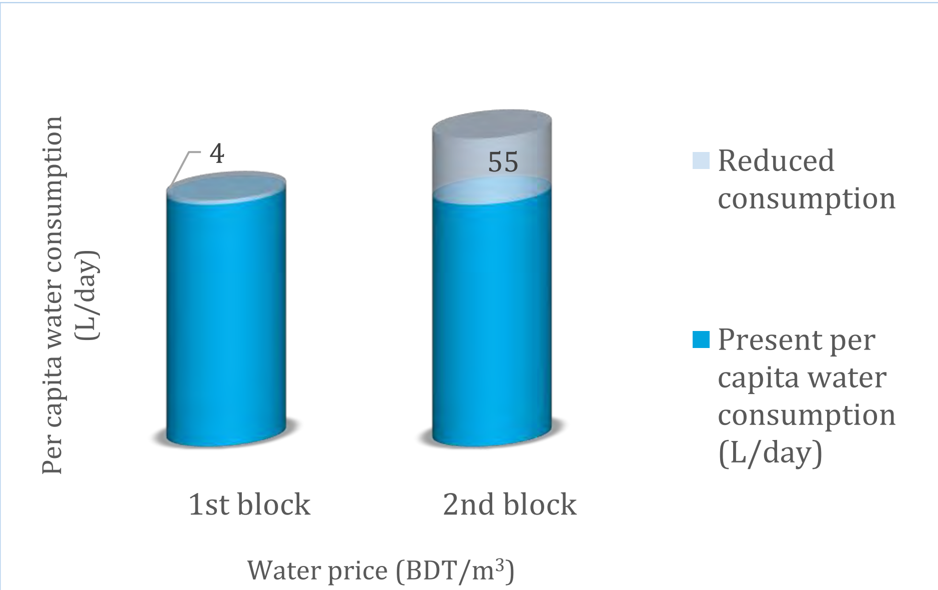

Figure 5.17: Reduced water consumption for price increment

Although the amount of reduced per capita water consumption is comparatively lower for the 1st block users, the significance rises to a greater extent when it is considered in a large scale. For instance, the amount of household water use can be saved up to 535 liters (1st block) and 8100 liters (2nd block) in a month. When it comes to the Tejgaon residential area, the yearly reduction in water would be 0.22 and 4 billion liters for the 1st and 2nd block users respectively. Moreover, when it comes to the Dhaka city, the water consumption can be reduced up to 255 billion liters in a year than the present use. Thus, the pricing model would help reduce the over-extraction of groundwater as well as conservation of this environmental resource.

In addition, the lower amount of water extraction will further influence the percentage of carbon footprint of water. As shown in Table 5.13, the amount of water, can be saved by the implementation of proposed pricing model, requires about 50 MWH to 750 MWH electricity for its extraction only in a year in the study area. Furthermore, the huge amount of electricity would emit about 35 tons to 505 tons carbon dioxide and its equivalent gases.

Table 5.13: Impact of proposed pricing model on environment

Indicators	**Tejgaon residential area**		**Dhaka city**	
	1st pricing block	2nd pricing block	1st pricing block	2nd pricing block
Amount of water saved	0.22 Mm^3/year	4 Mm^3/year	17 Mm^3/year	255 Mm^3/year
Amount of energy to extract the water	50 MWH/year	750 MWH/year	3710 MWH/year	56160 MWH/year
Amount of CO_2e emitted for that amount of energy production	35 tons/year	505 tons/year	2485 tons/year	37630 tons/year

Considering Dhaka city, the proposed pricing model would influence the environment more significantly. It can reduce about 3710 MWH to 56160 MWH electricity consumption which will further decrease the greenhouse gas emission up to 37630 tons in a year. Hence, the proposed pricing model satisfies the 'environmental integrity' theme of IWRM through its substantial positive impact on the environment in both terms: conserving groundwater resource as well as reducing greenhouse gas emissions.

The last key principle of IWRM based water pricing is ensuring **social equity**. The two-tiered pricing further leads to a cross-subsidy system that large consumers subsidize small consumers who usually are low-income households. On the other hand, the large water users (formal residents) are using water capriciously because the existing water price consists only 1% of their income on an average. As their over-consumption tendency is highly responsible for the groundwater depletion, the cost of externalities should be paid by them. According to the proposed pricing model, whenever water consumption is maintained in the first block, households could reduce its water bill by about 67%. On the contrary, in households whose water consumption involves both the first and second blocks, the percent rise of the water bill is higher as water consumption increases. Thus, the proposed pricing contributes to cross-subsidy system that large consumers pay for low consumers.

Contrarily, the slum dwellers are paying about 17% higher water price which compels them to use inadequate water due to their low affordability. The implementation of the proposed pricing model would be beneficial for the slum dwellers in two ways: diminishing the economic burden of water and providing enough water for assuring hygiene.

Figure 5.18 shows that, the proposed price would be almost 17 (1st block) and 10 (2nd block) times lower than the existing slum water price. As a result, one slum dweller can save from BDT 336 to BDT 352 in a month even if he/she uses 50 liters of water in a day which assures hygiene with a low risk of health concern. Furthermore, the additional burden of cost (BDT 210 per month) that is spent for their treatment of water shortage related diseases will also be deducted from their expenses.

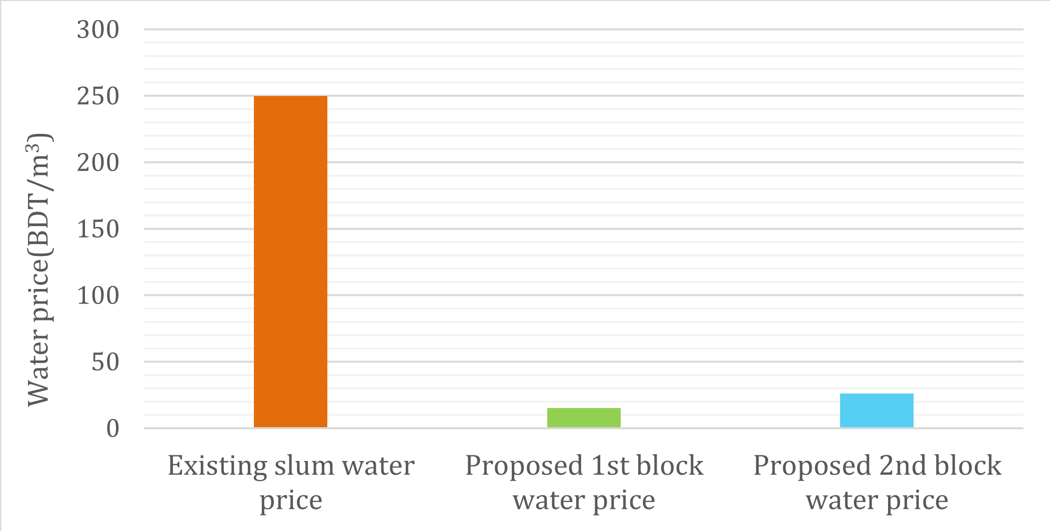

Figure 5.18: Differences between slum and proposed water price

The second point, provision of sufficient water can be better understood when it is compared to a slum with legal connection. Here the Baganbari slum has been chosen for this comparative analysis due to its legal water connection by DWASA (Table 5.14).

Table 5.14: Comparison of water issues with LIC slum

Existing water issues	Baganbari	Tejgaon
Type of water supply	Legalized connection from DWASA	Illegal connection from private vendors
Water price (BDT/m^3)	14.46	250
Average HH income (BDT)	5600	6440
Income spent on water (%)	1.3	8.0
Average water consumption (lpcd)	40	18

As shown in Table 5.14, even having comparatively low income, the dwellers of the Baganbari slum use about two times more water (40 lpcd) than the Tejgaon slum dwellers on average. The quantity of water consumption of the Baganbari slum dwellers has met the basic access standard (20 lpcd) of WHO (Howard et al., 2020) which indicates a significant impact of water price on the use. Thus, the lower first block price of the proposed pricing model can assist the slum dwellers in attaining the basic water access. In addition, they do not have affordability for luxurious water needs such as car washing, swimming pool and gardening, and they are highly habituated to consume less water (18 lpcd). So, the water limit of the first block (50 lpcd) would be enough for them to maintain a healthy and safe life. Therefore, from an equity point of view, the implementation of the proposed water rate contributes to improve the social equity.

To sum up, the proposed increasing block tariff model fulfills multiple objectives such as groundwater conservation, cost recovery of water supply and deduction of price burden of water from the low-income people and thus satisfies the three core principles of the IWRM. However, there are some challenges for implementation of this water pricing framework. Figure 5.19 presents the possible challenges and related solutions.

- The most important of these is the necessity to quantify individual household consumption as well as household size to allocate the consumption to the relevant block and allow customers to be charged at the rates according to their consumption levels and to be billed accurately. The lack of effective water metering in Dhaka city is thus an obvious barrier to the proposed water tariff's implementation. In this case, the solution can be drawn from the Israel metering practice where standard water meters are mandated by law for all wells, water producers, and consumers in the country. The metering and IBT form the basis of demand management which has been able to reduce the water usage by 26%. Moreover, the non-metered users can also be encouraged to install meter in their households either by provision of loan for sharing the meter installation cost or levying an additional fee to discourage their practice.
- In Dhaka city, DWASA provides legal water connection to the slums through NGOs which sometimes become unsustainable after accomplishment of the NGO project. In this case, supplying water directly through the community group like rural Barind Tract can be an efficient solution for this problem. In that area, Barind Multipurpose Development Authority (BMDA) supplies water where deep tube well maintenance and bill collection are maintained by the community management group. The community management group are directly supervised by the BMDA authority.

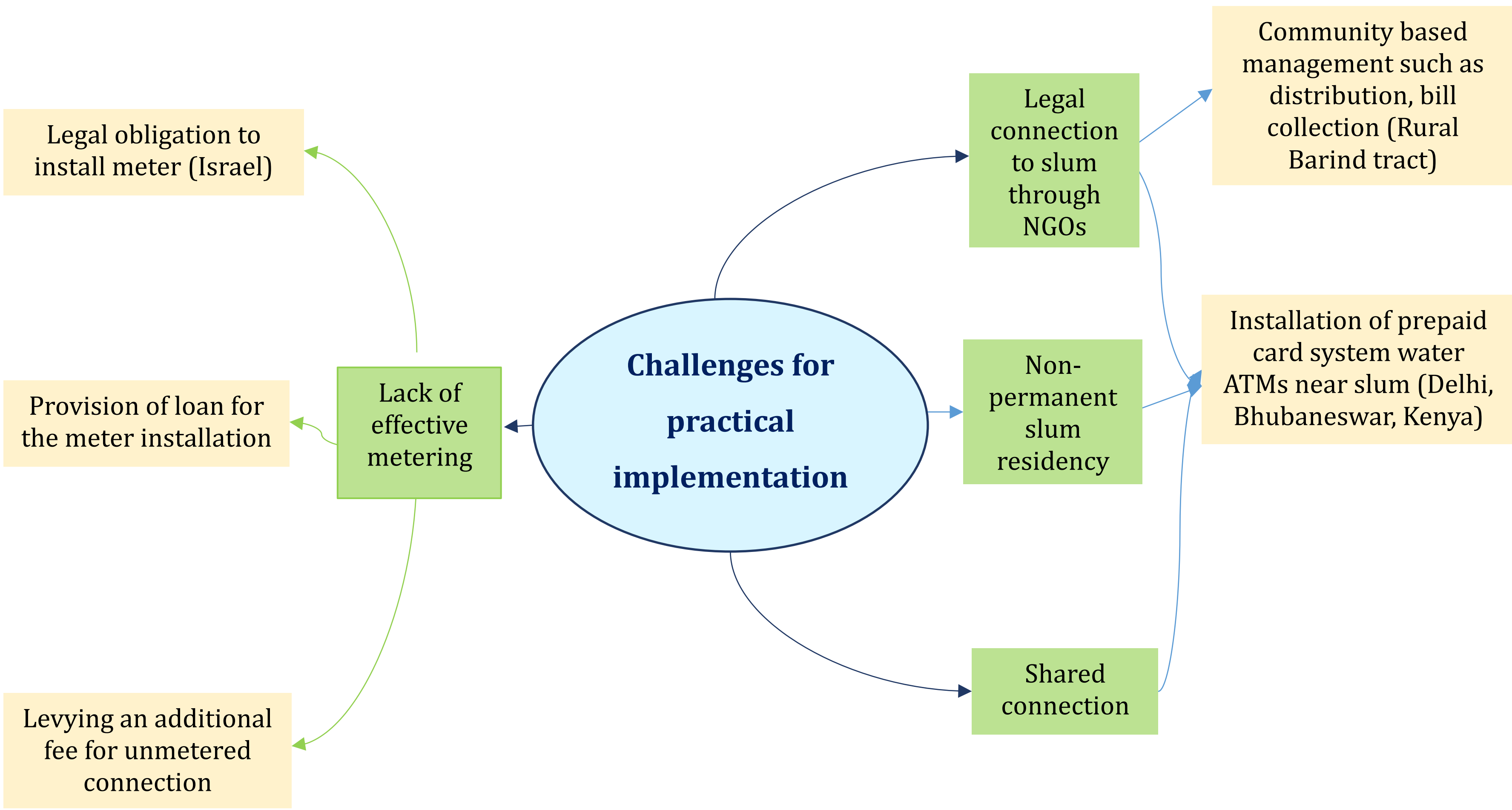

Figure 5.19: Possible challenges for implementing proposed pricing framework and recommendations

- On the other hand, slum dwellers sometimes find less interest in spending money for taking legal water connection due to their non-permanent slum residency. Also, in IBT, they are penalized for their shared water connection. In those cases, installation of Water ATMs near the slum can lead to efficacy. In many areas including Kenya, Bhubaneswar and Delhi, the slum dwellers collect water from nearby water ATMs using a prepaid card. The amount of water consumption is automatically updated in the water supplier database and billed accordingly. Recently, DWASA has established water ATM in the Fakirapool slum.

In conclusion, the technological innovation (standard meter installation and water ATMs establishment) needs a huge investment, but it can be recovered from the additional earned revenue from the implementation of the proposed water pricing.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Being non-renewable in nature, water is becoming scarcer in many regions because of growing population, rising incomes, and climate change. Water pricing is increasingly becoming one of the important policy tools to manage scarce resources more efficiently because of price-demand elasticity. Multiple objectives should be addressed by a well-designed water rate structure, including economic efficiency, equity, environmental and financial sustainability. In this context, this study proposes a water rate structure that integrates the three core aspects of IWRM: environmental criteria, economic efficiency, and the social concerns (equity and affordability). The specific conclusions drawn from this study are summarized below:

- The study slum is still excluded from the LIC scheme of DWASA. As a result, a group of businessmen works as middlemen to provide water from DWASA to the slum unethically at a higher price for their profit.
- The slum dwellers pay more than 17% higher price for buying the same amount of water (1000 liters) than the DWASA set price for domestic use**.**
- The average income of the slum dwellers is almost 7 times lower than the formal residents. The combination of high water price with low income forces the slum dwellers to spend about 8% of their monthly income for water on an average while the formal residents pay only about 1% of their monthly income for water.
- A single formal resident uses about 202 liters of water on an average. Contrarily, a slum resident uses an average of 18 liters of water to meet his/her daily demand which is even less than basic access standard (average water use per capita<20 liters).
- The insufficient water use is stirring up several inconveniences in the life of the slum dwellers, such as low drinking water consumption, improper bathing and

sanitation practice, water shortage related diseases and gender inequalities.

- Considering the improper water price practice, a new water pricing model is developed following an increasing block tariff strategy. The consumption limit of the first block is considered to be 50 lpcd in the proposed pricing model.
- The suggested unit price of water considers that the consumption in the first block covers the unit extraction cost while the volumetric rate in the second pricing block includes the cost of resource degradation externalities as a compensation for the high consumption.
- In Dhaka, DWASA provides water at a 5% subsidy on the unit water price set by the government or other donor agencies. If the subsidy is not deducted, the unit water price will be the same as the unit extraction cost of water (BDT 15.18). Therefore, the unit price of the 1st block is set to be BDT 15.18.
- The study considered four externalities relevant for the study area including two economic (increased energy consumption for the lifting of the water in the wells, and damage cost for the dryness of the wells), and two environmental (carbon footprint of water and health externalities) and evaluated in monetary terms.
- The total cost of the groundwater exploitation externalities is calculated as about BDT 443 M where the economic externalities share the major portion (about BDT 412 M). This cost of externalities for 1000 liters of water production is calculated as BDT 10.19 and therefore, the water price of the second block is suggested to be BDT 25.37.
- When the externalities cost is incorporated, the price of the water is estimated to be about 75% higher than the existing price. The extremity indicates the severity of the groundwater depletion in the study area.
- The proposed water pricing model satisfies the core principles of IWRM that can be summarized as follows:
    - ✓ From an economic point of view, DWASA can earn an additional 5% to 75% more income implementing the first and second block price respectively.
    - ✓ From an environmental context, the implementation of the proposed water pricing model can reduce yearly water consumption from 2% to 27% for the 1st and 2nd block users respectively. It can also reduce about 3710 MWH to 56160 MWH electricity consumption which will further decrease the greenhouse gas emission up to 37630 tons in a year in Dhaka city.

- ✓ Finally, from a social (equity and affordability) perspective, whenever water consumption is maintained in the first block, households could reduce its water bill by about 67%. Thus, the proposed water pricing contributes to cross-subsidy system that the large water consumers pay for the low water consumers. Moreover, one slum dweller can save from BDT 336 to BDT 352 in a month even if he/she uses 50 liters of water in a day which assures hygiene with a low risk of health concern.

- Finally, the study identifies some challenges for implementation of this water pricing framework such as the lack of effective water metering, legal connection to slum through NGOs, non-permanent slum residency and shared connection in the slum. It further mentioned some technology-based solutions including standard meter installation and water ATMs establishment near slum. Although the technological innovation needs a huge investment, it can be recovered from the additional earned revenue from the implementation of the proposed water pricing.

6.2. Recommendations for Further Study

Based on the present study, the following recommendations are made:

- The study has considered the groundwater externalities which occurred in the study area, but the externalities can vary from area to area. Hence, further study should be conducted on a larger scale to identify more diverse types of externalities.
- The result from the analysis would have been more representative if the sample size would have been larger.
- Future research should focus on refining the proposed model of water pricing and on developing the guidelines for implementing the model.
- Future study can validate the proposed pricing model in some other ways noted below:
    - ✓ Measuring the 'willingness to pay' of the water customers.
    - ✓ Incorporating the opinions of the water experts.

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APPENDIX A

SURVEY QUESTIONNAIRES

A Questionnaire on the research titled

'DEVELOPMENT OF A WATER PRICING MODEL FOR DOMESTIC WATER USES IN DHAKA CITY USING IWRM FRAMEWORK'

Demographic information:

Name		Sex	
Age		Occupation	
Residence location		Income	

Water consumption in informal settlements

- Number of family members ……………………………..
- How many pitchers of water do you collect every day?
  Ans.: ....
- Size of the pitcher (in liters): ……………………………………….

Assessment of the impacts of current price

- Monthly cost spent for water?
  Ans:
- What is your opinion about the current water price?
    1. High price but affordable
    2. High price but not affordable
    3. Low price
- If water price is high, what types of problems are you facing for this excess price?
  1. Low drinking water consumption
  2. Water shortage related diseases
  3. Dependency on another water source

4. Compromising with other water demands
5. Others (……………………………………………………………………………………………………)

- What type of water needs do you compromise to adjust with the high price?
  1. Bathing
  2. Sanitation hygiene
  3. Menstrual hygiene
  4. Drinking water consumption
  5. Others (…………………………………………………………………………………………)
- How much water do you drink in a day?

  Ans.:
- Do you take bath every day?

  1. Yes 2. No

  If no, kindly mention the interval of bathing.

  1. 1 day
  2. 2 days
  3. 3 or more days
- What type of water-shortage related diseases are you (or your family members) suffering from?
  1. Diarrhea
  2. Itching
  3. Kidney diseases
  4. Constipation
  5. More than one

Estimation of cost of health externalities in informal settlements

- Do you suffer from water shortage related diseases?

  1. Yes 2. No
- How much money do you spend for the treatment of above-mentioned water shortage related diseases in a month?

  Ans.:

APPENDIX B

SOME PHOTOS FROM FIELD VISITS

Photo B1: Sub-standard housing condition in the Tejgaon residential area

Photo B2: Water point-1 in the Tejgaon slum


Photo B3: Water point-2 in the Tejgaon slum


Photo B4: Water point-3 in the Tejgaon slum


Photo B5: Water point-4 in the Tejgaon slum

Photo B6: Water point-5 in the Tejgaon slum

Photo B7: Water point-6 in the Tejgaon slum

Photo B8: Water point-7 in the Tejgaon slum (closed at present)