Dynamics of Household Water Insecurity and Poverty – Drivers and Implications: Experiences from Dhaka Urban Riparian Areas

In partial fulfillment of the Requirements
for the Degree of Doctor of Philosophy

By

Md. Abdul Khaleque

Registration Number: 134/2016-2017

Session: 2016-17

Department of Development Studies
Faculty of Social Sciences
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DECLARATION

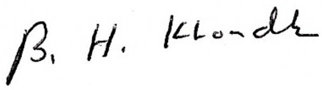
I do hereby declare that this dissertation entitled "Dynamics of Household Water Insecurity and Poverty – Drivers and Implications: Experiences from Dhaka Urban Riparian Areas" has been composed by myself and all the research works presented herein are my own. I do further declare that this work has not been submitted anywhere for fulfilling any academic degree. The research follows the ethical guidelines set by the Central University Research Ethics Committee (CUREC) of the University of Oxford.

(Md. Abdul Khaleque)

Dhaka, 2021

CERTIFICATE

This is to certify that the research work presented in this dissertation titled "Dynamics of Household Water Insecurity and Poverty – Drivers and Implications: Experiences from Dhaka Urban Riparian Areas" is carried out by Md. Abdul Khaleque bearing Registration No. **134/2016-2017** under our supervision. To the best of our knowledge, the work presented here is original and suitable for submission as a dissertation of fulfilling the degree of Doctor of Philosophy (Ph. D.).



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Author

Dedicated to

My Beloved

Wife

Shamema Nasrin

Son

Sadeem Ayaan Shaan

&

Daughter

Aisha Alaiya Safreen

List of Abbreviations

ADB	Asian Development Bank
BBS	Bangladesh Bureau of Statistics
BGMEA	Bangladesh Garments Manufacturer and Exporter Association
BOD	Biological Oxygen Demand
BUET	Bangladesh University of Engineering and Technology
CBN	Cost of Basic Needs
COD	Chemical Oxygen Demand
DHS	Demographic and Health Survey
DO	Dissolved Oxygen
DoE	Department of Environment
EKC	Environmental Kuznets Curve
EPI	Environmental Performance Index
ETP	Effluent Treatment Plant
FAO	Food and Agriculture
FGT	Foster, Greer, and Thorbecke
GDP	Gross Domestic Product
GSP	Generalized System of Preferences
HCI	Headcount Index
HIES	Household Income and Expenditure Surveys
IDMVS	Institute of Disaster Management and Vulnerability Studies
IRWR	Internal Renewable Water Resource
IWFM	Institute of Water and Flood Management
JMP	Joint Monitoring Programme
LPL	Lower Poverty Line
MDG	Millennium Development Goal
MICS	Multiple Indicator Cluster Survey
MoF	Ministry of Finance
MoEF	Ministry of Environment, Forest, and Climate Change
MPI	Multidimensional Poverty Index

ODK	Open Data Kit
OLS	Ordinary Least Square
OOP	Out-of-pocket
OSWC	Open-source Water Contact
PLI	Pollution Load Index
PG	Poverty Gap
PSM	Propensity Score Matching
PSCORE	Propensity Score
RME	Relative Margin of Error
RMG	Readymade Garments
SDG	Sustainable Development Goal
SD	Standard Deviation
SE	Standard Error
SPG	Squared Poverty Gap
TDS	Total Dissolved Solids
UNCED	United Nations Conference on Environment and Development
UPL	Upper Poverty Line
VIF	Variance Inflating Factor
WSI	Water Security Index
WASA	Dhaka Water Supply and Sewerage Authority

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ABSTRACT

Population, economy, and environment are very closely related to each other. Economic activity generally involves the usages of factors of production which are mostly supplied by households, firms, and the environment. Socially unjust usages of environmental resources may cause environmental hazards which can affect health of the populations forcing them to bear unwarranted expenses. Urban areas are the hub of industrialization which has accelerated economic growth and allow increased contribution of urban people to GDP, national savings, employment, and poverty alleviation. In Bangladesh, greater Dhaka is surrounded by the rivers like Buriganga, Balu, Sitalakhya, Dhaleshwari, and Turag. Review of existing literture suggests that health of those rivers is deteriorating day by day, but studies are scanty in showing the relationship between water insecurity and the welfare of the communities in riparian areas. Since many people are dependent on water bodies in urban areas for their livelihoods, and the quality of river water affects the health and productivity of the working people of neighboring communities, this study aimed to understand the state of water insecurity in Dhaka urban riparian areas and the possible effects of such water insecurity on health, productivity, and the overall welfare. We followed a quantitative approach and data was collected through household survey. A total of 1826 households from the twelve survey points of Turag riparian areas were drawn using systematic random sampling. The research followed the ethical guidelines set by the Central University Research Ethics Committee (CUREC) of the University of Oxford.

The study showed that most of the households collected their water from motorized tube-well, deep tube-well, and piped water for drinking purposes within 10 minutes. Only 2.47 percent of households in the survey areas used open-source water for drinking purposes. Members of 28 percent of the households used open-source water for other purposes like bathing, washing utensils, cleaning clothes, and livelihood. It was found that the members of the poorest households had more contact with open-source water and the contact intensified when the source of improved-water was shared by a group of people. The binary regression results revealed that the higher distance of the household from the improved-water source enforced the households to use open-source water for various purposes. Similar effect was observed for a high price of improved-water, whereas education and experiences reduced the odds of using open-source water.

The exposure to open-source water created health burdens to the households. Diseases like skin disease, gastric, ulcers, and dysentery were high among the users of open-source water and they had to spend additional Tk. 321 ($3.9) per month as treatment cost compared to non-users. Among the users of oper-source water, the sickness of the household members reduced their working days by around 4.48 days per month. Overall, the results revealed that the tendency to use open-source was higher among the disadvantaged and marginalized people, and this increased illness, reduced productivity, increased treatment expenditure, and raised poverty significantly. Hence, it was recommended that sufficient improved-water should be made available at a minimum distance, and at a minimum cost.

Chapter 1

Background of the Study

1.1 Overview

Bangladesh, a country of 147,570 square kilometers with 1063 people per square km and a per capita income of USD 1909[1] (MoF, 2020), is called the motherland of rivers, nearly 700 rivers crossing within its territory having the length of around 24,140 km and have the most populated river basin where around 6 million people live (Kolås et.al., 2013). During 1977-2001, on an average, the country had a total internal renewable water resource (IRWR, henceforth) of 105 cubic km per year with a per capita IRWR of 732 cubic meters and a total natural renewable water resources of 1211 cubic km with the trans-boundary annual river flow of 1106 cubic km (FAO, 2002). The country has a tropical monsoon climate: a favorable condition for rainfall. The average national rainfall was around 2375 mm for the period 1958 to 2017 with a minimum rainfall of 2063 mm and a maximum rainfall of 2634 mm. Ponds, rivers, lakes, and streams are important sources of available freshwater. The

[1] In fiscal year 2018-19, the per capita income was USD 1909 and for fiscal year 2019-20 the target was set to attain USD 2079 and the projected per capita income is USD 2326 for fiscal year 2020-21

ample freshwater, mild tropical climate-induced rainfall, and fertile land favor agriculture and the economy of this region developed as an agrarian economy (Lesser 1988) . Before 1971, the country was a part of Pakistan, known as East Pakistan. In 1971, the country achieved independence and started to fight against hunger. The flood of 1974 exacerbated the hunger scenario and then political unrest hindered the development path. In sum, the 1970s was a period of post-war social, political, and economic unrest in the country with limited resources and the primary level of institutional setup[2].

Over the period 1968-1972, the major income came from agriculture: agriculture contributed near about 60 per cent to GDP which declined to around 49 per cent, on average, throughout 1975-1979. During 1980s, the average growth of real GDP was near about 3.32 per cent with an average per capita GNP of around 794 taka [3]. In 1990-91, the annual GDP at constant factor cost estimated at 3.34 per cent[4] in which agriculture, forestry, and fishing constituted around 28.4 per cent of GDP whereas the contribution of manufacturing was 12.5 per cent. In 1999-2000, the GDP growth rate stood at 5.27 per cent in which the contribution of industry increased to 14.8 per cent whereas that of agriculture, forestry and fishing declined to 24.6 per cent. In 2010-11, the sectoral contribution of agriculture, forestry and fishing declined to 18 per cent and that of industry increased to 17.8 per cent. In 2015-16, the contribution

[2]In 1970, the GNP size was estimated at USD 450 crore (exchange rate $1=BDT 7.28) or equivalently 3276 crore taka with a per capita GNP of around USD 50-70 and high unemployment rate of 25-30 per cent. The contribution of broad agriculture sector to GNP was around 59.4 per cent and the contribution of broad industry and service sectors were 6.6 per cent and 34 per cent respectively. Agriculture had the first lead share, service had the second and industry had third. The ADP size was close to 501 crore taka of which 75 per cent came as foreign aid. In between 1969 and 1972, the average export earnings was approximately USD 42 crore of which majorly came from the single product jute which contributed around USD 27 crore, around 65 per cent of export. [Daily Prothom-Alo, Friday, December 16, 2016 (page 13) based on interviews of Jahid Hossain, Lead Economist, World Bank, Dhaka]

[3]1972-73 was the base year. The per capita GNP was estimated at constant factor cost.

[4]Base period 1995-96=100

of manufacturing was estimated around 20.7 per cent and that of agriculture, forestry and fishing at about 16 percent [5]. Albeit the sectoral contribution of agriculture, forestry and fishing to GDP is declining, still now, it is the predominant sector for creating employment of around 47 per cent of the total labor force.

In increasing the contribution of industry to GDP, the textile industry (RMG, Textile, and Knitwear) has the predominant roles. Before 1971, most of the textile firms were owned by West Pakistani and hence, after liberation, the country lost textile related capital and technical expertise. The strategy of import-substitution and nationalizing industries did not work for industrial development and soon after the adoption of export-oriented industrialization policy and denationalization process encouraged new entrepreneurship. There were only nine "export-oriented" garment manufacturing units in 1978 and in that year, Bangladesh first exported 10000 shirts to a Pakistani firm. The realization of growth potential and relevant government policies like duty free import machinery and raw materials, bonded warehouse facilities and cash incentives soon after helped grow the number of garment and textile industries.

In 1984-85, in total 384 garment factories operated and opened up the scope of employment of 0.12 million labor. Up to 1990-91, the growth of garment factories was slow but a linear momentum was observed at least up to 2012-13. With the growth of garment factories, the employment size also grew linearly in that period. In 2012-13, the number of garment factories increased to 5876 and over 4 million workers were employed in that sector. Currently near about 20 million people are directly and indirectly benefited

[5]In 2015-16, the GNP size was estimated to be USD 113.21 billion (five year average exchange rate $1=78) or equivalently 8830.5 billion taka with a per capita GNP of USD 1465. The ADP allocation was 97000 crore or USD 1243.6 crore of which 35 per cent came from foreign aid. In 2014-15, the export earnings was USD 31209 million of which 96 per cent came from industrial products, majorly from RMG, knitwear, and home textile.

from RMG (BGMEA, 2018). The growing sector soon after started faceing some challenges like the child labor issues, working conditions at factory, and various binding constraints imposed by foreign importers limiting the growth of the sector.

During the shift of national growth wheels, cities/urban areas play the important roles in Bangladesh. Industries are mostly urban centric and mostly Dhaka and Chattogram centric. Riverbanks were the business centers at the early stage and subsequently became important sources of environmental capital and important sources of growth of various industries. The labor-intensive agrarian economy shifted to labor-intensive manufacturing and service economy. The industrialization strategy, a shifting from exuberant dependence on agriculture or a shift from agrarian economy to small scaled manufactured economy, is often considered to be the development strategies for better economic growth and human welfare. But such strategy is not costless and the growth scenario is not endless rather it has some limits.

Some specific industries often directly uses some environmental capital like water in their production process directly and dispose the industrial wastewater in the environment like water bodies or air and such disposal alters the nature of water bodies causing water pollution, hampering human welfare and the ecosystem. The urban centric industrialization process has accelerated the sector specific and overall economic growth and increased the contribution of urban people in various economic indicators like GDP, national savings, employment, and so on. The process has lifted many people out of poverty but putting significant stress on environment to supply fresh air, water and hence forced to absorb pollution. Like other Asian mega-cities, finding solutions to maintain growth and development is directly underpinned by protecting its water ecosystems that supply water to industry, communities and agriculture.

Dhaka, the major manufacturing hub and the capital of the country lies on the lower reaches of Ganges Delta, has a population over 20 million and the urban population is growing at the rate of 4.2 per cent (McGee, 2006).

Dhaka, the major manufacturing hub and the capital of the country, lies on the lower reaches of Ganges Delta, has inhabitants over 20 million and the population in urban areas is growing at faster rate, 4.2 per cent annually. The greater Dhaka is surrounded by the five big rivers like Buriganga, Meghna, Sitalakhya, Dhaleshwari, and Turag. The urban based especially Dhaka based, strong export oriented garment industries flourished in 20th century. The recent statistics showed that the garments of Dhaka contributed over 19 billion USD in the export volume. The Government of Bangladesh has taken several initiatives to ameliorate the water security at urban areas with the support from public and private partners. The booming Bangladesh economy sheds auspicious light on expanding earning through the expansion of Readymade Garments (RMG) sector. The sector leaders has planned to increase the annual revenue to USD 50 billion by 2021. The RMG sector is heavily dependent by and large on environment and is a source of employment of many unskilled workers. Among the workers, a part of them live near to and interact with the river systems adjacent to the industrial settlement. This industry contributes around 75 percent of export earnings of Bangladesh and has already helped lift millions of families out of poverty.

Water security index (WSI) indicates Bangladesh is the 44^{th} out of 48 countries. Although Bangladesh has abundant of water but sometimes some parts of the country suffer from acute seasonal water scarcity. The supply shortage and deteriorating water quality due to pollution is threatening the water security. Moreover, poor water governance, high level of wastage in water supply lines, poor quality and toxicity of water, arsenic and salinity problems of the country are exacerbating the overall as well as the household water security. The overuse of agricultural land, increasing industrial effluents, and climate change is affecting the water security of the country. After all, access to safe water is worsening day by day due to a set of socioeconomic and ego-physical factors: the rapid population growth; contamination by industrial growth and industrial uses of environmental resources; slumization; the improper and overuse of synthetic agricultural chemicals and pesticides; lack of proper monitoring and control, the indiscriminate disposal of municipal wastes, poorly designed flood control system, the water supply systems, drainage and irrigation works, lack of effective and adequate regulatory measures, and lack of institutional setup.

According to Asian water development outlook (2016), around 80 percent of wastes were being dumped into river in Bangladesh and around 250 industries were discharging chemical pollutants into the nearest rivers like the Buriganga and Sitalakhya. Around 4,000 tons solid waste and 22,000 tons tannery waste were mixing with water in the Buriganga River. The major pollution contributing industries in Dhaka were pulp and paper (47.4%); pharmaceuticals (15.9%); metals (14%); food industry (12.1%); and fertilizers/pesticides (6.6%).

Water security as a concept was highlighted in the Ministerial Declaration of The Hague in March 2000 and had been addressed as crucial crisis in the near future and so the global poverty reduction is keenly related with the improvement of water management. Water security has wider implications: a reliable water source is required for sustainable industrial and agricultural growth, which is very much needed for the sustainable ecosystem. The unplanned industrial growth and lack of effluent treatment have great impacts on the aquatic environment for neighboring community people who are sharing the same water resources, particularly for drinking, cooking, and bathing purposes. The continued rapid urban growth and expansion of Dhaka city in neighborhoods also raises questions about long-term water security for people of expanded areas who will consequently exposed and dependent on poor water. Water insecurity overtime appears as social dilemma (Abedin et..al., 2013) because of the wide-spread presence of arsenic in ground water, salinity in both surface and ground water in part of the country, and climate change induced disasters (Habiba et.al., 2014). Moreover, the issue is getting bigger because of increasing population growth, rapid urbanization, and increasing agricultural production (Webb & Iskandarani, 1998). In Bangladesh, the health condition and the capacity of the Turag and the Balu rivers have raised the question of safely absorbing the incremental point sources of pollution and the question has necessitated the improved monitoring and smarter policy to support the sustainable industrial and agricultural growth, that is growth not at the cost of environmental damage and public health impacts, particularly for the poor people relying on rivers for washing, bathing or cooking water, in particular for their livelihood.

The impact of Dhaka's dynamic and complex river systems to changing flow regimes, bulk abstraction and contamination from untreated sewerage, industrial effluents or water from upstream is poorly understood. Specifically, it is less understood about the health of rivers surrounding Dhaka whereas the major industrial settlements are growing on the banks of rivers or water bodies. So, industrial waste is becoming a major concern like other industrial economies. The less developed and developing countries are now on the move of getting industrialized. Therefore, the query "how river quality affects the health and productivity of the working people of neighboring communities" is an increasingly important question for government and the enterprises which rely on healthy workers to be productive and competitive in highly competitive markets.

River is the income source of fishermen, boatmen, and the government itself. The fishermen and the boatmen do contact with river for their livelihood purposes. Some farmers having land near to the bank of rivers have the contact with rivers for agriculture production purposes. Some people washes their business things in the water and some industries and firms use the river as the waste disposal center. Sometimes the poor and disadvantaged people are forced to contact with unimproved water for various purposes.

Access to safe water for drinking, cooking, bathing, and hygiene purposes is important and it is iterated in sustainable development goals. The government of Bangladesh aims to attain 100 percent safely managed drinking water services and sanitation services including hand-washing facility with soap and water by 2030. The baseline level of water stress, freshwater withdrawal as a proportion of available freshwater resources, is 3.79 which is expected to reduce at 3 within 2030. Various ministries are working to achieve the stated goals within the timeline. LGED has several ongoing project related to indicators 6.1.1, 6.2.1, and 6.4.2. The MoWCA has 2 ongoing projects related to SDG Indicator 6.2.1 which pertains to safely managed sanitation services.

How are poverty and water security interlinked? Soussan (2003) highlighted on the association between human welfare and water security and focused on secure and sustainable access to water resources of the poor in the entitlement framework and the governance conditions which dictates access. Health and welfare of the poor are closely associated with water security as the poor are the most vulnerable to water-related hazards like floods, drought, pollution, and so on.

1.2 Motivations of the Research

At the early stage of industrialization, it was hardly felt about the social cost of industrial production. Firm level production decision was broadly determined from the financial perspective. Conventionally, a firm aims to maximize profit by minimizing cost and maximizing output. Under perfect competition, a firm chooses its input in such a way that ensures the efficient level of output at the minimized costs. The inputs, having cost and limit of supply, are selected cautiously from profit maximizing point of view. But financially priceless inputs from entrepreneurs view, mostly environmental free resources, are selected and used without taking proper caution. When firms ignore the social cost of negative externality, engendered by their production, threaten the welfare of future generation. Not only the future generation, the current generation could also be affected by the negative externality. The negative externality should be internalized for ensuring better present and the upcoming future. Thereby, for better and equitable future, a sustainable development strategies ensuring inclusive growth and inclusive benefits should be adopted and followed.

Today, developed, developing and even less developed countries are thinking about green growth and green economy for sustainable and inclusive development. Meeting the need of increasing global population, automation, mass production of agriculture and manufacture items are essential. The valuable environmental resources, renewable and non-renewable resources, should be used in the production process in such a way that the industrial emissions do not hamper the environment much. The emissions should be recycled and the environmental resources should be kept all time usable.

The key motivation of this research is to decipher the relationship between the households of the community and the usage of open-source water in the

Dhaka riparian areas, the impact of the use of open-source water on health risks, productivity, and poverty. The discussion will relate the unidimensional, multidimensional, and water poverty .

1.3 Aims of the study

While scientific studies on water, water body, and water management are available in Bangladesh but studies are scanty in drawing relationship between water insecurity and human welfare. Most importantly, the water pollution is not natural. The growth hunching tendency often exploits excessive freshwater and discharged wastewater into rivers/lakes/canals without making any compensation of polluting the water and the air. This dissertation frames the water insecurity and the welfare of the households adjacent to the water-bodies. The simultaneous setting will help us to understand their complex interactions among social institution, economic institutions, and political institution.

1.4 Research Objectives

According HIES (2010), 4.01 percent of households collected water from unimproved source[6] which declined to 2.81 percent in 2016 (HIES, 2016)[7]. Around 5.25 percent of the urban households had to collect drinking water from unimproved source whereas in rural areas, 3.56 percent (HIES, 2010), and though the pattern change in 2016, urban 2.54 percent and rural 2.92 percent, still now around 5 million people are out of improved drinking water. The source of water for drinking purposes is predominantly important to ensure the im-

[6]Tap/supply water and tube-well are the improved sources of water. The unimproved water sources includes pond/ river/ lake, well/indra, water falls, and others.

[7]According to HIES 2016, 1.15 percent of households collect drinking water from pond/ river/ lake, 0.6 percent from well/indra/ water falls, and 1.07 percent from the non-specified sources

proved drinking water facility for all but the access to safe and improved water source for non-drinking purposes like bathing, hygiene, washing clothes, cleaning utensils, and even washing hand is also important as people often suffer from water-borne diseases. Kazi et.al. (2015) found that in the South-Eastern coaster belt of Bangladesh, the prevalence of water-borne disease has been induced due to climate change: incidence of water-borne diseases were diarrhea 35.71 percent, fever 23.8 percent, cholera 10.37 percent, dysentery 9.69 percent, skin disease 9.52 percent, typhoid 5.44 percent, malaria 3.4 percent. According to HIES (2016), 5.71 percent of the people suffer from diarrhea and 1.32 percent from scabies/ skin disease in the last 30 days whereas 2.42 percent of the urban people suffer chronically from skin diseases. The average out patient cost is estimated at BDT 378 in urban areas which is BDT 312 in rural areas.

Since one of MDGs was related to improved safe drinking water and an important component of MPI, the information about source of drinking water is available but the source of water for non-drinking purposes is not readily available. The water-borne disease does not occur not only from drinking water but also other usages of water. The issue of the usages of water for non-drinking purposes is very much important to mitigate water-related health risks and to improve well-being by reducing health risks.

1.4.1 Broad Objective

In a broad sense, this study aims to understand the pattern of usage of commons specially water-bodies in urban areas. Water-bodies are used by entrepreneurs and local people for different purposes. The industrial settlements are often seen on the banks of water-bodies. This influences the costs of production and production volume of the industry whereas the local people use the same environmental resources for livelihood purposes. It aims to decipher the relative significance of the usage of environmental resources (mostly water) for various domestic purposes in the Turag riparian areasand the effects of non-treated wastes of industries on human health and health expenditures and the potential social costs of non-environment friendly waste disposal.

1.4.2 Specific Objectives

The contribution of industry in GDP is increasing in Bangladesh and major contributions are coming from RMGs. The RMGs are heavily dependent on water. A significant portion of water, the precious environmental resource, is consumed for industrial purposes and this sector is employing the unskilled, semi-skilled and skilled workers, and yielding high productivity compared to other sectors. National statistics showed that a part of the households in the riparian areas had the contact with nearby open-source water mostly for non-drinking purposes.

a) Study the linkage between water security, attributes of the households, and ecology.

b) Study the linkage among health risks, productivity, out-of-pocket expenditure (health expenditure), and overall poverty in relation to the use of poor water (open-source water contact/ unimproved water use). That is, health risks of the people who are using water from unimproved sources, are affecting the productivity, the ultimate sources of income or welfare of the individual or nation, and affecting the overall poverty.

1.5 Research Questions

There is a valid question what are the sources of water for drinking and non-drinking purposes of the households. Since the urban poor people live in low-cost areas like slum, riverbanks, roadside, a little bit disconnected areas whereas the industrial settlements grow on banks of water-bodies to minimize waste disposal cost or to overuse of commons. Such interdependence of commons, industry, and local community raises the questions of how such interdependence affects the water security of the local people and how the welfare of the people are changed due to the negative externality of overuse of commons by industry. In particular, the question basically focuses on the incidence of water insecurity and the associated costs of contacting with or use of unsecured/unimproved water. Exposure to unimproved water has implication on health risks, illness, productivity, earnings, out of pocket expenditure, poverty, poverty dynamics, and overall well-being of the people.

To fulfill the research aims and objectives, the following key problems will be answered:

- To study the extent and way of the people come in contact with and use unimproved water sources for various purposes.

- Study the conceptual linkages among unimproved water source contact, human health and human welfare.

- Study the effects on household welfare like illness, diseases, productivity loss, and treatment expense due to contact with and use of open-source water for domestic and livelihood purpose, and study the poverty and poverty dynamics in relation to water related risks.

1.6 Research Hypotheses

At first, the perception is that the poor, marginalized, low-income, and geographically disadvantaged people sometimes, voluntarily or involuntarily, do contact with unimproved water sources and become dependent on those risky water for their livelihood, and domestic purposes. Although it is perceived that such exposure with unimproved water has some deleterious effects on human health which ultimately brings the concurrent effects on household welfare like poverty. Under the crude null hypothesis, it is presumed that in Bangladesh, the poor and low-income households have mere contact with such unimproved water, and do not use open-source water, and the exposure to open-source water has no significant effects on household welfare. More importantly, there is no gap in health risks, productivity, and poverty between the users and non-users of open-source water. If the average of a respective variabel of user of open-source water is presented by μ_1 and that of non-user is by μ_2,then the null hypothesis states that $\mu_1 = \mu_2$ and the alternative hypothesis becomes $\mu_1 \neq \mu_2$. The key hypotheses of this study are:

1. The null hypothesis H_o : there are no roles of socio-ecological factors in assessing the water insecurity of the households, and the alternative hypothesis H_1 : the socio-ecological factors have significant influence on water security of the households.

2. The null hypothesis H_0 : The water insecurity, the use of open-source water, has no effect on welfare of the households, and the alternative hypothesis H_1 : the economic cost of using open-source water is statistically significant compared to the non-users.

The variables-specific detailed hypotheses are discussed separately in the the relevant sections of the methodology chapter of this study.

1.7 Relevance

The study primarily deals with industry, households, and environmental issues, it will have relevance for those organizations or institutions governing households, industry, and environment. From the industrial perspective, BGMEA and MCCI can gain some idea from this study about the social cost of industrial production and therefore may take some measures to curb the social cost.

The DoE and MoEFC are directly the policy stakeholders of this study. The findings of this study is expected to contribute in formulating environmental policy related to water management. In broader perspective, the study will give a policy direction for achieving water related targets in SDGs and perspective plan of the country.

In SDGs, the government is envisioning a poverty and hunger free society having better access to drinking water and sanitation facilities, the idea of safe water among others includes freshwater for the sustainable management of natural resources. Since availability of freshwater is limited, the efficient use of water should be ensured at all levels for sustainable development and the water resources should be used at minimized social cost. Hence, this study has relevance at stakeholders and at policy level.

1.8 Contributions

This study aims to contribute in the knowledge of household level water insecurity and the likely effects of such insecurity on human welfare. In particular, the study aims to show the socio-ecological framework describes the water insecurity of the households and explains the water insecurity - health risks, water insecurity - productivity, and water insecurity - poverty relationship as well as the magnitudes of the impacts.

1.9 Limitations

The study covers a part of Turag river, from Kodda bridge to Damra bridge, as study areas and it did not consider the other important riparian areas in Dhaka. Although the study will reveal the scenarios of the respective variables in the other growing industrial areas in the riparian zones.The study therefore opens up the scope of broader study covering those issues in future by expanding the sample areas. The current study is cross-sectional in nature whereas access to resources, human health and welfare are dynamic in nature.

1.10 Outlines of various chapters

The dissertation contains in total eight specialized chapters. There are two key objectives of the study, and few research questions related to the stated objective. The research questions are studied for specific purposes using the REACH Household Survey (2018). A short description of the objective, objective-oriented resesearch questions, arguments of the analysis, and materials and methods used is given below:

Table 1.1: A summary matrix of research objectives, research questions, methods and analysis

Research Objective	Research questions	Arguments	Materials and methods
Study Objective 1: Study the linkage between water security, attributes of the households and ecology.	• To what extent and what ways, people come in contact with unimproved water sources. • What factors induce the people of such contact?	The first objective of the study is studied under the title 'Dynamics of water insecurity and water poverty of the households' in chapter 5. The discussion of this chapter focuses on the state of water insecurity, and the potential factors that are exerting pressures on it. The discussions are necessary to add and to fill the gap in the literature of how water insecurity is determined in socio-ecological framework.	The research questions related to the first objective of the study are studied using the REACH Household Survey (2018). The descriptive univariate, and bivariate tables are generated and analyzed. The binary regression models are also used to find the determinants of water insecurity, and water poverty.
Study Objective 2: Study the linkage among health risks, productivity, out-of-pocket expenditure, and poverty in relation to the use of open-source water.	• What are the likely impact of the use of open-source water on illness, and illness induced out-of-pocket health expenditure? • What is the relationship between use of open-source water and productivity of workers? • What is the aggregate effect of the use open-source water on poverty?	The second objective of the study is studied under the title 'The impact of use of poor water on health risks, out-of-pocket expenditure, productivity, and poverty' in chapter 6. The discussion of this chapter is important to know the economic cost of water insecurity on various welfare indicators of the households, and this will add value to the literature on economic costs of water insecurity.	The research questions related to the second objective of the study are studied using the REACH Household Survey (2018). The data inaccordance with research objective have been analyzed using the descriptive tables, correlation analysis, and regression analysis (OLS, Tobit, and Logit)

The outlines of this disseration is briefly described her. The first chapter elucidates the background, motivation, objective, relevance, rationale, and contribution of this study. In elucidating the background of the study, we have dealt with the current position, prior to covid-19 situation, the indicators like GDP growth, per capita income, hunger, Dhaka surrounding river, river health, water-source, and poverty. We have also shortly explained the motivation of the study. A bit detail discussion on objective and research questions has been done. Bangladesh is on the auspicious path of development with increasing and spectacular GDP growth rate, rising per capita income, declining poverty incidence but the downside scenarios are also there: the health of Dhaka surrounding rivers is very poor and the pressure on environment is augmenting. It is evident that people of the study areas are unsecured due to water insecurity and their welfare is influenced by the environmental resources especially water.

In chapter two, the detail conceptual issues related to this research work like defining water insecurity, the underlying theories, and the implications of water insecurity. The thematic reviews on the existing literature on riparian industrial growth, environment and poverty dynamics in the macro-micro framework considering production and consumption decision have been discussed in chapter three. This chapter will help us to understand what have been done and what are not known about industrial growth and poverty dynamics in the existing literature which will further invokes some research questions to be answered in this current study along with elaborate description of previous studies and analytical approaches.

Chapter three discusses the detailed research methodology. We have discussed the nature of the survey areas, the population, and the water-bodies surrounding the areas. The chapter covers the sampling frame, sampling design, sample areas, statistical analytical methods, and analytical tools.

The characteristics of the samples such as the location of the households, housing status, pattern of water usages, water security index, water poverty status, poverty incidence both at uni-dimension and multi-dimensions at household level have been stated in chapter four.

Chapter five describes the nature of water insecurity, the factors behind the water insecurity, and their significance by using descriptive and econometric approaches. The results suggesting that a variety of factors influences the decision of using unimproved water for various purposes.

Chapter six describes the impact of poor water on illness, out-of-pocket expenditure, productivity, and poverty. Chapter seven summarizes the findings of the research and draws specific recommendations for the relevant stakeholders and introduces some new research questions for future studies.

Chapter 2

Literature Review in Developing Theoretical and Analytical Framework of the Study

This chapter is related to the in-depth review of literature related to growth, environment, and poverty nexus. The review focuses on theoretical and empirical evidences on various nexuses such as growth and environment; growth and environmental degradation; health risks and water insecurity, productivity and water insecurity, poverty and water insecurity, etc. Although the key objective of this chapter to decipher the nexus between health, productivity, and use of open-source water in urban riparian areas, a wider understanding of water security and health from the micro and macro perspectives have been discussed.

The conceptual and theoretical aspects of the current research have been drawn based on the discussions in the literature sections. The conceptual framework, an analysis of the distinctions between concepts and of organizing ideas, help to know the way in which the research concepts are interlinked and how they are different. On the other hand, the theoretical framework, will give us the background of the inter-links among industry, environment, and household level poverty dynamics. The current research is complex in nature as it deals with the problems of the households, and the environmental resource management. The conceptual framework has been here developed to serve two purposes: (i) to understand the relationship betweem population and the environmental resources, and (ii) to understand how the environmental quality affects the welfare of the households.

2.1 Use and Implications of Water

2.1.1 Water as Goods

Water, the most indispensable natural resource for human (Solomon, 2010: 3 ; Koehler, 2008; Ashton, 2002) and in fact indispensable for all forms of life (Bates et.al, 2008, Young et.al, 2004), hence, is called life. Water is a renewable resource. It dissolves nutrients and transfers them to cells of living being. Water regulates global temperature, supports structure and removes waste products.

Water is an input, mostly acts as natural capital, to almost every production process: agricultural production is almost impossible without water, industry uses water for various purposes, and maintaining good ecosystem requires water. Water supports biodiversity, economic growth, the well-being of the community and it has cultural values (Jackson, 2006).

Water is abundant but freshwater is a finite resource (Kahrl, 1979 ; Al-Jayyousi, 2003). Globally, the total volume of water was estimated to be 1.386 billion cubic meter (Halder, 2002) of which 97.5% being salt water and 2.5 percent of water is fresh and majority of the freshwater is frozen and locked up in Antarctica, the Arctic and glaciers, and only 0.5 per cent water is available for drinking purposes (UNESCO, 2003).

According to the United Nations Conference on Environment and Development (UNCED, 1992), there are four principles of water. (i) freshwater is a finite and valuable resource (UNESCO, 2003; IWRM ; WaterSense ; FAO); (ii) it is essential to sustain life; (iii) it is important for development and environment; and (iv) water has an economic value in all its competing uses and should be recognized as an economic good. The other principles focuses on water management and development issues.

Around 71% of the earth surface is surrounded by water in seas, glaciers, lakes (salted and fresh), rivers, ice caps, ponds or others liquid body. Surface water, otherwise called freshwater, is found in streams, lakes, river, reservoir, and wet land. Natural stores of water in hydro-logical cycle [1] are oceans 97.41%, ice caps and glaciers 1.9%, ground water 0.5%, soil moisture 0.01, lakes and river 0.009% and atmosphere 0.0001% (Table 2.1).

Table 2.1: Distribution of freshwater on earth

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Sources of freshwater (estimate)	% of the total freshwater	Cumulative Percentage
Glaciers and permanent snow cover	68.7	68.7
Groundwater	30.1	98.8
Freshwater lakes	0.26	99.06
Rivers	0.006	99.066
Atmosphere	0.004	99.080
Biosphere	0.003	99.083

Source: Ganoulis (2009)

Water, although debates exist, is considered to be an economic good (Mc-

[1] Hydro-logical cycle or water cycle describes the continuous movement of water, above and below the surface of the Earth.

Neill, 1998 ; Rogers et.al, 2002 ; Savenije and Zaag, 2002). The optimal allocation of a private good, according to the standard economic theory, is determined in a competitive market environment (Aylward, 2009) but in case of goods like freshwater, the overall efficiency, simultaneous private and social efficiency, are hardly achieved, a sign of breaking the orthodox market efficiency condition, due to the common pool and public good aspect of freshwater. Assigning property right is hard to establish, due to its complex and multi-functional uses, it requires high enforcement and transaction cost (Aylward, 2009). Available and quality freshwater supply, a necessary condition for economic growth and development, hence, determines the activities in the major sectors like agriculture and industry. According to UNESCO (2003), globally, 8 per cent of the freshwater is used for domestic purposes and the remaining 92 per cent was used for industrial (22%) and agricultural (70%) purposes. The industrial usages of water was around 59 per cent in high income countries while it was 10 per cent in low and middle income countries. The global water consumption in 1980 was 1200 km^3 which increased to 1700 km^3 in 2016, around a 41.6 percent increase in demand for water globally (Table 2.2).

Table 2.2: Trends in global water demand

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Usages of water	1980	2016
Global Water Consumption	1200	1700
Inflexible water consumption	460	590
Irrigation purposes	85	140
Reservoir management	320	360
Thermal power generation	6.5	19

Source: Qin et.al. (2019)
Note: The figures are measured in ($1000km^3$). The inflexible water consumption includes agriculture, energy, and domestic sector.

The demand for water also increased in households, agriculture sectors, and inn power generation process. The production processes produce economic output and also produces some wastes which are being recycled or disposed of in the environment directly such as the natural freshwater systems like rivers and lakes thereby increasing the wastewater size and reducing the water quality. Consequently in the downstream areas, water does not remain usable without expensive treatment. Though environmental input directly benefits the society but sometimes it yields direct/indirect cost. Production of food, beverage, pharmaceutical and garment sectors consume water as an input which are used for human consumption. Goods, required water input, if, exported, is sometimes called the export of “virtual water” by the water experts.

2.1.2 Use of Water

Water is normally used for domestic, agriculture and industrial purposes. Agriculture and industry are the major user of water which used around 92 percent of world over and 8 percent for household purposes. Lu (2001) mentioned four major usages of water for domestic purposes: (i) consumptive use which in-

Figure 2.1: Water use at household level

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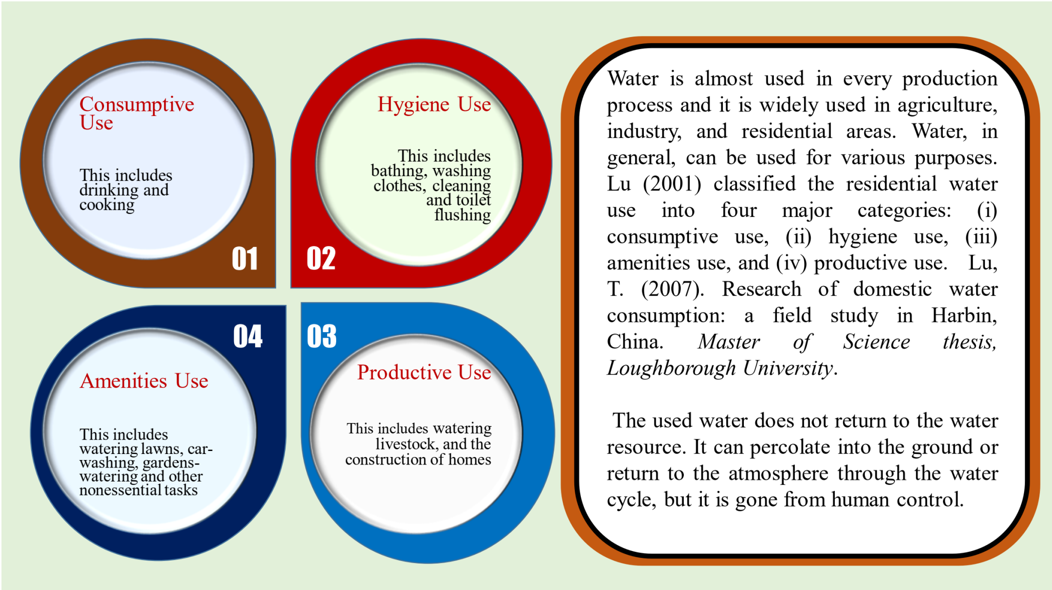

Classification of residential water proposed by Lu (2001)

cludes drinking and cooking purposes, (ii) hygiene use which includes bathing, washing, cleaning and flushing, (iii) productive use like livestock and house construction, and (iv) the amenities use like watering lawns, washing cars, watering garden and other non-essential purposes.

The four types of water used as proposed by Lu (2001) have been shown in Figure 2.1. Basic household water requirements have been estimated at around 50 liters per person per day, excluding water for gardens. The textile and the apparel manufacturing sectors require a high quantity of natural resources like water, fuel and various types of chemicals in completing its manufacturing processes (Dey and Islam, 2015).

2.1.3 Water security: Concepts and Measurement

Since the emergence of the concept 'water security' in 1990, it has evolved significantly. The concept of water security has got importance overtime because of its influence on individual, household, community, economy, society and the globe as a whole. Water security is also important for economic growth and development (Grey and Connors, 2009 ; Grey and Sadoff, 2007). The Global Water Partnership (2000) first defined water security simply as an overarching goal where every person has access to enough safe water at affordable cost to lead a clean, healthy and productive life, while ensuring the environment is protected and enhanced. Swaminathan (2001) then stated that water security involves the availability of water in adequate quantity and quality in perpetuity to meet domestic, agricultural, industrial and ecosystem needs. Cheng et al. (2004) subsequently defined water security to include access to safe water at affordable cost to enable healthy living and food production, while ensuring the water environment is protected and water-related disasters, such as droughts and floods, are prevented. Finally, Grey and Sadoff's (2007) defined water security as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies.

Bakker (2012) defined water security as an acceptable level of water-related risks to humans and ecosystems, coupled with the availability of water of sufficient quantity and quality to support livelihoods, national security, human health and ecosystem services—has been the object of increased academic and policy interest over the past decade.

Soussan (2003) explained water security as a condition where people and communities have reliable and adequate access to good quality water to meet the full range of their needs, able to take advantage of the opportunities that water resources present, protected from water-related hazards and have fair recourse where conflicts over water arise.

The concept has two sides: qualitative and quantitative. However, the quantitative nature will help us to understand the presence, absence, or degree of insecurity (Lautze and Manthrithilake, 2012). Several frameworks are used to assess water security (Zeitoun, 2011 ; Lautze and Manthrithilake, 2012; Mason and Calow, 2012 ; ADB, 2013, 2016; Lankford, 2013; UN-Water, 2014; Fischer et al., 2015; Sadoff et al., 2015). Zeitoun (2011) identified six elements of a water security web: (i) Human/Community Security, (ii) National Security, (iii) Water Resources Security, (iv) Food Security, (v) Energy Security, and (vi) Climate Security.

According to Lautze and Manthrithilake (2012), country level water security index should consider five indicators: (i) basic needs - proportion of the population with sustainable access to an improved water source; (ii) Food production – the extent to which water is available and harnessed for agricultural production; (iii) Environmental flows – proportion of renewable water resources available in excess of environmental water requirements; (iv) Risk management – the extent to which countries are buffered from the effects of rainfall variability through large dam storage; and (v) Independence – the extent to which countries are safe and secure from external threats.

The Figure 2.2 showed five key dimensions (KDs) in the ADB (2013, 2016) proposed framework of water security. The first one considers the household water security which includes water supply, sanitation, and hygiene. The second one is economic water security covers agriculture and industry sectors. The third dimension is urban water security which focuses on urban water management such as water supply, wastewater treatment, flood control, and river health. The fourth one focuses on river health and environmental governance, and the last one is resilience to water-related disasters.

Lankford (2013) proposed a two-dimensional framework for measuring water security constructed from "equity" and "sufficiency" indicators. UN-Water

Figure 2.2: Key dimensions of framing water security

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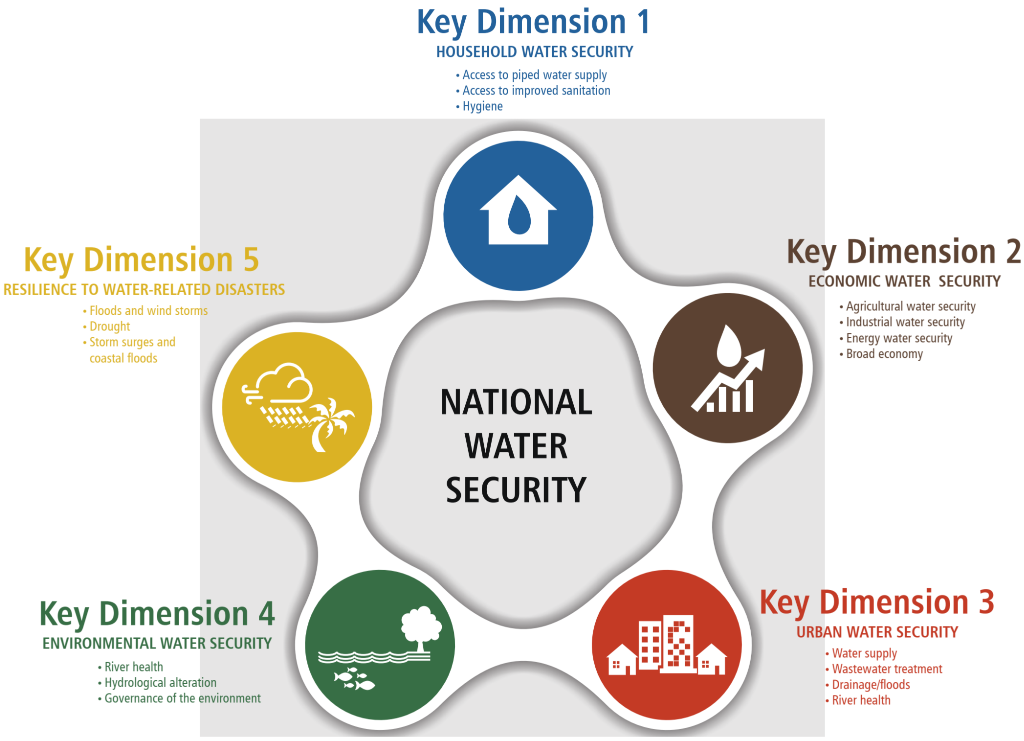

Source: ADB (2016)

(2014) focused five pillars to clarify "securing water". The first pillar was drinking water, hygiene and sanitation which was similar to the key dimensions of ADP framework, the second one was water resources, the third one was water governance, fourth one was water-related disasters and the last one considered wastewater pollution and water quality.

Fischer et. al. (2015) also used four indicators: (i) total renewable water resources per capita; (ii) the ratio of annual water withdrawal to total renewable water resources; (iii) runoff variability; and (iv) the ratio of external to total renewable water resources. Most recently, Sadoff et. al. (2015) proposed a set of indicators to quantify four headline risks: (i) droughts and water scarcity; (ii) floods; (iii) water supply and sanitation; and (iv) ecosystem degradation and pollution.

2.1.3.1 Affordability

Access to water for various purposes is related to the potential sources of water. River is an important source of water for agriculture and is also an important source of livelihood some specific households, households totally dependent on river-based resources. The river health determines the level of benefit and costs to the society.

Conceptually, affordability is not unequivocal. Someone calls it vague (Bradly, 2009) and someone calls it theoretically clear (Whitehead, 1991). Conceptually, affordability refers to capability to purchase a necessary commodity at certain quantity without suffering undue financial hardship (Kessides et.al., 2009). Some social impact analysis defines affordability as the 'burden threshold' of the household income or expenditure (Barrantes and Galparin, 2008). Affordability is a concern in providing public utilities as the escalation of price or the relative price of the utility in relation to income which can affect poor households negatively and the situations get worsen among the economically hardship households who are struggling to manage money to meet their essential elements like food, medicine, cloth etc. (Kessides et.al., 2009). The standard poverty headcount and poverty gap are used as a measure of affordability (Kakwani & Silber, 2008), but they are criticized (Miniaci et.al., 2008). The access to improved utility services or improved water source has an impact on non-monetary dimension of well-being (Corvalan et.al., 2005, Hunter et.al., 2009).

Affordability of the low-income group determines the access to safe and sufficient water. Cashman (2014) examines the nature of affordability at customer level and service providing level in the Caribbean. The author stated that in Caribbean, the concern of the ability of low-income households to be able to access sufficient water has been addressed through charging a fix amount for a volume of sufficient to meet basic water requirements 10-15 m^3 per month and after that level, the consumption has been charged progressively to discourage excessive usage. Alvarez et.al. (2018) identified affordability of water treatment and wastewater reuse as determinant of water security and similar concern is addressed by Global Water Partnership. (2000). Ahlers (2016) focuses on financialization, water governance (ownership, control, distribution, and affordability), and uneven development in analyzing the role of water sector.

The characteristics of household head, the person who led the household through making decision and contribution to resource base, determine many social, economic, and political problems. The household attributes also determine the water security at the household level. The attributes of the household head includes the age, occupation, and education whereas the household attributes includes the composition of the households, assets, ownership of equipment, and access to physical resources.

2.1.3.2 Accessibility

Accessibility is another dimension of water security. It means the ease and convenient access to water. It can be measured by distance from the water point or required time to collect safe water. For example, Wagah et.al. (2010) measures accessibility by the proportion of the households with access to adequate amount of safe drinking water in a dwelling or located within a distance of not more than 200 meter from a household to a public stand post. One can apply the gravity technique to measure accessibility as well. We have considered the time dimension of accessibility which implies single mode of transport to collect safe water and the available in a shortest time. We have used the term availability and accessibility interchangeably.

2.1.3.3 Sufficiency

The sufficiency of water implies that the households have enough safe water for all of its member for both drinking, cooking, washing, and bathing. In the broad sense, sufficiency implies, the households have enough water for all types of domestic works, agriculture work and even for industrial work.

2.1.3.4 Stability

The water insecurity, the reverse of water security, has three dimensions: adequacy, access and life style (Stevenson et.al., 2012) and it is associated with coping strategies and health risks. Basu et.al. (2015) pointed out that the coping strategies of water unsecured households were found impulsive, sensitive and largely stirred up by crisis and the water insecurity followed a complex vicious cycle: water insecurity pushed to contact with unsafe water, which increased the health risks and the economic loss due to poor health and poor productivity, and hence, water insecurity ultimately pushed rural livelihoods and domestic life to further deprivation and poverty. Mmopelwa et.al. (2014) also mentioned some short-term and long-term coping strategies during water insecurity like accessing untreated water, harvesting traditional rainwater, carrying and purchasing bulk water, and purchasing bottled water as opposed to adaptation. The households were abstracting groundwater, connecting storage tanks to main water systems and modern rainwater harvesting. The unsecured access to key resource was associated with physical, mental and emotional stress (Wutich & Ragsdale, 2008). The nature of coping varied by the household attributes like better off households invest in private water management like storing water in boreholes, storage tanks, and purchasing bulk water to tackle the water insecurity in a more sustainable way (Manzungu & Chioreso, 2012).

2.1.3.5 Water Governance

Water governance is an important component of water security as seen in the framework of water security. The water security governance has a wide dimension covering political, organizational and administrative processes. The governance describes how the interests of the community are articulated, how is their input incorporated, how are decisions made and implemented, and how decision-makers are held accountable in the development and management of water resources and delivery of water services (Bakker & Munk, 2003). The water governance has been increasingly recognized as a critical contributor to the long-term sustainability of water resources (Pahl-Wostl, et.al., 2012, Huntjens et.al., 2011). The social power is often considered as the central dimensions of water security debates as insecurity arises not only through poor management decisions, sub-optimal governance processes, insufficient science and evolving environmental pressures, but also through power relations, confrontation (whether violent or non-violent) and competition between political and socioeconomic interests with respect to land and water ownership and control (Bakker & Morinville, 2013).

2.2 Water Source and Water Infrastructure

The WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply and Sanitation compiled the coverage of improved water and sanitation[2] from

[2]An improved drinking-water source is defined as one that, by nature of its construction or through active intervention, is protected from outside contamination, in particular from contamination with fecal matter. JMP considers the use of (i) piped water into dwelling, plot or yard, (ii) piped water into neighbor's plot, (iii) public tap/standpipe, (iv) Tubewell/borehole, (v) protected dug well, (vi) protected spring, and (vii) rainwater as improved drinking water and the use of (i) unprotected dug well, (ii) unprotected spring, (iii) small cart with tank/drum, (iv) tanker truck, (v) surface water (river, dam, lake, pond, stream, channel, irrigation channel), and bottled water as unimproved drinking water. On the other hand, improved sanitation includes the use of (i) flush or pour-flush (piped sewer system,

various data sources like Demographic and Health Survey (DHS), Multiple Indicator Cluster Survey (MICS), Bangladesh Sample Vital Registration Survey, Maternal Health Services and Maternal Mortality Survey 2001, World Health Survey 2003, and HIES.

Table 2.3: Access to improved drinking water and improved sanitation

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Year	Improved Drinking Water (%)			Improved Sanitation (%)		
	Urban	Rural	Total	Urban	Rural	Total
1990	88	76	78	56	18	26
1995	87	76	78	54	21	28
2000	86	77	79	51	26	32
2006	85	78	80	48	32	36
2016	97	97	97	67	35	44

Source: WHO/UNICEF JMP (2016) and HIES (2016)

The Table 2.3 showed that the urban people used more improved drinking water source and improved sanitation. According to HIES (2016), around 97 percent of the urban and rural households had access to improved drinking water and around 3 percent of households were under the risk of unimproved drinking water. The sanitation scenarios improved both at rural and urban areas but the the urban scenario was promising than the rural.

The places, where the poor live, suffered from poor infrastructure, unavailability or low quality of services; were prone to crime, pollution, and are susceptible to drought, flood and landslides (Kakwani and Silber, 2007). The rural poor who migrated to urban areas start living, mostly hazardous and unhealthy ways (Stephens et.al, 1994 ; Stephens, 1996; Douglas et.al, 2008),

septic tank, pit latrine), (ii) ventilated improved pit latrine (VIP), and (iii) pit latrine with slab, and unimproved sanitation includes the use of (i) flush or pour-flush to elsewhere, (ii) pit latrine without slab or open pit, (iii) bucket o Hanging toilet or hanging latrine, (iv) public or shared sanitation facilities, and (v) no facilities or bush or field (open defecation).

in an overcrowded tenements, informal settlements (Mitlin and Satterthwaite, 2013). Water is used by every individual for drinking, cooking, washing and bathing purposes. People collect water from different sources like tube-well, tap, open-source (river/lake), etc. The industry also uses water as production input.

In an unregulated society, the industry mostly discharge their waste and wastewater into the nearby river/ canals/ lakes. Therefore, river and lake water can be contaminated by point and non-point sources. The important non-point sources of pollution for rivers and lakes are agricultural activity like usage of pesticide and fertilizer, urban storm-water runoff, seepage and surface run-off of septic tank effluents and individual disposal systems. Although majority of the households uses supply/ tap/ tube-well water for drinking purposes and very few percentage of the household uses water from pond/ river/ canal/ well/ waterfalls, in absolute number, according to HIES (2010), 5.8 million people use water from pond/ river/ canal/ well/ waterfalls. There is no data related to the usages of water for bathing and washing.

Figure 2.3: Distributions of Households by Sources of Drinking Water
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Sources of water	HIES (2010)			HIES 2016			Census (2011)	
	N	R	U	N	R	U	N	U
Supply/tap water	10.6	1.47	35.6	12.0	2.14	37.3	8.1	37.4
Tube-well	85.4	95.0	59.2	85.7	94.9	60.2	89.1	59.5
Pond/river/canal	0.94	1.27	0.05	1.15	1.5	0.36	1.7	-
Well/Indra	0.99	1.29	0.15	0.47	0.53	0.32	0.7	-
Water Falls	0.08	0.11	0.01	0.13	0.14	0.09	-	-
Others	2.00	0.89	5.04	1.07	0.8	1.76	0.5	3.1

Source: HIES (2010) and Census (2011)
Note: N=National, R=Rural, and U=Urban

Both HIES (2010, 2016) and Census (2011) showed that households mostly collected drinking water from tube-well. According to HIES (2016), tube-well was the major source of drinking water for 85.7 percent of the households of the country, 94.9 percent of the rural households, and 60 percent of the urban households. Supply or tap water was the second important source of drinking water in urban areas: 37 percent of the urban dwellers used supply/tap water for drinking purposes. Households collected water from open-sources like pond/river/lake, well/indra, and water falls: nationally 1.75 percent of the households, in rural areas 2.17 percent of the households, and 0.77 percent of the households in urban areas.

2.3 The Economic Growth and Environment

2.3.1 The Growth and Environment

The nexus between growth and environment was bidirectional: first, environment contributes in economic growth which contributed in reducing poverty, and second, the growth might have two roles: the complementary role where economic growth cared of environmental quality, and the conflicting role where maintaining growth and exerting more growth created pressure on environment and hence degraded the environment. In the paper, "Economic Development and the Environment: Conflict or Complementary?" Beckerman (1992) widely discussed the relationship between economic growth and environment.The author analyzed the scenarios of water supply, sanitation, health condition, and air pollution in developing countries, in two-periods, 1980 and 1990.

Trade driven growth or growth driven trade whatever the direction, trade and environment are interlinked. The idea can be explained by the two hypotheses: (a) pollution haven hypothesis, and (b) porter hypothesis (Frankel

& Rose, 2005). The pollution haven hypothesis stated that some country adopted lax environmental standards to attract foreign investment and so export pollution intensive goods, and others adopted high standards and import pollution-intensive goods, in short, this hypothesis stated that environmental regulation will move polluting activities to poorer countries (Eskeland & Harrison, 2003). Cole (2004) described it as the displacement of dirty industries from developed countries to the developing regions. Taylor (2004) explained the theory behind pollution haven hypothesis, and empirical evidences have been tested by Aliyu (2005), Dietzenbacher & Mukhopadhyay (2007), Wagner and Timmins (2009), Kearsley & Riddel (2010), Millimet & Roy (2011), and Akbostanci et.al. (2007). The Porter hypothesis presumed that the tightening of environmental regulation stimulated technological innovation and thereby had positive effects on both the economy and the environment. It suggested that environmental policy improved both environment and competitive use of environmental resources (Xepapadeas & Zeeuw, 1999 ; Desrochers, 2008 ; Rexhäuser & Rammer, 2014), benefits the affected firms (Ambec & Barla, 2002; Mohr, 2002, Desrochers, 2008) through product design and corporate morale (Liston & Heyes, 1999), and enhanced total factor productivity (Lanoie et.al., 2008) by fostering innovations (Mohr & Saha, 2008). But tighter environmental policy was not costless: it increased costs conditioned on a given level of sales, and thereby, it lowered profitability (Rassier & Earnhart, 2010).

Figure 2.4: Environmental Kuznets Curve

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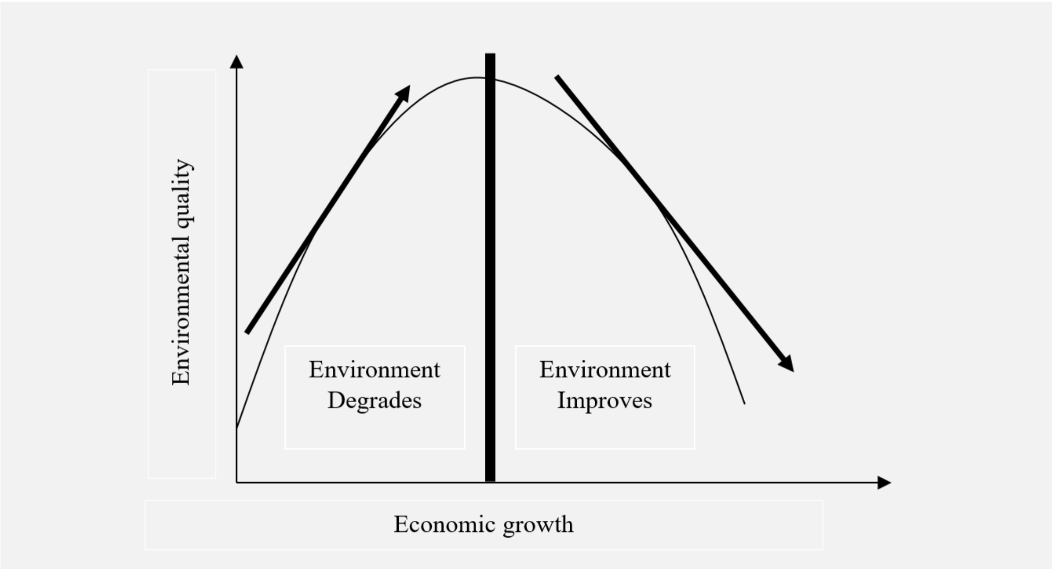

Source: Everett et.al. (2010)
Note: This is a modified Kuznets curve, mostly used in environmental applications

The Environmental Kuznets Curve (EKC) (Figure 2.4) showed that at the early stage of development or at low level of income per capita, pollution control or abatement is not stringent for the sake of meeting their basic consumption needs in a resource limit stage. Once a targeted better stage of income or living standard achieved, the concerns of trading-off between environmental quality and level of consumption arise and after that level individuals prefer better quality of environment to further consumption, over the targeted consumption. The environment protection policies along with economic growth policies, therefore, will contribute in reducing environmental degradation or damage (Beckerman, 1992, p 482). The shape of EKC can be explained by the technology, non-friendly technology at earlier stage and environment friendly technology at the advanced stage latter can be called the green technology, by changing the human behavior, switching the preferences. The EKC and modified EKC can further be elaborated from the development-environment linkage perspective. At low level of development, the degree of environmental degradation is expected to be quite low due to limited quantities of biodegradable wastes as a result of subsistence resource-based economic activities but at the middle-stage of development, the state of industrial economies, intensive extraction of resources and the process of industrialization accelerate the depletion of non-renewable resources and waste generation. Finally, in a well-informed society, with more efficient and green technology, the preference bias to environment will lead to a low degradation (Panayotou, 2003, p. 1-2) .

Panayotou (2003) stated that at the per-industrial economies, the environment will possess a high degradation tolerance rate and after that the economy reaches in industrial economies stage where the environment reaches in a state of tolerable range of degradation and will help to achieve high development or growth. The achievement of high growth, therefore, will make individuals realizing the preference for green environment for sustainable development.

Grossman and Kruger (1991, 1995) found the Kuznets curve pattern for urban air pollution. Hilton and Levinson (1998) also found the U-shaped relationship for automotive lead emissions and Bradford et.al. (2000) found some evidence of the environmental Kuznets curve for arsenic, COD, dissolved oxygen, lead and SO_2.

2.3.2 Economic Growth, Industry, and Environment in Bangladesh

Bangladesh got the independence in 1971 and followed a socialist economic system by nationalizing industries but underwent a dawdling growth of fundamental factors of production specially the labor force like experienced entrepreneurs, managers and administrators (Lesser, 1988). Bangladesh had minuscule of foreign exchange resources, the banking and monetary systems were mostly at the primary level and had large unskilled workforce. The 1970s was a period of post-war social, political, and economical unrest in the country and the 1980s was a period of founding, building, and developing the social, political and economic institutions in the country. In the early 1990s, the Bangladesh economy commenced on the increasing path of economic growth with occasional ups and downs in the rates of economic growth.

In the early 1990s, the Bangladesh economy commenced on the increasing path of economic growth with occasional ups and downs in the rates. In 1990-91, the annual growth of real GDP was only 3.34 which tended to increase to 5.04, a 1.7 percentage point increase. But the gain in growth of real GDP did not sustain and tended to decline two successive periods and reached to 4.08 in 1993-94. One interesting feature of the growth of real GDP in between 1990-91 to 1993-94 is that the initial gain in growth of real GDP has declined but it does not go below the growth rate of 3.34 in 1990-91. The growth of real GDP increased from 4.08 in 1993-94 to 4.93 in 1994-95 and again this growth did not sustain and consequently declined to 4.62 in 1995-96. It is noted that the economy converges to the growth which is a little bit close to the growth of real GDP in 1991-92, a period of high growth (Figure 2.5).

During 2001-05, the average GDP growth was 5.5 per cent which tended to reach at 6.2 per cent during 2005-10. In the last three fiscal years, the average GDP growth rate was somehow constant on an average as during 2010-13 the GDP growth was about 6.3 per cent. The increasing average rate of GDP growth now has been slowing down and, in fact, the actual year to year GDP growth rate showed a downward trend. Therefore, it is really challenging task to maintain relatively high economic growth and even it is more challenging to have higher growth in future. The low population growth has contributed

Figure 2.5: Trend of GDP growth rate in Bangladesh

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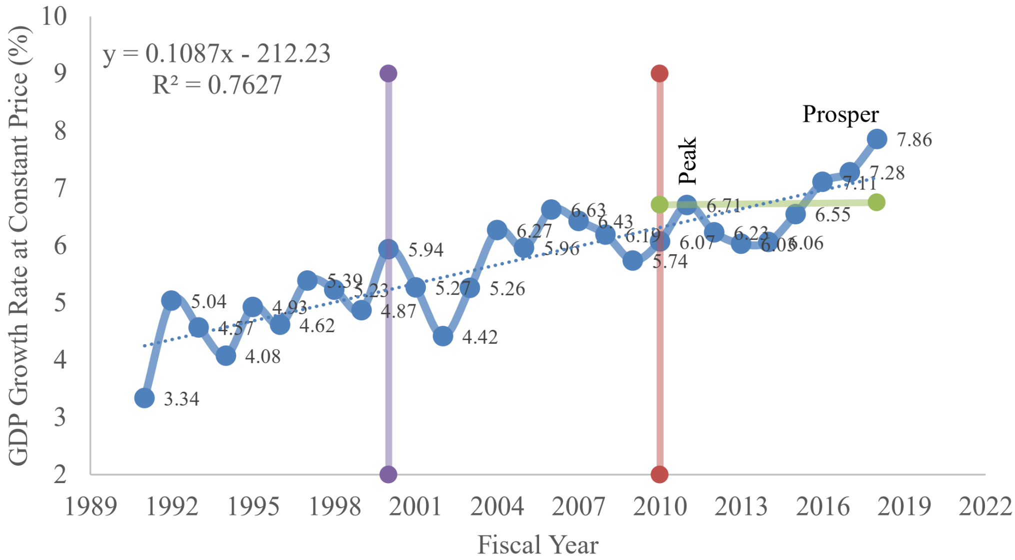

Source: Publications of MoF in various years in between 1990 and 2020.

in the growth of GDP per capita. Some new initiatives are required to move back the economy on the upward trend line (Figure 2.5).

The three major sectors of Bangladesh economy are: agriculture, industry and service sectors. Although the agriculture sector is growing at a slower rate than the industrial and service sectors, it has been maintaining a stable growth rate. The growth rate of the service sector is also more or less close to 5.5 percent but the growth rate of the industry sector is increasing and is increasingly contributing to the GDP.

The current contribution of agriculture and forestry is around 15 percent which is expected to prevail by 2021 as well. Then, service and industry sector are expected to take the lead in wheeling the economy. By 2021, the major contribution to GDP is expected to come from service sector and the manufacturing sector. We foundthat the contribution of manufacturing sector, a part of industry sector, is keeping its increasing rate of contributing to the

GDP which is expected to accelerate overtime and to reach 28 percent by 2021.

Ready-made Garments (RMGs), the major export earning industry (Ali, 2008) of Bangladesh, is contributing over 80 per cent in total export earnings (BBS, 2016; Bangladesh Bank, 2016) or foreign exchange earnings (Kabeer and Mahmud, 2008) and is the important contributor of GDP. In 1982-83, the sector had a contribution of only 1.1 per cent to the total export which grew to 79.63 per cent in 2013-14. The spatial contextualization of industries especially RMGs indicates an urban centric industrialization due to better infrastructural facility or transportation facility, management opportunity, and better opportunity of access to finance and utility facilities.

The Economic Census of 2003 showed that around 37.4 per cent of the industrial establishment and 48 per cent of total industrial employment were in urban areas whereas the urban areas covered only 7.2 per cent of total area of Bangladesh (BBS, 2003). The growing urbanization in Bangladesh increases the number of economic establishments in urban areas in absolute size from 1,386,418 to 2,257,980 but the number of economic units grows faster in rural areas (Economic Census, 2013). The industrial activities are concentrated mostly in large urban centers, for example, of the 532 urban centers of Bangladesh, the top 10 urbanized districts covers around 58 per cent of industrial establishments and 67.4 per cent of urban employment (Hossain, 2011). The top three districts are Dhaka, Narayanganj, and Gazipur.

The Greater Dhaka Urban Region alone comprises one-fourth of industrial employment (BBS, 2008) and of three million off-farm employment in Greater Dhaka Urban Region, nearly 40 per cent were engaged in manufacturing industries (ADB, CUS, 2010). Around 9.7 per cent of industrial establishment and 16.8 per cent of employment were in Dhaka alone. More than 60 per cent of large manufacturing industries were in Dhaka, 20.8 percent in Narayanganj and 9.6 percent in Gazipur respectively. In large manufacturing industries, the employment share in Dhaka, Narayanganj, and Gazipur were 52 per cent, 26.6 per cent and 17.6 per cent respectively.

The spatial concentration of large manufacturing industries in Greater Dhaka Urban Region in 2005 was depicted in the above map. Almost half of the manufacturing industries were located in Dhaka Metropolitan Areas and the concentration in Narayanganj was ranked second and Gazipur as third. In Tangi and Gazipur, the concentration of manufacturing industries is along the Dhaka – Mymensingh and Dhaka – Tangail highway (Figure 2.6).

The growth of industries in the core city was negative but in periphery it was significantly positive. From 2004 to 2009, the growth rate of large industries was 2.3 per cent per year and growth of employment was 4.1 per cent (BBS, 2010). In Dhaka central, the growth rates of large industry and employment was low, 2.3 per cent and 1.9 per cent respectively, while in Gazipur and Narayanganj, that were high and more than twice than the average of the region.

Figure 2.6: Distribution of large manufacturing industries in Greater Dhaka Urban Region, 2005

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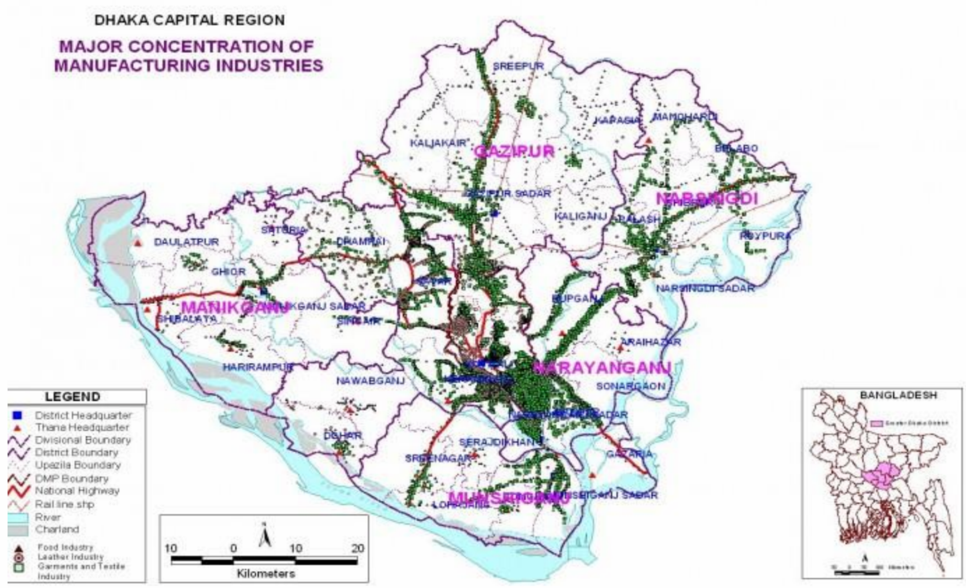

Source: CUS 2010

In 2009, half of the large industries, in RMGs and Textile industries sectors, the number being of which around 8970 approximately: 4484 textile industries with employment of 0.46 million and 4486 RMG industries with employment of 1.77 million (BBS, 2010). Most of the textile and RMG industries were located in Dhaka (around 60 per cent), Narayanganj (nearly 8 per cent), and Gazipur (around 17 per cent) (BGMEA, 2008). The locations of textile and RMG industries have been shown in Figure 2.6.

After 1995, the locations of industries shifted from city centre to the north, west and east of core city. There were only 50 firms and a few thousand of labor in RMG sector in 1980 (Kabeer and Mahmud, 2004). In 1984-85, there were only 384 factories in RMG sectors and in 1985-86, the number of RMG factories increased to 594, almost 1.55 times higher than 1984-85. The number of firms increased sharply in 1990-91, almost 6.13 times higher than 1984-85.

The number of firms continued to increase up to 2012-13 and reached at the maximum, 5876, in 2012-13, then it tended to decrease and reached 4328 in 2015-16. The number of firms decreased from 5876 in 2012-13 to 4222 in 2013-14 (Table 2.4). The reduction in firms could be due to the GSP suspension by US and concurrent industrial turmoil.

Table 2.4: Number of firms/factories in RMG and its growth

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Year	Actual Number of Firms	Growth of firms (%)	Growth Multiples Compared to 1984-85 (%)	
			Average	Actual at
1985	594	23.16		1.55
1990	834	18.4	1.75	2.17
1995	2353	12.28	2.31	6.13
2000	3480	6.67	1.47	9.06
2005	4220	4.76	1.26	10.99
2010	5150	4.41	1.23	13.41
2015	4328	-8.55	0.81	11.27
2018	4621	2.02	1.06	12.03

Source: BGMEA (2018)

The collapse of Rana Plaza in April 24, 2013, and the failure of Bangladesh government in ensuring safety for workers induced by USA to suspend the GSP. Since the GSP facilities provided by US do not include the RMG sector, the economic cost of GSP suspension by USA was not too much but the fear of GSP facilities suspension by EU made the garment sector shake as the GSP facilities provided by EU include the garments, the major export earning items in Bangladesh.

After the significant reduction of number of factories in RMG sector of Bangladesh and the fear of GSP facilities suspension by EU, the number of

Figure 2.7: Employment and directly benefited population from RMG

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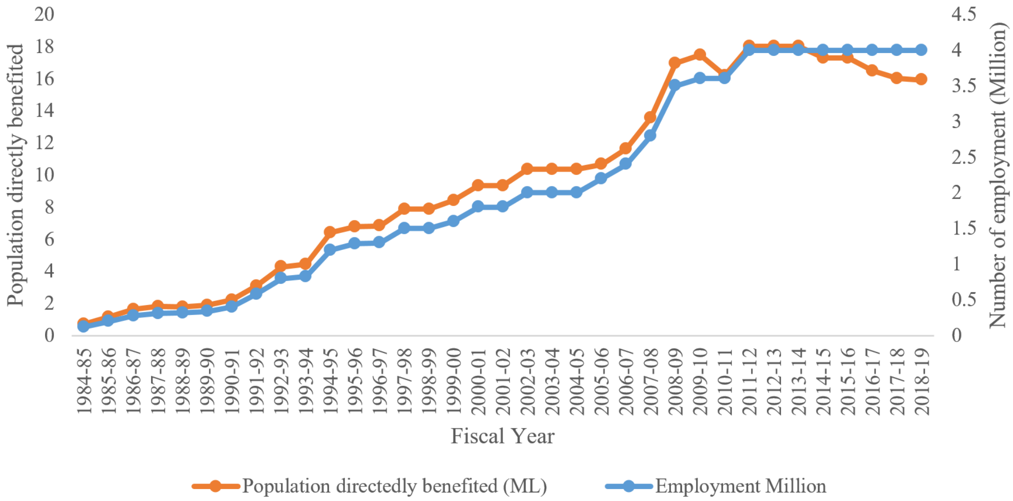

Source: Drawn by author (Data Source: BGMEA, 2018)

employment, the total number of people directly benefited from this sector, and the trend of alleviation of poverty felt the potential threat in achieving the MDG goal of eradicating extreme poverty.

The trends of total employment and the directly benefited population have been shown in figure 3.6. The primary vertical axis measures the number of people directly benefited from this sector and the secondary vertical axis measures the number of employees in this sector. Although the sector started creating a few thousand of employment, later on, it became the major places for industrial workers especially for women workers (Kabeer, 2000 ; Islam and Zahid, 2012). In 1984-85, there were around 0.12 million employees were employed in RMG sector and near about 0.7032 million were directly benefited from these employment (Figure 2.7).

The Figure 2.7 shows that during 1980s, this sector employed labor slowly but in 1990s, and 2000s, the rate of employment were relatively high, though almost linear, than 1980s. In between 2004-05 and 2009-10, the employment level was steadily increasing than other periods, consequently, the number of

Figure 2.8: Total export, RMG exports and its share

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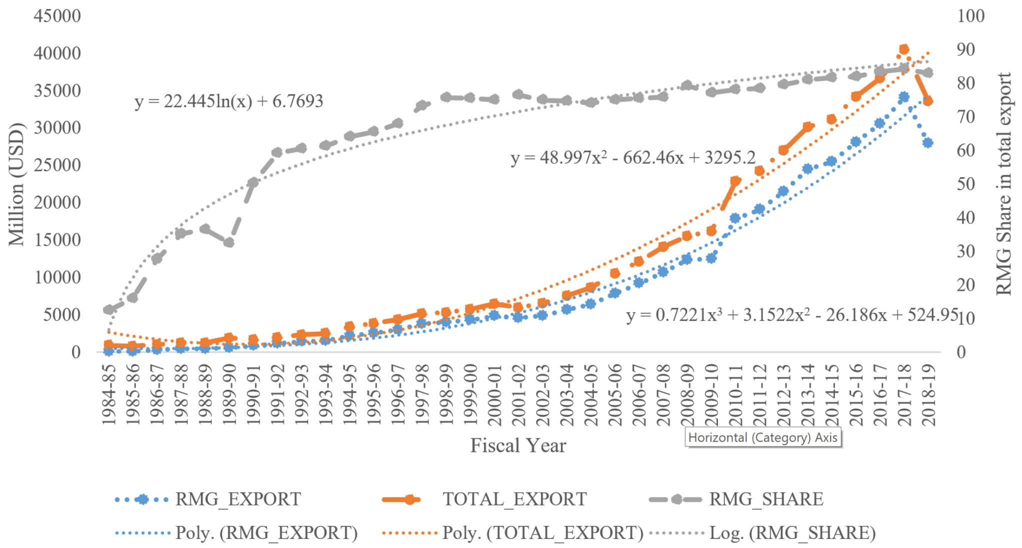

Source: Drawn by author (Data Source: BGMEA, 2018)

directly benefited people increased to around 17.5 million in 2009-10. Currently, directly or indirectly, near about 25 million people are reaping benefits from this sector (Rashid, 2013).

Since the employment size remained stagnant at four millions and the size of directly benefited from this sector slightly decreased due to the reduction of average household size . The unprecedented contribution of this sector in enhancing the overall women empowerment scenario is well-acknowledged and the sector will continue to help in achieving some important goals in SDGs.

The drastic reduction in number of firms in RMG sector did not influence on number of employees in this sector, but it has broken the trend and in fact, it has plateaued near about 4 million. Therefore, the stagnation of labor growth and the reduction of factories are expected to have eventual effects on RMG exports and total exports. The trends of RMG exports, total exports, and the share of RMG exports in total exports have been shown in Figure 2.8.

Bangladesh started with low level of exports and in 1983-84, the export earnings were below USD 1000 million. The total export earnings grew slowly before 2002-03 and after that it grew increasingly. In general, the total export earnings increased at an increasing rate over time. The increasing export earning is largely due to the exponential growth of RMG. Although in 1983-84, the contribution of RMG to total export earnings was about 12.4 per cent which stood at over 82 per cent in 2015-16.

The share of RMG to total exports grew logarithmically. Bangladesh, the second largest apparel exporter in the world, has been witnessing a steady growth in apparel manufacturing and exports. It is expected that the current USD 28 billion plus garment industry will help to achieve a two-fold increase in export in the next three-five years and The sector is supposed to contribute nearly USD 50 billion in the export volume by 2021 (Minister of Ministry of Industries, Second Apparel Summit, February 25, 2017).

Study from Cambodia by Yamagata (2006) discussed how and why export-oriented garment industry contributed in alleviating poverty. Based on 164 sample companies, the author concluded that entry level labors received wages above the poverty line and as most of female got employed, the opportunity of unemployed labor force and the direct contribution of women, contributed to in reducing poverty.

Keane and Velde (2008) discussed on the role of textile and clothing industries in growth and development strategies. They argued that the workers in textile and clothing industries were getting higher wages compared to the available employment opportunities for them.Water is used for domestic, agriculture and industrial purposes. Agriculture and industry is the major user of water. It is estimated that 15% of worldwide water use is for household purposes. These include drinking water, bathing, cooking, sanitation, and gardening. Basic household water requirements have been estimated at around

50 litres per person per day, excluding water for garden. The textile and the apparel manufacturing require a high consumption of natural resources like water, fuel and various types of chemicals in completing its manufacturing processes (Dey and Islam, 2015).

Table 2.5: Water Consumption and Corresponding Effluent Generation in Various Processes of Textiles in India (L/100kg)
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Activities	Water Consumption (KL/Day)	Volume of Effluent (KL/Day)
Sizing/slashing	50-820	50-80
Desizing	250-2100	250-2100
Bleaching		
a) Yarn (hypochlorite)	2400-4800	2250-4600
b) Yarn (H_2O_2)	2400-3200	2250-3050
c) Cloth (hypochlorite)	4000-4800	3800-4600
d) Cloth (H_2O_2)	1700-3200	1700-3200
Mercerizing	3600-17000	3500-17500
Dyeing		
a) Yarn (Light & medium shade)	3600-4800	3500-4700
b) Yarn (dark shade)	4800-6400	4700-6300
c) Yarn (very dark shade)	6600-8800	6500-8700
d) Yarn (Light & medium shade)	7800-9600	7700-9500
e) Yarn (dark shade)	10400-12800	10300-12700
f) Yarn (very dark shade)	14300-17600	14200-17500

Source: Garrett, Shorofsky & Radcliffe; Das, 2000

In Bangladesh, Dey and Islam (2015) showed that at low level of production, the volume of effluent was low and increased with an increase in production. The high level of production required high level of water consumption and generated high level of effluents. Mostly due to low efficiency produces a significant amount of wastes which are disposed, either directly or partially treated, in the environment, thereby, causing environmental damage which is exacerbating day by day due to lack of environmental management like lack of effluent treatment plant (ETP) and lack of appropriate waste management. The Table 2.6 showed that textile was responsible for big level of water pollution and the pollution product of textile industries was estimated 3.35 mg/L. The second most polluters were leather and sugar. Both sector polluted the water at extreme level. The third major sector which polluted the water most was agriculture. The paper industry was the fourth water polluter, and transport and construction were the low level of water polluters.

Table 2.6: Major polluters in Bangladesh

Industry	Water Pollution	Pollution Product (mg/L)	Ranking
Agriculture	Moderate	1.08	3
Textile	Big	3.35	1
Transport	Small	0.02	6
Construction	Small	0.14	5
Paper	Very big	0.67	4
Leather	Extreme	1.88	2
Sugar	Extreme	1.72	2

Source: Dey and Islam (2015)
Note: The pollution product is measured in milligrams per liter (mg/L).

RMGs are the source of foreign exchange earnings and major source of industrial employment. The one side scenario is very optimistic and the other side rather opposite. It can be argued that the growth in industrial sector is at the cost of environmental degradation which is eventually affecting the sustainable goal. The scenario is quite apparent if we consider the environmental resource used in textile and apparel sectors.

The sectors is not only using huge amount of resources but also it is using them inefficiently. Nearly 1700 fabric producing factories, the wet processors, each consuming 300 liters of water to produce one kilogram of fabric which is over six times higher than the international practice. Over 1500 billion liters ground water is annually consumed by the sector which is even higher than the total water demand by the residents of Dhaka (Anas, 2015).

2.3.3 Bangladesh at Environmental Performance Index

A measure of the score on environmental performance index rank and score of 180 countries about 24 performance indicators and several critical issues covering environmental health and ecosystem vitality etc have been jointly prepared index by Yale University and Columbia University in collaboration with the World Economic Forum. Based on the 2020 Environment Performance Index Report, the Table 2.7 showed the score and rank in various indicators of Environmental Performance Index (EPI) for Bangladesh.

The Table 2.7 shows that Bangladesh was the 162^{th} among 180 countries. Bangladesh's worst performance was in water resources having zero score. In term of fisheries, Bangladesh's performance was quite good. Although the MDGs performance in water and sanitation, and drinking water was much lauded, the EPI gave Bangladesh rather disappointing marks. The Sustainable Development Goals (SDGs) endeavor to make all three areas, economy, society, and the environment, priorities for development. Bangladesh's opportunity in achieving development in a sustainable manner is quite challenging. The initiatives for institutionalization and the enforcement characteristics can enhance the access and use of environmental resources efficiently.

Table 2.7: Score and rank of Bangladesh at Various Indicators of Environmental Performance Index (EPI)
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Issue Categories	Rank	Score
Environment Performance Index	162	29.0
Environmental Health	159	33.5
Air Quality	166	20.2
Water & Sanitation	129	27.3
Heavy Metals	129	27.3
Ecosystems Vitality	143	22.4
Biodiversity & Habitat	124	46.8
Fisheries	22	19.6
Climate change	140	35.6
Water Resources	134	0.0*
Waste Management	117	5.0
Ecosystem Services	147	22.8
Agriculture	54	49.9

Source: Environment Performance Index (2020)
* Many countries are at this rank having zero score.

2.4 Deprivation: A Focus on Poverty

2.4.1 Uni-dimensional Poverty

Poverty as a concept is not simple, rather it is complex (Danziger, 2001) and the complexity is widening with shifting from uni-dimensional to multidimensional concepts or from the static to dynamic phenomenon and with dissecting the scenarios by location like rural, urban, and many more. It is a social, political, and economic phenomenon (Alcock, 1997).

Although there is no general consensus about poverty among sociologists, politicians, and economists, in a wider sense, poverty can be considered as social exclusion (Hagenaars, 1986; Dagum, 1989; Sen, 1992; World Bank, 2001) arising from lack of resources (Callan et.al., 1993). In a simple sense, poverty is "pronounced deprivation in well-being" where well-being primarily implies the command over commodities. The individuals or households who do not have enough income to maintain an adequate minimum threshold or cannot maintain the consumption level to some adequate minimum threshold.

In term of subjective judgment, poverty implies lack of food, lack of shelter, lack of access to healthcare facilities, lack of access to specific rights, etc. According to Amartya Sen (1987), well-being is derived from a capability to function in society and thereby, poverty arises when people lack key capabilities, such as inadequate income or education, or poor health, or insecurity, or low self-confidence, or a sense of powerlessness, or the absence of rights such as freedom of speech. Hence, poverty is considered as a multidimensional phenomenon (Ferreira, 2011; Bourguignon & Chakravarty, 2003).

The first step in measuring poverty is the identification and measuring a welfare indicator. Most popular welfare indicators are calorie, income or consumption per capita: calories as indicator focuses on the items an individual consumes as food item and when non-food items are mostly overlooked. The income indicator is considered as less reliable as the potential tendency of people is to under-report the income information.

The selection of welfare indicator is important. While most of the rich countries measure poverty using income as most of people generate income from wages/salaries, the most of the poor countries use expenditure as in less-developed countries income is typically hard to estimate as much of income comes from self employment activities (agriculture or non-agriculture), while expenditure is a little bit straightforward and hence is easy to estimate (Khandker, 2009).

Calories consumed per person per day are sometimes considered as indicator of poverty and the notion is that adequate nutrition is a prerequisite for a decent level of well-being. Later on, the cost of basic needs (CBN) method has been used. The method estimates the cost of acquiring sufficient food for having adequate nutrition usually 2,122 Calories per person per day and then adds the cost of other non-food items like spending on clothing, utilities, education, and shelter.

In the second step, we have to establish a minimum acceptable standard of that indicator, the poverty line, to separate the poor from the non-poor. Therefore, the measurement of poverty is dependent on the welfare indicator and the poverty line.

Although the officially two types of poverty lines are estimated and households are classified broadly into three categories – non-poor, poor, and extreme poor, but based on expenditure we want to classify the households into three categories – non-poor, moderate poor, and extreme poor.

Households will be classified as extreme poor if the per capita expenditure becomes lower than the lower poverty line. Households will be considered as moderate poor if the per capita expenditure is above lower poverty line but below the upper poverty line and households will be non-poor if the per capita expenditure becomes above the upper poverty line. This classification will mutually classify the households into the above four categories.

2.4.2 Multi-dimensional Poverty

Poverty, in a true sense, is multifaceted and thus multidimensional. The single income based or consumption based poverty is not adequate to explore the state of poverty. The multi-dimensional poverty index considers the deprivation in health, education, and standard of living.

Money-based poverty measure is no doubt important, but deprivations in other dimensions can not be overlooked. Multi-dimensional poverty index (MPI), a composite measure of the deprivations that the people face at the same time, reflects both the incidence of multidimensional deprivation, and its intensity – how many deprivations people experience at the same time.

2.4.3 Poverty Dynamics

The indicators are affected by two sets of variables namely exogenous variables and endogenous variables. Alternatively, the indicators can be affected by the endowment sets and exogenous set to individual or household. The variables could be from households, from the community, and from the entire environmental space. The endowment set originates from the household/individual that may contain endogenous and exogenous variables and the variables from outside the household will be treated as exogenous. In the dynamic setting, households are categorized as chronic, movers, fallers, and always better off group.

2.5 Dhaka Urban Riparian Areas

2.5.1 Riparian and Welfare Changes in Dhaka

Dhaka, the capital of Bangladesh, has some glorious stories of development. It has expanded geographically and economically. With its growth horizon, a series of changes has been occurred politically, socially, and economically which are presumably contributing to the changes in culture, behavior, norms and beliefs. The city was earlier known to us as the "City of Mosques", later on, the "City of Gardens", and very recently, "the City of Trade and Commerce".

The commercial and industrial or business activities in a city are most of the times as old as the city.

Dhaka City has a four hundred years old story to tell. In the process of the development of Dhaka city, the role of river cannot be overlooked. In course of time, the river health has deteriorated. The physical, chemical and microbiological composition of river water has been altered and the rivers have lost their suitability for any safe and beneficial use. The signs of contamination have become obvious in taste, odor, and color. The blink scenario is observed in terms of the decrease in the number of aquatic animals and vulnerable nearby ecosystem.

Generally, surrounding rivers of Dhaka are now known to us for their excessive pollution nature. The pollution is due to several factors like the discharge of untreated industrial effluent, disposal of urban wastewater and sewage water, and massive encroachment, solid waste dumping, sedimentation, encroachment etc. Industrialization has increased and the location of industrial settlement has shifted from the center Dhaka. The RMG industry has grown and the associated sector dyeing, washing and textiles have also been grown. Very recently, the tannery industry shifted from Hazaribagh to Savar. The chemical, dyeing and textile industries are important source of river water pollution in Dhaka (Hasan, 2011).

There is no doubt that Dhaka city lacks systematic waste management process. Almost in everyday, around 60,000 m^3toxic wastes and7000 tons solid wastes are disposing to surrounding Dhaka city. Textile industries annually discharge as much as 56 million tons of waste and 0.5 million tons of sludge, and tanneries discharge around 7.7 million liquid wastes and 88 million solid wastes (Islam et.al., 2015).

In Dhaka, around 0.4 to 0.7 kilograms of solid waste per capita per day is generated but the per capita waste collected per day is 0.2 kilograms (Islam & Rahman, 2002). The waste which is not managed by the Dhaka City Corporation is dumped into the rivers (Hasan, 2011). Furthermore, untreated liquid waste is being poured in the rivers (Hasan, 2011). Of the discharged untreated liquid waste, 61 percent is industrial and 39 percent domestic (Roy, 2009).

Encroachment on rivers is a common practice in Bangladesh and such practice is damaging the natural drainage system (Hasan, 2011). Encroachment, mostly through unauthorized construction and dumping of solid waste in violation of regulations, make it difficult to drain out the runoff and the pollutants (Mahmood et.al., 2017). Hossain et.al. (2016) estimated that in 2016, the textile industries in Bangladesh produced around 1.80 million metric tons of fabric which generated around 217 million cubic meter of wastewater containing a wide range of pollutants and it was projected that the production of wastewater will increase to 349 by 2021 under the current dyeing practices.

The heavy polluted river is a serious threats to public life (Hasan et.al., 2019). People living near the rivers, having no other alternative, are often forced to use polluted river water for various purposes not for drinking purposes but for other purposes. Some households also use the water without much aware of the potential health risks which spreads water borne and skin diseases.

The disposal of solid waste and different effluents into the rivers making it difficult for aquatic and other sub-aquatic organisms to live. The infiltration of solid waste and effluents into the river, the Biological Oxygen Demand (BOD) in the water rises, creating oxygen crisis for the sub-aqueous life. The decrease of dissolved oxygen (DO) content of those river water below the critical level of 4.0 mg per liter is posing serious threats to bio-diversity in and around the rivers.

At the government level, several rules, regulations, policies and strategies have been formulated to protect the rivers from pollution and encroachment. But the failure of implementation of regulation, strategies and enforcing the existing policies lead to the poorer quality of river water and river health, consequently, further pollution is generated. Lack of property right and the less involvement of community and civil society in protecting the rivers is responsible for river pollution.

2.5.2 Health of Dhaka-sourrounding Rivers

Dhaka is surrounded by rivers like Buriganga, Balu, Shitalakkha, and Turag. These rivers are playing very important role. They are used as a mode of transport system. In the recent years, the discussion on river in Bangladesh focused on the severe reduction of water flow, prolonged silt deposition, riverbanks erosion, and encroachment.

The rivers are currently suffering from high level of pollution from industrial waste (60 percent) and municipal/household drainage of toilet wastes (30 percent). In the near future, the environmental degradation originating from rapid population growth and rapid industrialization will exacerbate the health of the surrounding rivers which will ultimately be a great threat to the living organisms including humans residing by the rivers sides.

Bangladesh is exceptionally vulnerable to climate change, and the effects have already been noticed such as the increased number of natural disaster, the lack of the availability of freshwater, diminished river flow during dry-season. The downstream riparian people need stable river for sustainable agricultural production. The pressure is building on basin's water resources and the riverine ecosystem due to both anthropogenic and environmental changes (Kolås et.al., 2013).

The Turag river is one of the most polluted rivers in Bangladesh which is

Figure 2.9: Dhaka surrounding rivers

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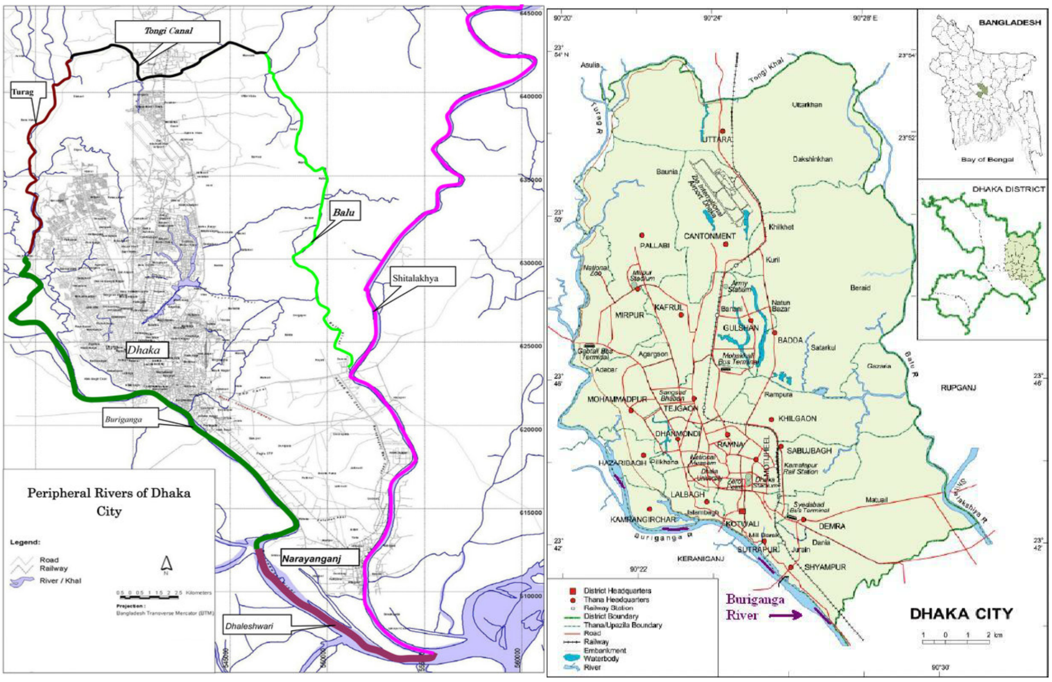

Source: Google Map

located to the north of Dhaka Metropolitan city. Numerous industries and business centers have set up in and around the banks of the rivers surrounding Dhaka and the new industrial growth centres are developing around them. Like Buriganga, the Turag is experiencing several problems like pollution and encroachment and such problems are exerting suffocation pressure on urban lives.

The thresholds of the physio-chemical parameters of water of three important surrounding rivers of Dhaka are shown in Table 2.8. The comparison between the threshold value of the parameters and the current estimated level of water quality of those rivers revealed a high level of water pollution. The pH values of these three rivers ranged from 7.7 to 8.0 throughout the year which are higher than DOE standard 6.9.

Table 2.8: General water quality of Dhaka-surrounding rivers

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	DOE Standard	Turag	Buriganga	Shitalakkhya
pH	6.9	7.9	8.0	7.7
EC	1200	1807	1209.0	1150
TDS	2100	1003	999.0	820
DO	>4.5-8	1.2	1.7	2.1
BOD	50	110	93.7	86.7
COD	200	97.7	100.0	87

Source: Banu et.al. (2013)
Note: The unit is mg/L.

The average EC value of Turag, Buriganga, and Shitalakkhya are 1807, 1209, and 1150 respectively whereas the threshold value according to DOE guideline is 1200 µS/cm and so, it is observed that all the three rivers are polluted. Compared to Buriganga, and Shitalakkhya, Turag has higher EC values. Like the pH values, the variation in EC of Turag River is remarkable and it is high during the dry season whereas in wet season, the situation improves.

The range of the measured average TDS[3] values in the three rivers lied between 820 to 1003 mg/L, and so the measured TDS lies within the threshold level. Again, highest level of TDS is observed in water of Turag rive. The TDS values differed by seasonality.

The DO value below a certain level, 2 mg/L, showed a great threat to the aquatic ecosystem. In dry season, DO becomes very low and in wet season, the situation improves a little bit perhaps of high flow.

[3]The TDS (Total Dissolved Solids which consists of different minerals and metallic substances in water that are in colloidal and dissolved conditions and also is an important chemical parameter of water

The average BOD[4] value was estimated at 110 mg/L for the Turag, 93.7 for Buriganga and 86.7 for Shitalakkhya and the BOD values lies above the threshold level in both dry and wet sessions suggesting the worse scenario (Table 2.8).

Table 2.9: Concentration of heavy metals (mg/kg dry weight) in Turag river and PLI
.

Heavy metals	Turag		Buriganga		Shitalakkhya	
	Wet	Dry	Wet	Dry	Wet	Dry
Al	92.7	294.4	79.6	152.3	113.2	116.6
Mn	9.77	6.4	6.12	77.3	3.27	258.99
Fe	12.67	380.8	9.82	358.68	11.19	341.21
Cu	2.52	7.4	4.13	6.75	1.97	15.83
Zn	2.59	ND	2.49	23.12	1.89	ND
Cd	5.46	ND	5.47	ND	5.45	ND
Pb	4.75	ND	4.87	ND	4.72	ND

Source: Banu et.al. (2013)
Note: The unit is mg/L. Al=Aluminum, Mn=Manganese, Fe=Iron, Cu=Copper, Cd=Cadmium, Pb=Lead, Zn=Zinc

The concentrations of metals in the three rivers by season are shown in Table 2.9. It was revealed that during wet season the concentration of aluminum was 92.7 which was 294.4, almost 3.2 times higher than wet season. In other rivers, Buriganga and Shitalakkhya, there were variation in the concentration of aluminum but the largest variation was observed in Turag river water.

The concentration of manganese was highest in Shitalakkhya during dry season though it was the lowest in wet season. The concentration of Fe was 12.67 during wet season in Turag river which was 380.8 during dry season. In Buriganga and Shitalakkhya, the situation was similar to Turag.

[4] With lower Dissolved Oxygen (DO) values, the Biological Oxygen Demand (BOD) levels are high due to available oxygen consumption by microorganisms.

The water quality of Dhaka surrounding river showed a seasonal pattern but the key message is that the scenario is very worse during the dry season and a little bit better off in wet season because of rainfall which led good flow of water.

Figure 2.10: Water quality in Dhaka-surrounding three rivers

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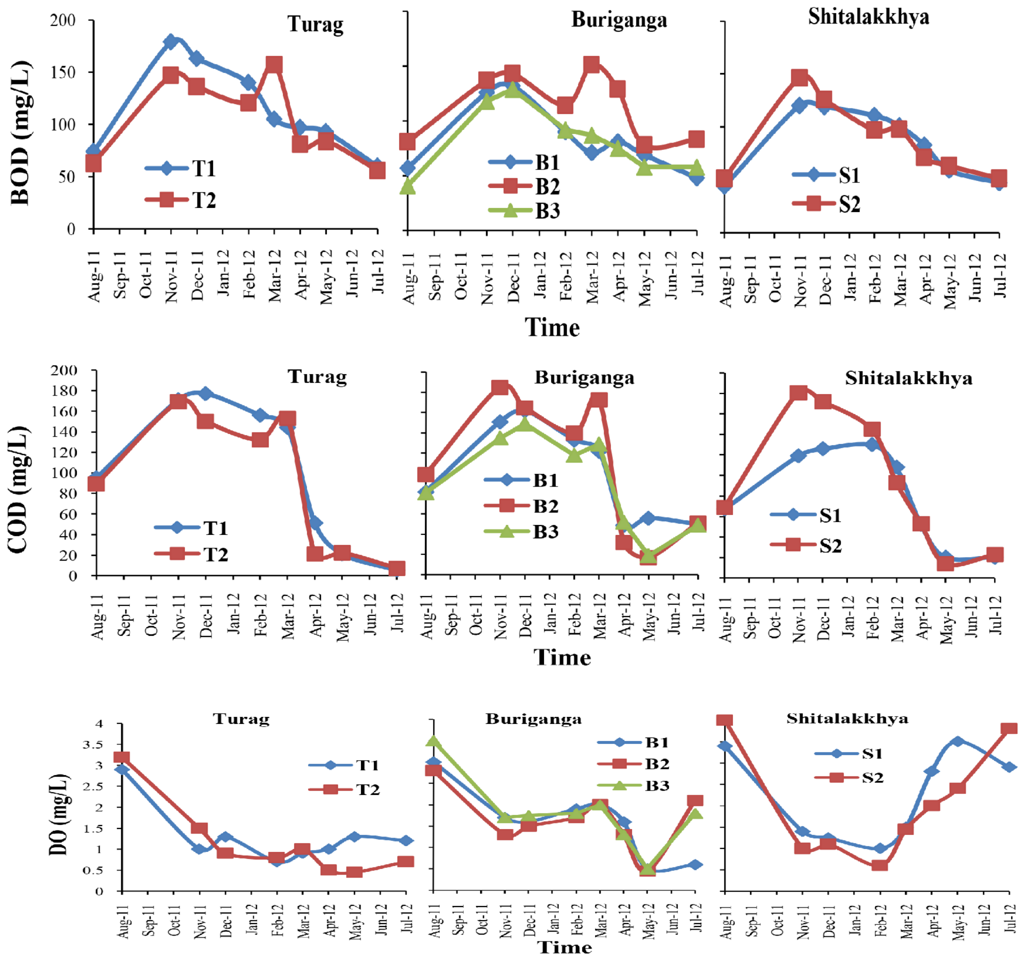

Source: Islam et.al. (2015)

Banu et.al. (2013) covers five stations of which three stations also belongs to the current study: Tongi Bridge, World Estema Field, and Kamarpara Bridge. The Figure 2.10 showed that the condition of river water deteriorated in between August to March, and it peaked up during November as reflected in BOD, and COD scenarios. The level of DO went below one in October and reached lowest in April to May in Turag river. In Buriganga, the level of DO reached lowest in May and in Shitalakkhya, it reached at lowest in February.

Table 2.10: Variation of water quality parameters in Turag river
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Parameters	2006	2010	Aktar and Moonajilin (2017)	DoE Standard
pH	7.1	7.5	U: 7.16, C: 7.45, D: 7.10	6.5-8.5
EC (electrical conductivity)	98	1800	U: 340, C: 610, D:485	-
Chloride	2	34	-	-
Turbidity	6.5	12.5	-	5
TS (total solids)	380	896	U: 920, C: 870, D: 846	-
TDS (total dissolved solids)	342	812	U: 655, C: 613, D: 582	2100
DO (Dissolved Oxygen)	6	0	U: 4.20, C: 1.85, D: 2.32	>4.5-8.0
BOD (biochemical oxygen demand)	2.8	22	U: 13, C: 73, D: 46	50
COD (chemical oxygen demand)	58	102	-	200

Source: Banu et.al. (2013)
Note: The unit is mg/L.
Aktar and Moonajilin (2017) estimated the water quality status of Turag River due to industrial effluent. They categorized the areas as upstream (U), confluence point (C), and downstream (D). The upstream areas considered high concentration of industries.

There were variations in the conditions of the presence of heavy metals in water of various rivers surrounding Dhaka (Table 2.9) and the quality of water of those rivers also varied by seasons (Figure 2.10).

The Table 2.10 showed that during 2006-2010, the value of all the parameters of water quality increased except DO, for example, pH increased from 7.1 to 7.5. The pH level, though lies below the maximum allowable concentration for drinking purposes, the level is reaching to maximum threshold of 8.5. The DO value has reached close to 0 and it is suggesting that fisheries, and aquatic life is impossible. According to Aktar and Moonajilin (2017), the quality of river water differs by location: upstream, downstream, and confluence point.

The concentration of heavy metals in the three areas are reported in Table 2.11:

Table 2.11: Concentration of heavy metals (mg/kg dry weight) in Turag river and PLI
.

		Tongi Bridge	World Estema Field	Kamarpara Bridge
Concentration of heavy metals	Lead (Pb)	36.4	34.4	30.4
	Cadmium (Cd)	0.1	0.1	0.0
	Chromium (Cr)	36	33.5	75.5
	Copper (Cu)	60	46.3	46.4
	Zinc (Zn)	179.3	113.8	190.1
Pollution Load Index (PLI)	Pollution Load Index (PLI)	1.74	3.03	1.4
	Lead (Pb)	5.13	5.37	5.9
	Cadmium (Cd)	25.12	25.12	31.6
	Chromium (Cr)	2.04	2.34	0.3
	Copper (Cu)	0.6	1.21	1.2
	Zinc (Zn)	0.1	0.67	0.7

Source: Banu et.al. (2013)
Note: The unit is mg/L.

The PLI score suggests that the three areas are moderately polluted and the heavy metals are present. Studies have been done by various researchers and a bunch of recommendations were listed. Most of the studies focused on the improvement of hydro-logical scenario of Dhaka surrounding rivers and limited studies focused on the welfare change of the riparian communities.

2.5.3 River Restorations Strategies

The government of the People's Republic of Bangladesh has been taking various initiatives to restore the river health. The concern of river health is acknowledged by the government, public, and various international organizations. The plans are highlighted in SDGs, vision 2021, vision 2041, and perspective plans.

In Dhaka Structural Plan 1995-2015, the government aimed to protecting flood flow zones along the rivers Shitalakhya, Balu, Turag, Buriganga, and Dhaleshwari and to ensuring sustainable water supply to the city from Shitalakhya & Balu River with pollution. But river pollution control targets have not been achieved and there was inadequate control over proposed land use.

In Dhaka Structural Plan 2016-2035, the government aims to ensure sustainable and safe potable water for Urban people through taking the policies: (1) prevent pollution of water sources, (ii) introduce loop closing system for water management, (iii) provide adequate water to the urban poor community at affordable rate, (iv) encourage rain water harvest, (v) introduce dual distribution system-potable and non-potable, (vi) ensure ground water recharge keeping the building set back space to remain unpaved.

The government also aims to reduce environmental pollution by (i) ensuring discharge of wastewater at recommended quality and (ii) relocating hazardous/ noxious industries. To protect the natural environment of Dhaka, the government has planned to keep the natural areas like river, khal, forest, parks as conservation areas.

2.6 Implications of Water

2.6.1 Water and Industrial Growth

The increasing supply of inputs like capital, labor, energy, and other resources and the technological advancement, enhancement factor or factors of production, are the key sources of growth. Since most of factors are finite (Romer, 1998): for example, lower population growth will bar the labor supply, the growth in future will be dependent on factor productivity. To understand the industry and environment relationship, let us consider the standard neoclassical production function which relates industrial output of a certain industry and a set of inputs. At the industry level, it is possible to distinguish the inputs. The major inputs are labor (L) and capital (K). The modern production requires energy (E), and raw materials (R) and some intermediate inputs (M), goods and services supplied by other sectors (both domestic and foreign). The environmental resources enter into the production functions as raw materials or energy inputs. In its most general form, a production function can be written as $Y = F(L, K, E, R)$,where Y is an industrial output or value of output produced.

2.6.2 Urban Agriculture, Pollution and Health

Although urban areas are the centers of industrial activities and services, the urban agriculture is important like the rural agriculture for ensuring urban food security (Zezza and Tasciotti, 2010 ; Altieri et.al, 1999 ; Maxwell, 1995 ;

Figure 2.11: Hazards associated with wastewater use in agriculture

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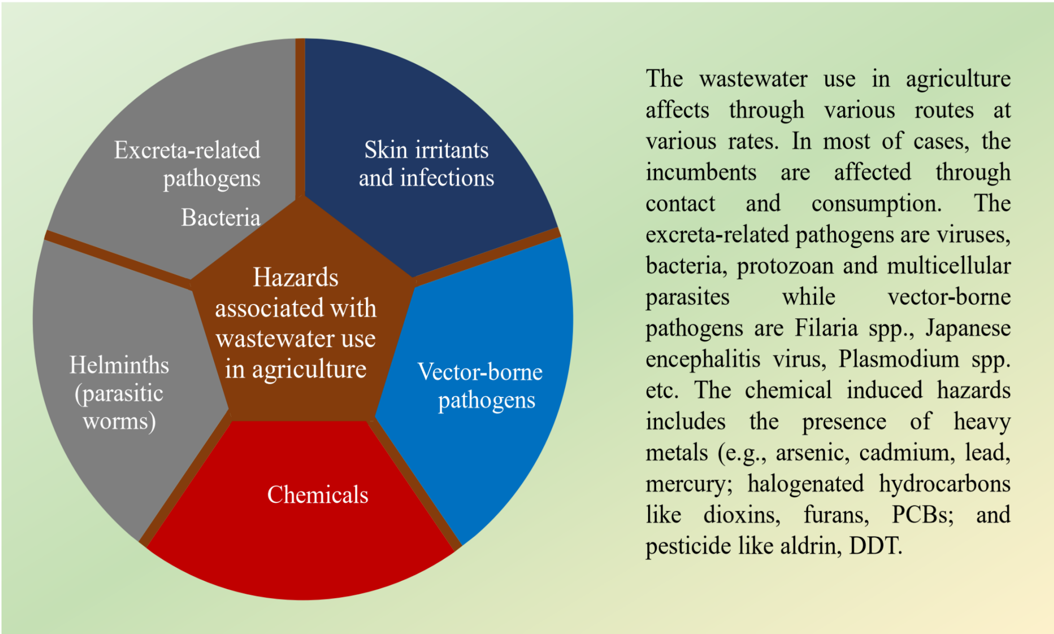

Source: WHO (2006)

Armar-Klemesu, 2000 ; Cofie et.al, 2003 ; Ellis and Sumberg, 1998), alleviating urban poverty (Mkwambisi at.al, 2011), enhancing social inclusion, and for overall economic development (FAO, 2002).

The pollution in urban natural water bodies is increasing day by day causing wastewater irrigation in developing countries (Drechsel, 2009 ; Jiménez & Asano 2008 ; Scott et.al., 2004). The Figure 2.11 showed the hazards associated with waster-water use in agriculture. It highlighted on skin irritants and infections, vector-borne pathogens, chemicals, helminths, and excreta-related pathogens. Wastewater irrigation is posing risks to health through various routes as it contain excreta-related pathogens (viruses, bacteria, protozoa and multicellular parasites), skin irritants and toxic chemicals (WHO, 2006).

Certain occupational groups, like farmers (Bayrau et.al., 2009) and fishermen, directly affected by contact to polluted water bodies (Blumenthal and Peasey, 2002; WHO, 2006) and thereby, more likely to be affected by water-related diseases, for example, high prevalence of hookworm infection (over 80 percent) in Haroonabad, Pakistan (Ensink et.al., 2002).

The human body is composed of $\frac{2}{3}$ water. Water is an essential nutrient involving in every function of the body, for example, water supports to transport nutrients and to release waste products. Water dissolves the carbon dioxide, oxygen and salts present in the body and distribute to the different parts through the process of blood circulation. Water helps in the utilization of the water-soluble vitamins as well as in removing the waste materials from body. It is also needed for the maintenance of proper body temperature.

Poverty is multidimensional (GC et.al., 2015 ; Thapa, 2008). It is affected by social, political, economic and environmental factors. The poverty and environment relationship is complex and is subject to extensive debate (Bucknall et.al. 2000 ; World Commission on Environment and Development 1987 ; Durning, 1989 ; Cleaver and Schreiber 1994 ; Ekbom and Bojo 1999) and the complexity is often mediated through micro and macro level factors like policy measures, institutional arrangements, land distribution, and entitlements to natural resources (Leach and Mearns 1991 ; Roe 1998 ; Ekbom and Bojo 1999). The poor is mostly affected by the natural resource degradation as the poor are tightly linked to the common-property resources (Bucknall et.al. 2000: 10) but the ways, poverty and environment is related, is not universal (Bucknall et.al., 2000).

From the dimensional analysis, it is clear that while natural resource base and access to markets directly affects the income and consumption pattern of the people which ultimately affects the opportunity dimension of poverty, the lack of access to water, sanitation facilities and better quality of air affects health which affects the capability dimension of poverty. From these interactions, we can see that the environment plays dual role: first, it contributes in generating income and enhancing consumption, and second, it affects the health through environmental degradation or environmental change, that is, it creates opportunities but it may erode some capability. Therefore, environmental resource based growth or welfare may be threatened by capability failure in future. Poverty not only contributed to deforestation in various countries like Thailand, Philippines, and Brazil but also modernization of agriculture, to reduce food poverty, contributed to environmental degradation which is attributed by the industrial effluent as well (Beckerman, 1992). The changes in production techniques in agriculture and non-agriculture are contributing to environmental degradation.

2.6.3 Water and SDGs

Notwithstanding the notable success in alleviating poverty and hunger, locally and globally, through the improvement of health and sanitation facilities during the last couple of decades, the people are still now facing exorbitant socioeconomic problems and the challenges of sustainability of the achievements. The sustainable alleviation of poverty necessitates the productive people having equitable access to sufficient quality food, water, and hygienic sanitation facilities.

Access to safe water (for drinking, cooking, bathing, and hygiene etc) is not only necessary for survival but also for the productivity of ecosystems and all lives in producing food, energy and daily necessary materials. A balanced water supply have a boon effect on the people and environment but the imbalance supply of water may create problems of drought and excessive water may be a cause floods. Therefore, a balanced water supply is required for prosperous economic development, healthy, and wealthy nation.

World Economic Forum (2014) identified ten global risks in the near future: (1) Fiscal crises in key economies, (2) Structurally high unemployment/underemployment, (3) Water crises, (4) Severe income disparity, (5) Failure of climate change mitigation and adaptation, (6) Greater incidence of extreme weather events (e.g. floods, storms, fires), (7) Global governance failure, (8) Food crises, (9) Failure of a major financial mechanism/institution, (10) Profound political and social instability. Among these crisis, water will be the foremost problem in future. The natural distribution of water has higher variability by geography and seasonality.

Table 2.12: Some water related monitoring and evaluation framework of SDGs
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#	Indicator	Baseline	Target
6.1.1	Proportion of population using safely managed drinking water services	87	100
6.2.1	Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water	61	100
6.4.2	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	3.79	3
6.a.1	Amount of water-and sanitation-related official development assistance that is part of a government coordinated spending plan	301.1mn USD	450mn USD
15.b.1	Official development assistance and public expenditure on conservation and sustainable use of biodiversity and ecosystems	41.07mn USD	200mn USD

Source: Monitoring and Evaluation Framework of Sustainable Development Goals (SDGs): Bangladesh Perspective (2018)

The inequity, heterogeneous distribution, extremity of water supply may exacerbate the impacts of accelerated climate change which includes incremental greenhouse gases, altered bio-geographical cycles, and hydro-logical cycles, and extensive loss of habitat and biodiversity (Schoeman, et.al., 2014). The effective management of water is necessary to ameliorate the resilience to shocks, and to provide sufficient quality water for human development and the well-being of billions of people on earth. Therefore, the challenges are profound and require global initiatives of institutional arrangements and investments to reduce the loss.

The government of Bangladesh aims to attain 100 percent safely managed drinking water services and sanitation services including hand-washing facility with soap and water by 2030. The baseline level of water stress, freshwater withdrawal as a proportion of available freshwater resources, is 3.79 which is expected to reduce at 3 within 2030. Various ministries are working to achieve the stated goals within the timeline. LGED has several ongoing project related to indicators 6.1.1, 6.2.1, and 6.4.2. The MoWCA has 2 ongoing projects related to SDG Indicator 6.2.1 which pertains to safely managed sanitation services.

2.7 Theories explaining water security

2.7.1 Catastrophe theory for water security assessment

Xiao-jun et.al. (2014) used catastrophic theory to assess water security. Water security includes every interaction between water and nature, society, economy and many other factors. Climate change may alter precipitation patterns and exacerbate water supply problems. Population growth and economic development may cause a steadily increase of demand for new clean water supplies. It is also necessary to achieve harmony among the stakeholder groups to ensure equity in water supply. Therefore, to assess water security it is necessary to understand all the factors influence the water security.

Yang et.al. (2012) also used catastrophe theory to assess the urban water security and considered three subsystem layers - flood control security, drinking water security, and water environment security.

2.7.2 Environmental Justice and Water Security

The United States of America had witnessed environmentalism and civil rights movements in the past half century and in the last three decades, it was widely acknowledged that environmentalist and civil rights do have a great deal in common. This is because more and more individuals and groups are pointing to the special environmental problems facing minority and low-income communities: hazardous waste sites, polluting industries, occupational hazards, and exposure to lead and other toxic metals. Environmental inequities were prevalent and during 1970s much attention was focused on air and water pollution (Newton, 2009). Environmental justice, the attempt to achieve environmental equity for all groups within society, is warranted to ensure better life for all.

2.8 Labor, leisure and Illness - A Relationship

2.8.1 The Grossman Model

To understand the effect of illness on available working days, earnings, and demand for health inputs, let us consider the comprehensive Grossman (1972) model which explained how health investment increases leisure and income to the individual. It was assumed that the health investment was produced by time spent improving health (T_H), and market health inputs (providers' services, drugs), M, home good B is produced with time, (T_B), and market-purchased goods, X. The individual wanted to purchase M and X using the available income. The individual used leisure time either for health care (T_H) or for producing the home good (T_B). Using the functional notation, $I = I\left(M, T_H\right)$ and $B = \left(X, T_B\right)$. The properties of the functions were: $\frac{\partial I}{\partial M} > 0, \frac{\partial I}{\partial T_H} > 0$ and $\frac{\partial B}{\partial X} > 0, \frac{\partial B}{\partial T_B} > 0$. They implied that the increased amounts of M and T_H lead to an increase in investment I, and that the increased amounts of X and T_B lead to increased home good B. It was assumed that the maximum available time to the individual was 365 days. To buy M and X, the individual had to trade some of his/her time for income, that is, s/he had to work (T_W). It was also assumed that the individual might be involved with unpleasant leisure (illness) or T_L. Therefore, the time constraint, the total time (T), for the individual was

$$T = 365 = T_H + T_B + T_L + T_W \tag{2.1}$$

The maximum amount of time that s/he had available to use either for work, T_W, or leisure, T_B, was thus $365 - T_H - T_L$, so:

$$365 - T_H - T_L = T_B + T_W \tag{2.2}$$

This equation suggested that the lost days due to either illness or more time spent for improving health reduced the available time for good leisure and income.

In the figure 2.12, leisure time (T_L) was measured toward the right while time spent at work T_W was measured toward the left. The choice of the individual was presented by the standard convex utility curve. The individual reached at the equilibrium where the slope of the indifference curve was tangent to the budget constraint: $wT_W = w\left(365 - T_H - T_L - T_B\right) = Y$, that is, the

Figure 2.12: Labor-leisure trade off and illness

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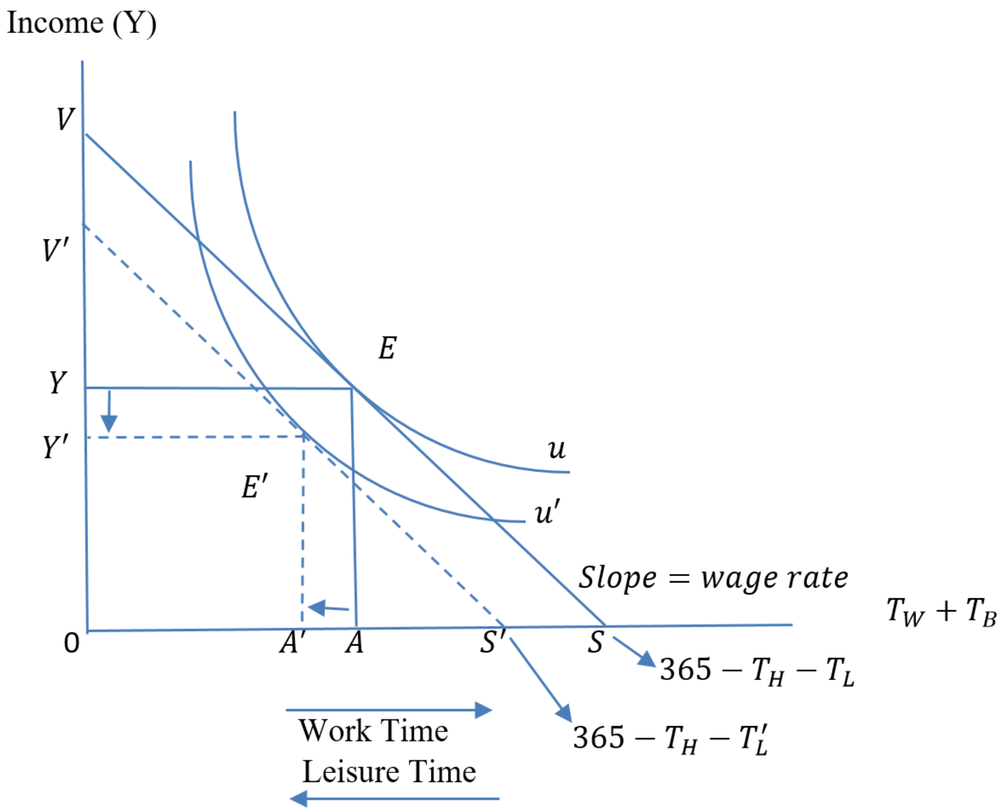

Source: Grossman (1972)

individual reached at equilibrium where the marginal rate of substitution between income and leisure was equal to the wage rate. The individual initially, for a given T_H and T_L chose OA amount of leisure time and AS amount of work time. From the AS amount of work at the given wage rate, the individual earned an income of OY and attained the satisfaction level of u.

Now, if the amount of time spent in illness shifted the budget constraint leftward as given by $V'S'$ and with this new constraint the individual reached at the new equilibrium E'. At the new equilibrium, the individual had less leisure time and less work time and hence lower satisfaction level u'. Therefore, an increase in illness from the threshold level of expected number of illness days, the amount of leisure time and the amount of work time declined which reduced the income of the individual and the households.

2.8.2 The Theoretical Model

Dasgupta (2004) constructed a theoretical model for valuing the damages originated from the contaminated water supply and the author used the theory of consumer's utility maximization to model human behavior in response to the risks. The model was used to evaluate the possible health effects of a change in an environmental or resource good on the changes in individual behavior stemming from the perceived adverse effects (reduction) on the individual's utility notably the choice between spending on health activities and private goods.

Dasgupta (2004) defined the utility function as follows:

$$U = U\left(X, L, S\right) \tag{2.3}$$

In the above expression the term$X$ represented expenditures on household's aggregate consumption excluding the expenditure on health related goods and for simplicity, the prices were set at unity, L refered leisure time per period and S was time spent ill (number of days sick). The household derived utility from the consumption of X and L, while S causes disutility. Thus, the first and second order derivatives were of the following nature: $U_X, U_L > 0, U_S < 0$ and $U_{XX}, U_{LL}, U_{SS} < 0$. Time spent ill ($S$) was modeled as a function of the exposure to contaminants (P) and averting or defensive behavior (D) to reduce the likelihood of illness. Thus, the health production function specified by Dasgupta (2004) was:

$$S = S\left(D, P\right) \tag{2.4}$$

It was assumed that $S_D < 0, S_P > 0$ and $S_{DD} < 0, S_{PP} > 0$. S was characterized as $S = S(T_d, P)$, where T_d was time spent on defensive activities (Alberini et al. 1996). In other words, the time spent ill was modeled as a function of the time spent in defensive activities, and the exposure to contamination. The household's budget constraint specified by Dasgupta (2004) was:

$$I + wT = wL + X + wT_d + wS(T_d, P) + P_d T_d \tag{2.5}$$

where I is total non-labor income; w was the wage rate; T was total time; P_d was out of pocket expense on defensive behavior. Assuming that all individuals work for a positive amount of time, it implied that $[T - L - T_d - S(T_d, P) > 0]$.

Dasgupta (2004) formulated the household's decision-making problem as:

$$\mathcal{L} = U\left(X, L, S(T_d, P)\right) + \lambda \left[I + w\left(T - L - T_d - S(T_d, P)\right) - X - P_d T_d\right] \tag{2.6}$$

and using the first order conditions Dasgupta (2004) derived the following equations:

$$\frac{U_s S_{T_d}}{\lambda} - wS_{T_d} - P_d = w \tag{2.7}$$

$$\frac{U_s S_{T_d}}{U_X} - wS_{T_d} - P_d = w \tag{2.8}$$

Dasgupta (2004) described various terms of the expressions of the above equations. The first term above, $\frac{U_s S_{T_d}}{U_X}$ gave the marginal rate of substitution between $\frac{dU}{dT_d}$ and $\frac{dU}{dX}$ i.e. it gave the (implied) gain in utility (in terms of X), from a unit increase in T_d. The second term, $(-wS_{T_d})$ was positive, (assuming that $w > 0$), since S_{T_d} was negative by formulation. As time spent on defensive activities went up sick time would reduce). Thus, - wS_{T_d} gave the gain due to reduced sick time, valued at the wage rate. Therefore, the term $\frac{U_s S_{T_d}}{U_X} - wS_{T_d}$ gave the gross gain from an increase in T_d. The third term, $(-P_d)$ implies the expense incurred for defensive activities. Therefore, the right hand side of the optimality condition gives the net gain from a unit increase in T_d.

At the margin, the wage loss (w) corresponding to the unit increase in time spent on defensive activities, must equal the net gains (in terms of non-health consumption expenditure and reduced sick time) from the increase in time spent on defensive activities.

2.9 Health and Economic Costs of Water Insecurity

Since people are by and large is dependent on environment, environmental pollution has deleterious effect on human health and well-being in various ways: bad health requires more investment on health such as medical expenses associated and non-medical expense, the income loss because of illness or the productivity loss, and lower leisure. The change is observed at micro-indicator level like the frequency of illness or the treatment cost borne as well as at the aggregate level like the stay in poverty for longer time and/or leading a miserable live.

The cost of water pollution is not scanty. According to WHO (2017), it is common that the inhabitants of the riparian areas have relatively more skin diseases, waterborne diseases and the unhygienic water is treated as one of the key causes of death around the globe: who reported that around 8.42 million people die from diarrhoea globally. The communities living adjacent to the river/khal, are vulnerable communities as they have to bear the prolonged sickness, higher medical expenses, low productivity, and above all, to live under the poverty line.

2.9.1 Health Risks: Diseases and Illness

Without water, life is impossible. But sometimes, water, itself, can be a great threat to lives for example flood and tsunamis. Water is the major source of water-related hazards. According to UN World Water Development Report (2012), around 90 per cent of all natural hazards is originated by water and globally their frequencies and intensities are generally increasing. Human suffers from water-related hazards and water-borne diseases.

Water pollution and illness is interlinked. Pandey (2006) stated that more than 2.6 billion people, 40% of the world's population, lack basic sanitation facilities and over one billion people still use unsafe drinking water. These cause the death of children from diarrhoea and other water, sanitation and hygiene-related diseases and many suffer and are weakened by illness. Cheung et.al. (1990) showed that the overall perceived symptom rates for gastrointestinal, ear, eye, skin, respiratory, fever and other illness were significantly higher for swimmers than non-swimmers in beach areas in Hong Kong.

2.9.2 Productivity Loss

Whatever may be the reasons, illness has an impact on productivity loss. It reduces the available and quality working hours of the working force. An illness induced productivity loss has a direct and indirect cost to the individual, the family, as well as to the nation as a whole. To measure the productivity loss in formal and semi-formal sectors, employment of individuals will be considered.

The cost of polluted water is not limited. Matin (2017) argued that there is correlation between disease and river pollution as polluted water can affect human health through various routes like the intake of food, drinking, washing, bathing etc. The health cost of pollution is around 21.5 percent of annual income in Hazaribag area, the earlier area of tannery industry. Jaundice, skin diseases and diarrhoea are high. Men and infants are the most vulnerable groups. Land productivity loss is estimated around 40 percent. Agriculture cultivation, fishing and boating are heavily affected.

The literature on absenteeism, presenteeism, and productivity is wide. The correlation among them has brought greater interests of the researchers. The findings of the studies showed that the impact of absenteeism and presenteeism on productivity and thereby on human welfare as well as on the overall economy is significant. The existing literature focuses on linkage of absenteeism and productivity; presenteeism and productivity; and on the correlation between absenteeism and presenteeism.

Absenteeism and presenteeism are determined by a set of factors: workplace, personal/individual, and health. The economists face problems in modeling the effect of environmental policy making. The economists estimate the costs of environmental policy like Clean Air Act (EPA, 1997 and 1999) as well as benefits (Williams, 2002).

"Absenteeism is failing to report for scheduled work. As such, it is the violation of a social obligation to be present in a particular place at a particular time. Traditionally, absenteeism was viewed as an indicator of poor individual performance and a breach of an implicit contract between employee and employer. Thus, it was seen as a management problem and framed in economic or quasi-economic terms. Indeed, economists most frequently view absenteeism in labor supply terms. More recently, absenteeism has increasingly been viewed as an indicator of psychological, medical, or social adjustment to work." (Johns, 2007).

The measurement of the productivity loss is challenging. Instruments can be used to measure the effects of ill health on productivity: it can be measured either through absenteeism or through presenteeism. The former refers to the measure of days absent from work, the latter to reduced productivity while at work (Koopmanschap et al., 2013 ; Zhang et.al., 2015 ; Hemp, 2004). Both absenteeism and presenteeism can be measured using recall method and as short recall (1-2 weeks), although the recall period could be in range between 1 week to 3 weeks, gives better and reliable data (Mattke et.al., 2007).

The definition of absenteeism is relatively straightforward but the presenteeism is quite complex. The presenteeism view considers the reduced intensity or quality of input due to illness. The questions ask whether the incumbent is employed; the number of hours missed from work; the number of hours actually worked; and the degree to which the respondent feels that a health problem has affected productivity while at work and affected their ability to do daily activities other than work (Hafner et.al. 2015). The productivity at farm household level can be affected by the quality of input, labor hour, and the low quantity of output due to other than quantity of inputs. The measurement of productivity loss for self-employed people is very much challenging.

The measurement of the total time lost due to presenteeism is complicated and it is harder to monetize the lost productivity. Mattke et.al. (2007) proposes three methods: (a) salary conversion method, (b) introspective methods, and (c) firm-level method. The first method requires salary information and survey responses to estimate productivity loss. The simplest version of salary conversion method is the human capital approach (HCA), a method typically used to estimate the economic effect of health-related productivity losses, which monetize the loss as the product of total missed workdays within a specific period, say in a week or the recall period, by daily salary (Kessler et.al., 2004).

This technique, although developed for absenteeism, is also extended to measure the productivity loss due to presenteeism as well. It accounts the total losses in the stated period by multiplying the total self-reported unproductive hours with the average daily salary (Lemer et.al., 2001 ; Berger et.al., 2001 ; Allen & Bunn., 2003). The wage can be the actual salary of the respondent (Stewart et.al., 2003) or the average salary of the corporation (Hemp, 2004) or national median wage (Goetzel et.al., 2004). This method is apposite for workers performing discrete tasks in isolation but is inappropriate when the bad performance of a worker due to illness affects the productivity of other workers beyond his/her own (Pauly et.al., 2002).

This interdependence of job functions in the neoteric economy has been operationalized by following three criteria proposed by Pauly et.al. (2002): (1) replaceability of an employee, (2) the extent to which an employee works as part of a team, and (3) the time sensitivity of an employee's work. They also propose different multipliers for different job category: for some simple jobs, the multiplier is simply 1.00 implying the productivity loss is just equal to the actual salary while for some jobs, the multipliers is greater than 1 and the larger the multiplier value the larger the interdependence among employees. Even different multipliers have been used for short-term (3 days) and long-term (2 weeks), and for ongoing activity as well. Pauly et.al. (2002) mention two practical challenges of HCA approach: first, diverse set of multipliers would have to create and maintain, and second, it entirely depends on individual-level characteristics and does not consider firm-level characteristics like unionization and competitive position.

Koopmanschap et.al. (1995) and Brouwer and Koopmanschap (2005) propose alternate method, friction cost method to measure indirect cost of disease, to overcome the problem of overestimates of absence related productivity losses by HCA technique. But friction cost method is also challenged at least theoretically as it is inconsistent with concepts of standard economic theory such as opportunity cost and profit maximization (Johannesson & Karlsson, 1997).

The second method to monetize the lost productivity due to illness is introspective methods. This method attempts to overcome the theoretical and practical challenges of salary conversion method by providing guidance to firms on deriving their own estimates precisely. The third method, firm-level method, represents a logical extension of the introspective methods and follows a top-down approach to estimate the costs of lost productivity.

This method presumes that the managers have high sense about the economic effects of health-related problems on firm's productivity. This method does not require detailed individual level data but it encounters the intangible measurement problem. The estimate of productivity loss in presenteeism is not also feasible in this method due to information asymmetry.

The cost of lost productivity due to illness is the sum of direct and indirect costs of an illness (Greenberg et.al., 1993; Rice & Miller, 1993; Hodgson & Meiners, 1982): direct costs include treatment costs and indirect costs include the lost value of output due to absenteeism or presenteeism. It is very much challenging in estimating the costs of lost productivity due to illness by using these methods. The methods not only have some shortfalls but related empirical evidences are not plenary. Notwithstanding the gaps, an empirical examination of the costs of lost productivity due to illness or specifically due to the exposure to nearby polluted water.

Good health is an important factor for labor productivity and so health status and productivity are linked. Better health means better productivity which is supposed to help accumulate wealth and enhance income and other way also exists: the better income helps to have better health and hence better productivity (Higgins and Alderman 1997) . Productivity, broadly in agriculture or non-agricultural activity, can be measured at individual, household or national level. The productivity of labor, whatever the way it is affected, is determined by a set of factors and the factors may be from workplace, employer side, the residential characteristics of the individual/household and the characteristics of the overall environmental quality like air pollution, water pollution etc. The study of Ullah (2006) claims that industrial pollution is affecting human health and the productivity of land.

High prevalences of skin diseases, diarrhoea, gastric ulcer, fever, and dysentery are among the riparian residents (Halder and Islam 2015). The illness of non-earners can reduce the productivity of earners (see Angrist and Evans, 1996 ; Corman et.al, 2003). Whatever the causes of productivity loss, a loss in productivity is a direct cost to the employers or to the individual/household and in a broader sense, a loss to the society or nation. The study of Mitchell and Bates (2011) showed that due to health, the cost of lost productivity is significantly high to the employers. The illness days are classified into two categories: waterborne and non-waterborne. The overall scenario is the aggregation of the effects of productive hour losses due to waterborne and non-waterborne related diseases. The estimate techniques considers the productive hour losses due to absenteeism and presenteeism in workplace.

The identification of factors determining productivity at workplace is complex. Hafner et.al. (2015) studied the workplace productivity using the concept absenteeism and presenteeism and he conceptually framed the workplace productivity using broadly three types of factors: (i) job and workplace factors like workplace policies, role of job demand, and management issues; (ii) personal factors like depression and stress, lifestyle factors and other factors outside work e.g., financial and family commitments; and (iii) health and physical factors like acute illness and long-term health conditions, functional limitations, etc.

Millions of waterborne, fully or partially, disease cases occur in USA and they were responsible for over 40000 hospitalizations and the monetary cost of such cases was around $970 million per year (Collier et.al., 2012).

2.9.3 Out of Pocket Treatment Cost

Conceptually, out of pocket (OOP) expenditure refers to the expenses, medical and non-medical expense, that the incumbent household or the patient pays directly to the healthcare service provider without the support of third-party.

2.9.4 Health Risks based Poverty Trap

Sala-i-Martin (2005) pointed that low income (poverty) tends to cause poor health which, in turn, tends to cause low income and this was called health-poverty trap. It was a trap because poverty can not be eradicated without dealing with the health issues of the poor, and health problems can not be fully solved without poverty eradication. Khullar and Chokshi (2018) also pointed that the poor health generates a negative feedback loop and generates health-poverty trap. Yang and Liu (2018) showed environment-health-poverty trap and empirically showed that pollution increased income inequality and health inequality. Bonds et.al. (2010) opined that poverty trap was formed by the ecology of infectious diseases and it can be broken by improving health. In the book "Poor Economics: A Radical Rethinking of the Way to Fight Global

Poverty", Banerjee and Duflo pointed the health-poverty trap many times as suggested by Sachs.

2.10 Framing the relationship among environment, population, and economy

In a circular flow analysis where households and firms are the key players in exchanging inputs and outputs, households can be classified broadly in two categories: (i) labor supplying households, and (ii) non-labor supplying households to a specific sector. Households supply labor-hours in labor market and firms hires labor-hours from it and thereby creates employment opportunities for labor supplying households. Households earn income from firms – wage or profit. The non-labor supplying households do not directly contribute in firm's production.

The firm's production process generally uses various types of capital, environmental or non-environmental, and labor and the production process yields output and some waste as by product of production process. The output directly contributes to GDP either through international trade (exports) or domestic trade which is presumably contributes in alleviating national poverty.

The national poverty comprises the poverty of labor supplying and non-labor supplying households. The labor supplying households are expected to be affected through various health risks (diseases or erosion of effective labor supply) due to pollution caused by discharged waste. The labor supplying households, therefore, have benefits as well costs, social or private. But the non-labor supplying households have the costs side of industrial growth: the cost of environmental damage, but have hardly the benefits. They may be affected through health shocks. Their loss may be intensified if they have agricultural land near to river and the agricultural productivity is affected by the industrial effluents.

Figure 2.13: Framing the relationship among environment, population and economy
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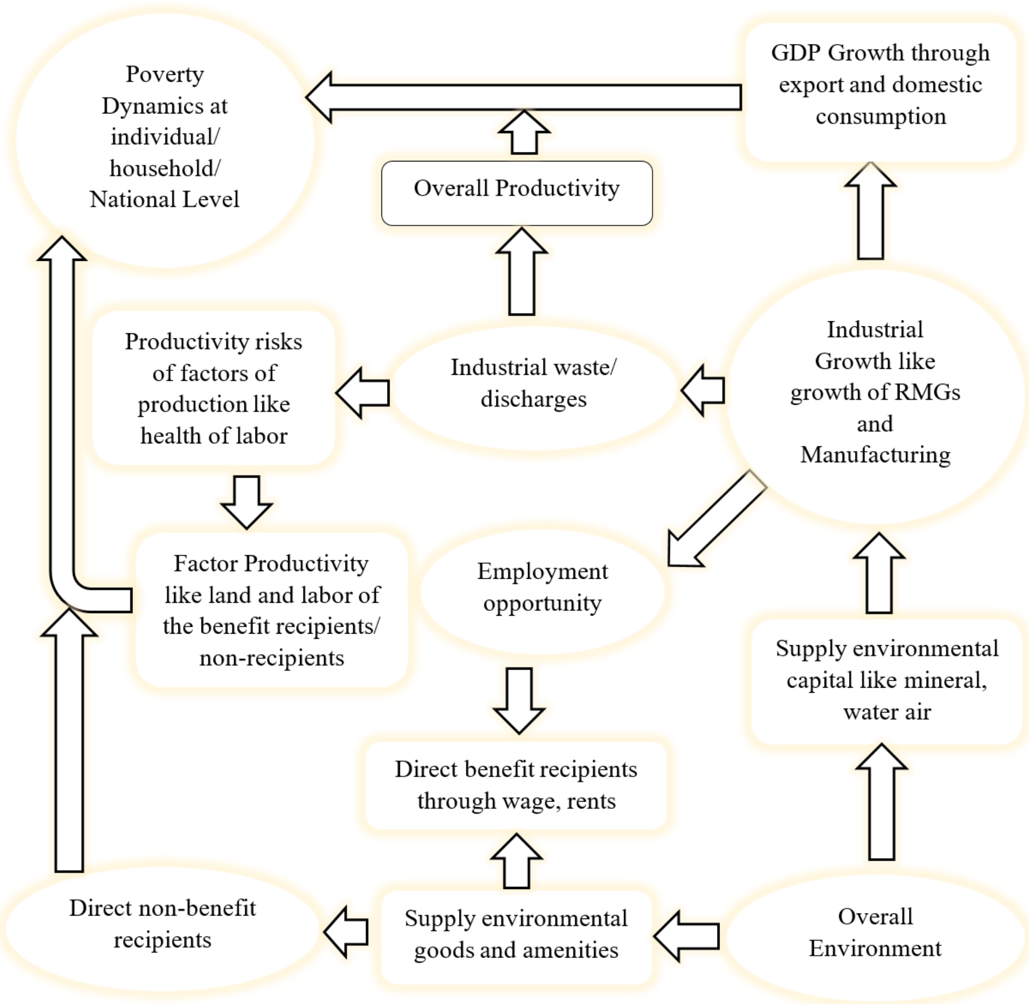

Source: Proposed by author

Therefore, the overall poverty can be a threat to the economy if the industrial growth is not enough to produce a surplus of aggregate benefits over the aggregate costs. The non-pro-environmental growth, therefore, has micro and macro implications. Securing an economy in a balanced state, we will need a mismatch between micro and macro policy related to environmental resources like water. The study aims to link between water led industrial growth and welfare of the economy.

In Bangladesh, The garment industry is considered as part of the overall industry sector and individuals/households will represent the population. The state of poverty of the individuals/households will be considered as the broad indicator of welfare. Since the study focuses on the linkage between industrial growth and poverty in the riparian areas, it is rational to examine the poverty status in relation to the status of the flow of river and production of agriculture and non-agriculture sectors. In a year, the river has two states – the monsoon period and dry period. In that two states, the environmental quality differs and, thereby, the poverty status is expected to vary with the differences in the state of the river and river water quality.

Hence, the ideas of static poverty, poverty at a single point, switches to a dynamic approach, status of poverty at monsoon and dry session. The cross-sectional concept of poverty, moderate or extreme poverty, turns to its dynamic concepts such as chronically poor, transient poor or never poor. The research has been forwarded through the integration of industry, environment, and human welfare concepts in a single frame.

Here, we are proposing the major role of environment in the industrial growth process and thereby in changing the welfare of the people. The idea is simple – the industrial production will depend on environmental resources – renewable and non-renewable resources, and the environment induced industrial growth is expected to bring changes in human welfare. The comprehensive conceptual framework presumes some relationships which should be discussed for integrating the problems of firms, environment, and the individuals/households. Some of the relationships have already discussed like the relationship between environment and the economy and the relationship between water resource and industrial growth. Other relationships should also be discussed for understanding the interaction of variables in the complex framework.

2.11 Framework for assessing the interactions with open-source water

The potential socioeconomic factors determining the interaction with the open-source water for domestic purposes have been discussed in chapter six. The chapter follows the social-ecological framework of analyzing the interactions with unsecured water which is a part of the the principle framework of the study. This part describes the process of accessing improved water for drinking as well as for domestic purposes like washing, cleaning, bathing, etc.

The framework focused on abstraction and use of water for drinking and domestic purposes. The framework proposed by Haque et.al. (2019) suggested that interactions were determined by four set of factors: (i) water resources, (ii) infrastructure, (iii) governance and institutions, and (iv) users, which determine the contact with or interactions with available water source.

They stated that the lack of access to improved water source was determined in a complex manner within the key principle issues. The water resources included quality of water, the quantity of water which is determined by the spatio-temporal distribution of rain, surface and ground water.

The access to water resources largely was dependent on water infrastructure and property right. This included the ownership of the water infrastructure, private, public, or shared, water supply technologies such as tube-wells, piped system etc. In this framework, water infrastructure had been considered as the input to the interactions of water.

The framework suggested that interactions by the users were supposed to the influenced by the individual and household characteristics and governance and institutions defined and set the rules and conditions for the users to access water and the interaction. As water security outcomes, the framework highlighted on accessibility, quality, quantity, affordability, and reliability of the services.

Figure 2.14: Framework of interactions with water proposed by Haque et.al. (2019)

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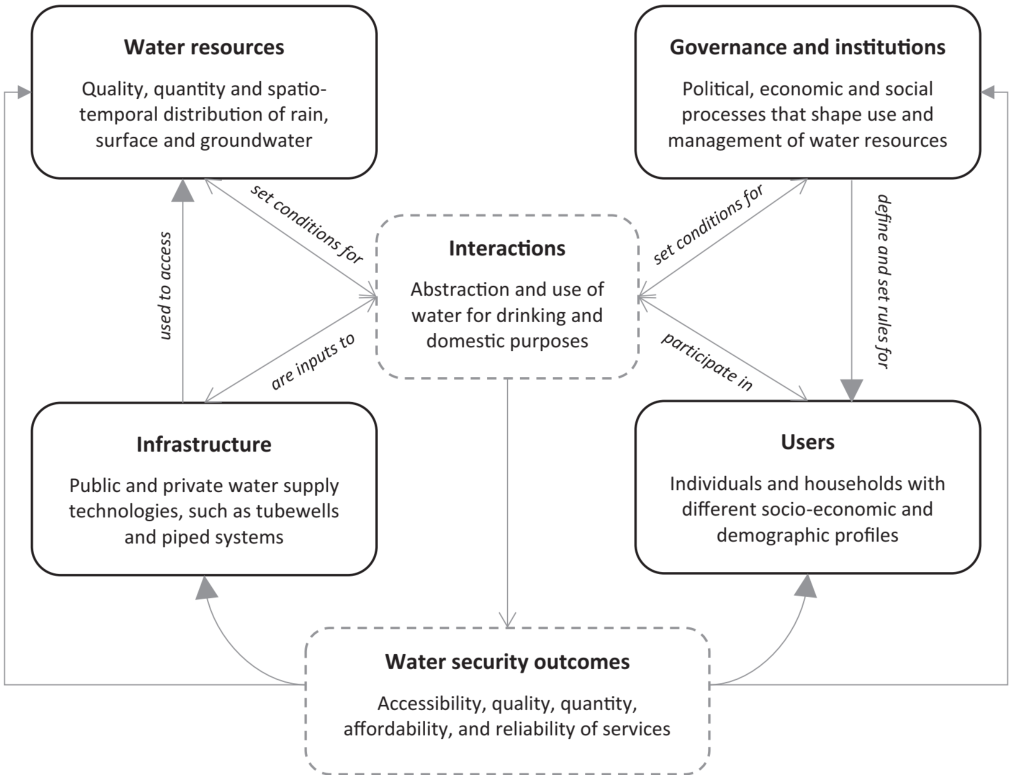

Source: Hoque, S.F. et.al., (2019)

Eichelberger (2018) argued that access to safe water is tied to hydro-social relationships predicated on sharing and reciprocity. In assessing the linkages between smallholder irrigation, water security and household food security, Sinyolo et.al. (2014) considered the physical or infrastructure factors like canals and pumps, socioeconomic factors like age, gender, income sources, geographic location, asset holding like land and institutional/ organizational factors. They found that age, income sources, ownership of pumps, and membership of social organization improves water security significantly whereas the occurrence of social conflict deteriorates water security status.

Rauf et.al. (2015) used location indicator, gender, household size, distance from water point, number of rooms, education, and transport mean to explain the determinants of water security in Punjab and similar factors are also used by Grafton et.al. (2011).

Aurona & Dabbert (2010) included water price, time for fetching water, education, wealth, household size, occupation, village population, ownership of tube-well or pumps and water accessibility to model the demand for free water and purchased water. Hinojosa et.al. (2017) listed administrative regions, social and environmental territorial characteristics as determinants of water security in rural areas of Ecuador. Shrestha et.al. (2018) considered central water system, alternative water sources, water consumption, access to improved water source, adaptability, affordability, and social capital to explain the community level water security.

2.12 Overall Analytical Framework

From this study a conceptual analytical framework has been proposed and placed under Figure 2.15 which shows the relationship among water security, health risks, and human welfare. Diarrhoea and other water-borne diseases, largely due to unsafe water, inadequate sanitation and poor hygiene among human population, have an increasing trend in cities of developing countries (Oguntoke et.al, 2009). Although now a days the mortality of many water-borne diseases is relatively low, the socioeconomic impact even of non-fatal infection is phenomenal (Avendano et.al, 1993 ; Payment, 1993).

Figure 2.15: Proposed conceptual analytical Framework showing relationship among water security, health risks, and human welfare
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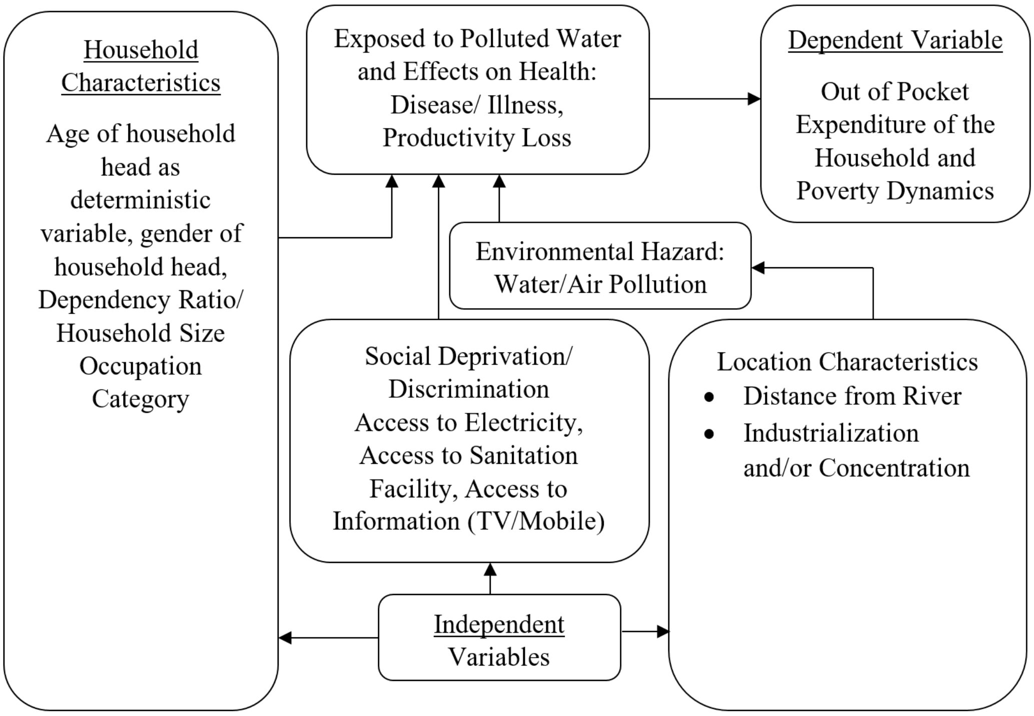

This framework helps to understand how households are influenced by different characteristics like household composition, location, and some exogenous factors both micro and macro indicators either through the environmental hazard and/or through incapability of functioning. In this framework, we have considered a set of explanatory variables covering household characteristics, characteristics of the location of the household.

The aim of this study is to find the relationship among water insecurity, the attributes of the households, the ecological attributes, and to assess the effects of water insecurity on human health, health expenditure, and poverty. In the first stage, it is required to know the potential factors affecting the water security of the households which has been assessed using the relationship of water secruity with household characteristics, the characteristics of the location, social characteristics, and the condition of the environment.

The effects are assessed considering the water insecurity variable as explanatory variable.

Chapter 3

Research Methodology

3.1 Introduction

This chapter describes the research methodology of the present study. The study aims to decipher the link between environmental resource usage and the dynamics of the welfare of the population in the urban riparian areas of Dhaka city. The study involves the industrial growth led pollution or damages to the environment, and the effects on human welfare which ultimately will describe how the industrial growth through inputs and a detail description of demographic characteristics who are exposed to the damaged environment especially the polluted open-source water like river/ lake/ canal water. The contact with polluted open-source water, therefore, has a deleterious effect on human lives. Therefore, it will explore the risk dimensions, and then compare them across the various personal and regional characteristics.

Figure 3.1: Industry, water pollution, and human interaction in study area during 2018

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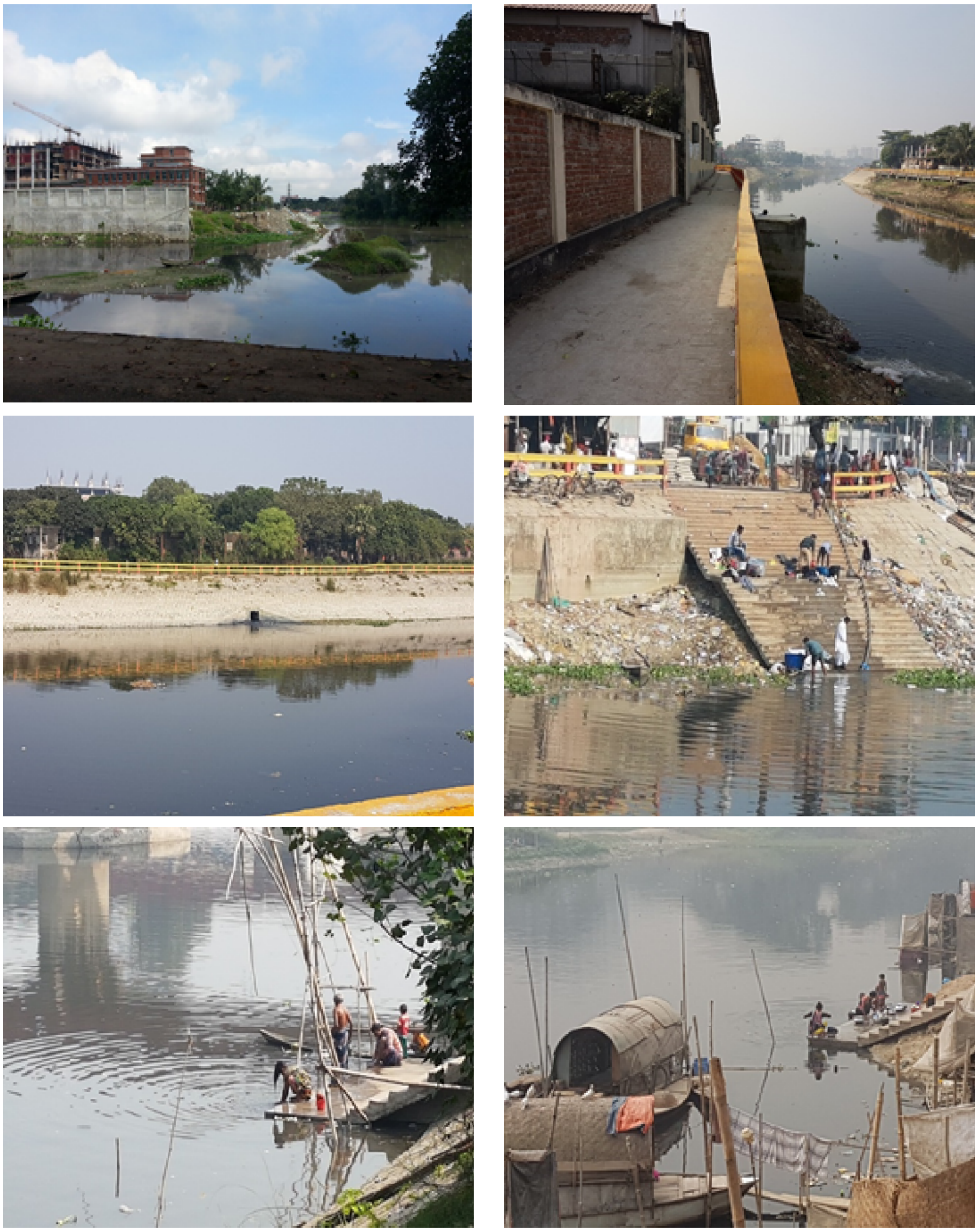

Source: Photo taken by author

3.2 Reconnaissance and Survey

To understand such a research problem properly, it is important to have some familiarity about the areas, know the problem types prevailing in the area, characteristics of the analytical units, pattern of local institutes, and local people. The primary reconnaissance visits helped fixing objectives of the study and helped familiarize the team with the people of the areas and enable to formulate research problems, research questions to ask for the research and to find possible ways to collect the data in the study areas. A research team made the initial reconnaissance collected photos and captured videos of the usages of river water in the riparian areas of Turag River.

Two field trips were organized: one in September and the other one in October 2016 in the upstream areas of Turag river: one was by road near to riverbanks, and the other through river by boat. The trips helped to understand the settlement structures specially the industrial settlements in the vicinity of river. It also gave ideas about how the industries are affecting the river and how households are being affected and at what extent. We observed that in between the Ashulia bridge and Kashimpur, there were few households located near the river.

Some industrial settlements were found in between Kashimpur and Konabari areas. Many factories are established on the banks of the river. The factories have discharge points connected to the river. In some areas, the municipal wastes are being deposited to the river. There are some households besides the two banks of the river. Members of different households take their bath in the river, some wash their utensils, and some were wash the bodies of their cows. Fishing is common there. Some children catch fishing in the river near to the industrial disposed zones where the water seemes to be highly polluted. It is apparent that human activities near to the river are interlinked with river and their health is inevitably risky.

3.3 Sources and techniques of the collection of data

The aims of study was to triangulate the inter-linkage of environment, industry, and population welfare. As the environment is affected by industry, the analysis has been concentrated on various aspect of water. Since garment industries are flourishing in Bangladesh, the study will, therefore, be concentrated on people's living in urban riparian areas, adjacent to the river affecting physically or economically. The broad challenge of the study was to develop a comprehensive research methodology.

The methodology of the research was mostly quantitative but qualitative analysis got significant attentions as they helped to understand the problems in a static as well as in the dynamic form, that is, in a comprehensive and holistic way. The quantitative and qualitative integration helped us to triangulate the nature of the problem in forward way. Both primary and secondary sources of data were used simultaneously.

Table 3.1: Types of data used in the study

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Primary Data	Secondary Data
Household Survey	Population Census 2011
Key Informant Interviews and Group Discussion	Household Income and Expenditure Survey (2010, 2016)
Participatory Observation	Published Documents (Journals, Reports, etc.)

1. **Primary Sources:** The information on problem related to the study

was collected primarily from household, and the respective community through structured questionnaire. The qualitative information was also be collected from the households, household members, and key informants through checklists. In addition, group discussion and focus group discussion, and participatory observation were also made.

2. **Key informant interviews (KIIs):** Different peoples having good understanding on the linkage of industry, environment, and household welfare were the key informant of the study.

3. **Group discussions:** Several group discussions (GD) arranged arranged in various sample areas and the GD included diverse people like male, female, adult, and child above 7 years from different households in the study areas.

4. **Household Interviews:** In depth interview was conducted at household level. The standard household survey methods were applied for selecting the respondents. The researcher visited more than one times to each of the respondents for exploring the interaction effect of industry, environment, and population welfare.

5. **Participatory Observation:** Researcher visited in the study area several times which helped better in understanding with people of the study area and made collection of data easier according to questionnaire through formal and informal discussion.

6. **Secondary Sources:** The study made diverse secondary sources of data to analyze the issues (i) the population and household census, (ii) Zilla series and Community series of the latest population census 2011,(iii) latest agricultural census, (iv) statistical yearbook, (v) various reports

like household income and expenditure survey produced by Bangladesh Bureau of Statistics (BBS), (vi) policy documents from relevant ministries, and (vii) related documents produced by international organizations/institutions like FAO or World Bank. Some relevant and cross-country evidences have been drawn from reports of other countries.

The study explored the nature of the research problems using these sources of data. Each of the data is supposed to complement to each other to draw a clear cut conclusion.

3.4 Areas under Study

The water survey conducted by Bangladesh University of Engineering and Technology (BUET) points covers the areas between the end point of Bongshai river and the connection points of Turag and Balu river, a distance around 49 kilometers by road (Joydevpur-Tangail Highway to Dhaka-Sylhet Highway to Tarabo to Rupganj).

The areas in between those points have some distinct characteristics: at the Bongshai-Turag points, mostly in the part of Konabari and Kashimpur areas, there are industrial settlements on one side and on the other side, there is low land mostly undergo during monsoon, and dwellers live mostly in scatter form but mostly attached with the river.

Few people live in the banks of river. As mentioned earlier, four areas were selected for the study: two areas from the upstream (having low pollution level) and two areas from the downstream areas. The maps of the survey areas have been given in figure 4.2. There are twelve survey points.

Figure 3.2: Study Areas

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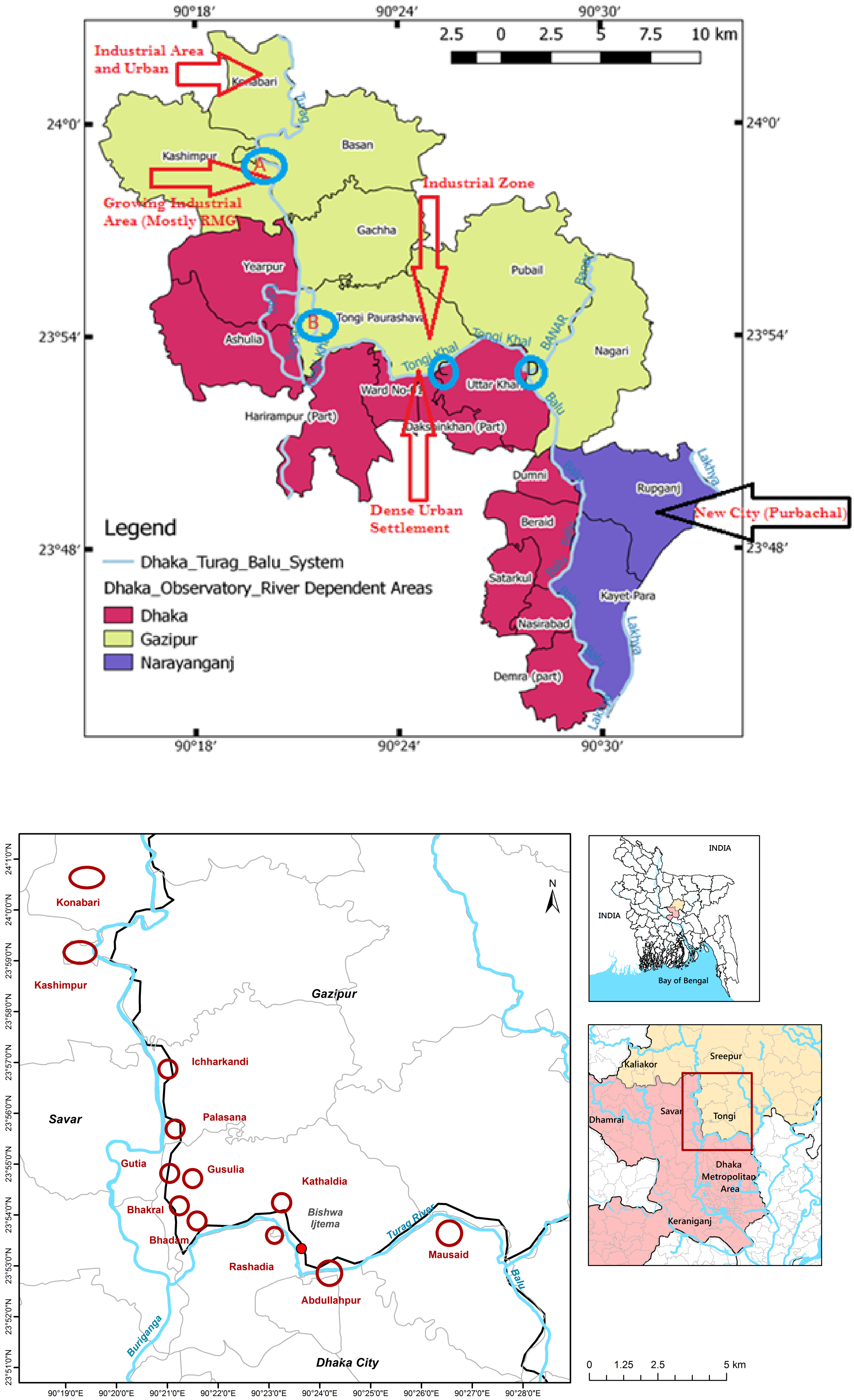

The survey areas have some features covering the issue of industrial growth, industrial waste, urbanization, and municipal waste. The areas, Kashimpur-Konabari, as labelled by A in the figure represent the zones of industrial waste (IW) from the newly growing industrial zone; areas, Bhadam and Bhakral, represent zones near to core urban periphery, some natural part and some parts affected by the municipal waste (MW).

Areas, located broadly near to Abdullahpur, labelled by C represent a mixed of heavy industrial waste and municipal waste. Areas, near to point D, represent the pollution plume. Therefore, the areas labelled by A and B represents the newly growing industrial zones and growing industries are concentrating on RMG expansion whereas areas C and D are the range of downstream areas: C is semi-downstream and D, up to now, relative downstream.

Table 3.2: Housing structure in survey areas (census, 2011)

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Area	Pucca	Semi Pucca	Kutcha	Jhupri
1. Rasadia	0	16.3	75.3	8.4
2. Mausaid	7.7	52.8	38.2	1.3
3. Bhadam	2.8	85.2	12.1	0
4. Bakral	3.4	45.5	51.1	0
5. Kasimpur	7.4	79.8	12.3	0.5
6. Konabari	15	73.9	10.7	0.4
7. Ichharkandi	8.3	20.8	62.9	8
8. Gusulia	15.1	56.6	28.3	0
9. Palasana	3.7	38.4	52.8	5.1
10. Kathadia	27.3	41.6	28	3.1
11. Gutia	9.7	28	53	9.4
12. Abdullahpur	29.7	26.8	40.6	2.9

Source: Census (2011)

In the survey areas, according to the census 2011, very few of the houses were pucca. In Kathadia, around 27.3 percent of houses were found pucca which is the second highest in the survey areas and the first highest pucca houses were in Abdullahpur.

Table 3.3: Supply of Water and condition of sanitation in study areas (according to census report 2011)
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	Condition of Sanitation				Water		
Area	With water seal	With no water seal	Non sanitation	None	Tap water	Tube well water	Others water*
1. Rasadia	0	67.9	32.1	0	39.5	48.4	12.1
2. Mausaid	42.3	46.6	10.7	0.4	67	28.1	4.9
3. Bhadam	82.4	16.8	0.3	0.5	97	2.4	0.6
4. Bakral	47.2	23	29.8	0	49.8	38.7	11.5
5. Kasimpur	84.9	11.7	3.2	0.2	85.2	13.6	1.2
6. Konabari	63.8	34.4	1.8	0	92.9	6.9	0.2
7. Ichharkandi	0.2	64.5	24.6	10.6	0	85.8	14.2
8. Gusulia	20.1	52.2	24.5	3.1	38.4	45.9	15.7
9. Palasana	6.3	22.5	64.6	6.7	18.3	81.7	0
10. Kathadia	47.3	36	16.7	0	84.9	0.5	14.6
11. Gutia	14	36.3	49.7	0	12.1	82.5	5.4
12. Abdullahpur	13	81.6	5.2	0.2	8.8	91.2	0

Source: Census (2011)
Note: * the other sources of water includes the collection of water from open-sources like river, pond, lake, etc.

In the rest of the areas, the percentage of pucca houses were less than 10 percent except Konabari (15%) and Gusulia (15.1%). Over 70% houses were semi-pucca at Bhadam, Kasimpur, and Konabari. The number of kutcha houses were the highest at Rasadia and the second highest was at Ichharkandi (62.9%).

The households have exposure to unimproved water sources although majority of the households have access to improved drinking water. Most of the households collects water from tube-wells and public taps.

Table 3.4: Ownership of household, electricity, literacy and household size (census, 2011)
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Area	Rented Household (%)	Electricity Connected HHs (%)	Literacy rate (%)	Household Size (Number of persons per family
1. Rasadia	82.1	84.7	34.9	3.6
2. Mausaid	15.5	95.9	68.3	5.0
3. Bhadam	89.7	100.0	69.0	3.3
4. Bakral	28.5	85.5	32.9	4.5
5. Kasimpur	81.3	98.8	72.2	3.5
6. Konabari	92.2	99.3	82.7	3.6
7. Ichharkandi	0.9	0.0	63.7	4.4
8. Gusulia	26.4	92.5	67.0	4.3
9. Palasana	16.9	91.4	54.8	4.4
10. Kathadia	76.4	98.4	67.6	4.1
11. Gutia	11.3	95.7	40.1	4.9
12. Abdullahpur	21.5	94.8	57.6	4.5

Source: Census (2011)

In the surveyed areas, according to Census (2011), over 90 percent of households have access to electricity and the literacy rate among the household is quite aligned to the natioanl literacy rate and the household size is around 4.3 and a significant portion of the households live in rented houses.

3.5 Selection of Samples and Method Used

The study focused on household level water security in urban riparian areas and so households were the sampling units. The households in Turag riparian areas constituted the population of the study. The study, therefore, included people residing in the households within a given areas who are more likely to be exposed to river water and river water related risks and people livjng in households a little bit away from the river and less likely to be exposed to the risks.

The study aimed to incorporate systematic random sampling method to avoid the biasness in selecting primary sampling units and sample elements. In drawing the sample, the team focused on the key sampling questions like representativeness, accuracy, sample size, time and budget constraints.

In determining the sample size, the team considered the nature of the samples, the degree of homogeneity, and the level of analysis. Since the statistical method of sample selection depends on the nature of expected outcome: proportions, means, and ratio (Chadha, 2006), the team was also aware of the selecting the statistical method in sample selection.

We assume that the chance of exposing people of the households to adjacent river was at best 50 percent. In designing the sample size, the design effect was set at 1.5. The relative margin of error (RME) at 95 percent confidence was kept at around 1 percent. The average proportion of target population in total population was expected to be nearly 8% and the average household size was 4.2.

Table 3.5: Parameter related to determination of samples

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Input: Parameter		Value	Output: Estimate	Value
Predicted value of indicator	r	0.5	Predicted r	0.5
Design effect	deff	1.5	Confidence limits	
Relative margin of error	RME	0.0996	Upper	0.5498
Proportion of target	pb	0.08	Lower	0.4502
Average household size	AveSize	4.2	Sample size	1826
Household response	RR	0.9	Standard error (se)	0.0249

Source: Author
Note: 95% Confidence limits are used in determining the sample size.

Determination of an appropriate sample size is important topics in statistics. As the survey was involved with the estimation of many parameters, the determination of a sample size was based on the estimation of a parameter of interest. According to Daniel (1999), the sample size can be simply calculated using the following formula:

$n = (Z^2 P(1 - P))/d^2$

where n= sample size, $Z = Z$ statistic for a level of confidence, $P =$ expected prevalence or proportion, and $d=$ precision or the desired margin of error. Since the prevalence of health risks in upstream and downstream is unknown to us, following the convention that $P = 0.5$, where the standard error $\sqrt{}((P(1 - P))/n)$ yields the highest standard deviation. Such consideration, in a budget constrained sampling, suggests a low level of samples but with relatively better sampling distribution.

To estimate the sample size for this study, the following formula has been used:

$n = (4 * r * (1 - r) * deff)/((RME * r)^2 * pb * AvgSize * RR)$

The standard error (se) has been estimated using the following formula:

$(r*RME)/2$ The total samples of 1826 will include the target samples, samples living near to river, and the geographical cluster defined control households and distance of the river from the household where people live in.

Table 3.6: Distribution of population and samples by areas

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Areas	Households	Pop	Water source other than tap and tube-well	Samples	Percent
1. Rasadia	193	705	12.1	68	3.72
2. Mausaid	466	2332	4.9	140	7.67
3. Bhadam	863	2850	0.6	199	10.90
4. Bakral	239	1068	11.5	85	4.65
5. Kasimpur	4065	13957	1.2	204	11.17
6. Konabari	7976	30176	0.2	242	13.25
7. Ichharkandi	423	1845	14.2	164	8.98
8. Gusulia	172	789	15.7	65	3.56
9. Palasana	471	2038	0	110	6.02
10. Kathadia	613	2640	14.6	222	12.16
11. Gutia	372	1818	5.4	107	5.86
12. Abdullahpur	1860	8289	0	220	12.05
Total	17713	68507	-	1826	100.00

Source: Author

The raw data collected using Open Data Kit (ODK) and the collected data has been converted into STATA. The data has been investigated to know its quality. The quality check has been done based on the understanding of respondents about the questions of the survey. The filled in questionnaires poorly understood by the respondents have been removed to enhance the quality of data. Moreover, there were some entry error which are also removed. After all correction, the final sample size becomes 1,826.

Figure 3.3: Location of survey samples

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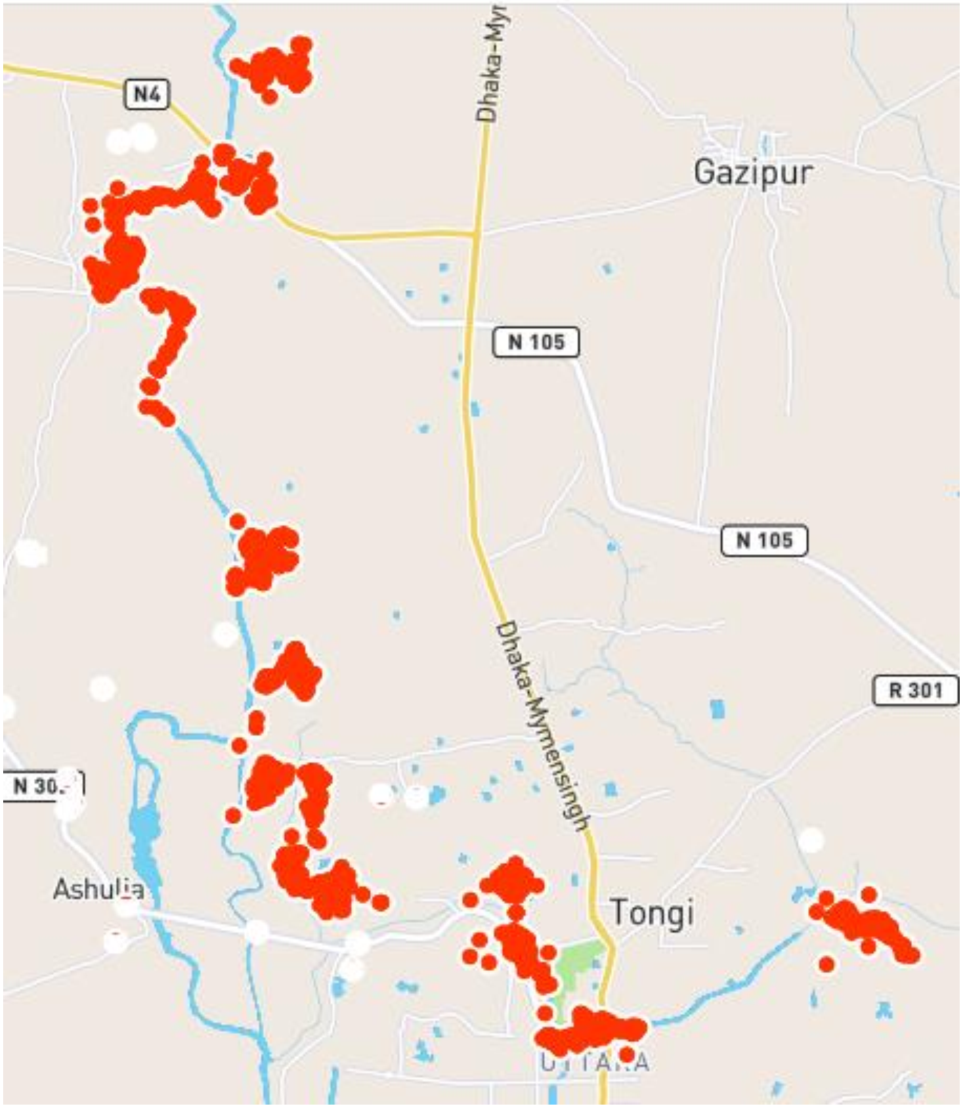

Source: ONA data collection tool

The surveyed sample households.

3.6 Survey Instruments

This section deals with the purposes of the six core modules and the specific questions within each modules have been included in the study. The household head or his/her spouse were the target respondents. While most of the modules required information at household level, some were applicable to all individuals within the household. To understand intra-household differences in water security, certain questions were asked for the adult male and female separately.

3.6.1 Module 1-3 – Identification, Demographics and Health

This module was included to identify the households and to track next round survey. This module inluded the ID of the enumerator, a short consent note, GPS coordinates of the household, area code, and periods of residence of the household.

According to the module 2, information on the main characteristics of household members were gathered. Firstly, all household members were asked about their gender, age and the presence of diarrhoea in the last 2 weeks of the survey. Secondly, household members aged 5 or more were asked about their education, school attendance and reasons for not attending if any. Third, the household head and his/her spouse were asked to respond questions about their main occupation, frequency and seasonality of their activity and the type of payment received.

Household members were asked questions related to various diseases faced by the members of the households and the number of days lost due to illness in module 3.

3.6.2 Module 4 – Domestic water use and sanitation

In this module the access, affordability, quality, storage and reliability of water use by households together with the type of sanitation and hand washing behavior of household members were assessed. The targeted respondents were the household head and his/her spouse. Firstly, each respondent were asked about their the main sources of water for drinking, bathing, and cooking. Second, each respondent will be asked to provide information about the affordability of the water they use, mode of payments of water used, and affordability to pay cost of water. Thirdly, each respondent was asked questions about the quality of the water they use for drinking purposes, in particular, their perception of the color, taste and safety of the drinking water. Fourthly, each respondent was asked about storage of water. All these were collected through observation (by the enumerator) of the household premises. Fifthly, each respondent was asked about the reliability of the main source of drinking water they use. These questions included alternative sources in case of unavailability of the main source, frequency of unavailability and their behavior resulting from it. Lastly, each respondent was asked about the type of toilet facility they use and children use and their hand washing habits.

3.6.3 Module 5 - Poverty

The well-being status of household members were assessed using the questions in this module. For this, the module included questions on objective and subjective metrics of poverty and life satisfaction. Objective metrics included questions about sources of income, occupancy status, possession of assets, main type of lighting and cooking fuel material and housing conditions. Subjective metrics included the perception of the respondent of his/her well-being situation in comparison with people of his/her village, and an overall assessment of how he/she describe his household situation. Each participant was first asked the sequence of questions related to objective metrics and then the subjective ones.

3.6.4 Module 6 - Selection of priority problems

The primary concern of this study was to identify the top socioeconomic and water-related priorities that people consider the government should address. To identify these priorities, the participants were asked to rank the top three concerns that s/he thought the government could help to solve. Secondly, the participants were asked their concern regarding drinking water, water for agriculture and aquaculture, and the natural environment. Participants were also asked to rank the top three concerns that apply in each case.

3.7 Survey Management

To ensure the collection of quality data of the survey, monitoring was at two stages: first, a supervisor used to oversee and monitor the survey activity and progress of the work. The research associate acted as the supervisors. The respective PhD and MPhil candidates jointly monitored the overall survey. The supervisor updated the survey progress to the PhD/MPhil candidates and they used to inform the update to the team leader.

3.8 Operationalization of Concepts

3.8.1 Measuring Uni-dimensional Poverty

In measuring poverty statistics, poverty line, the minimum threshold level income or expenditure per capita, plays critical role. Formally, following Ravallion (1998), the poverty line for an individual, z_i, is defined as the minimum spending or consumption (or income, or other measure) per capita needed to achieve at least the minimum utility level u_z, given the level of prices (p) and the demographic characteristics of the individual (x), so

$$z_i = e(p, x, u_z) \tag{3.1}$$

Since u_z is immeasurable, and hence $e(.)$ too, it is common practice in many countries to construct one per capita poverty line for all individuals, but the line adjusts a lot of factors controlling the size of the threshold value, for example, prices of the goods and services, household composition, location of the household, and geographical variables. The adjusted per capita is then compared with the threshold poverty line to identify if the individual lives below the poverty line or above the poverty line.

The simple headcount index is the simplest and best known and most used poverty measure. The headcount is calculated by comparing the income y_i of each household to the poverty line z, the index $i = 1, \ldots, M$, where M is the total number of households in the sample. An indicator variable is constructed which identify whether the household is poor having per capita expenditure below the threshold poverty line and the indicator variable takes value 1 and when the per capital expenditure falls above the poverty line the value of indicator variable becomes 0. More technically, if per capita expenditure is greater: $I(y, z) = 1$ if $y_i < z$, otherwise 0. The headcount index (HCI) is simply the sample average of the variable $I(y, z)$, weighted by the number of people in each household n_i. The measure is calculated by first counting the number of poor individuals, $D = \sum I(y_i, z)n_i$ and the total population of the sample can be calculated similarly as $N = \sum n_i$. Therefore, the overall headcount is then the ratio of D and N, that is, $H = D/N$, where the sample is not representative of the underlying population (e.g., if the sampling strategy involved random stratification), population weights should also be included in the calculation.

This second widely-used measure is poverty gap which measures the amount of money by which each individual falls below the poverty line. The starting point is to calculate the total shortfall,G, in welfare indicator for the poor population: $G = \sum \left(z - y_i\right) I \left(y_i, z\right) n_i$ where the poverty line is z, income is y, $I(z, y_i)$ is a 0 or 1 indicator of poverty for each household, household size is n_i, the total number of households in the sample is M, and individuals are indexed by i. The calculation gives the total sum of resources that would be needed to make up for the gap between the existing incomes of the poor and the official poverty line. The calculation above is correct only if income is in per capita terms.

The third measure is Squared Poverty Gap Index (SPG). Foster, Greer, and Thorbecke (1984; henceforth, FGT) propose a class of measures built on this idea which have found their way into much of the poverty analysis published by the World Bank. With income expressed in per capita terms, the measures take the form: $\frac{1}{N} \sum \left(\frac{z-y_i}{z}\right)^{\alpha} I \left(z, y_i\right) n_i$. When income is in adult-equivalent terms, the household size variable n_i should be replaced with the adult equivalent size a_i.

The parameter α determines the degree to which the measure is sensitive to the degree of deprivation for those below the poverty line. When $\alpha = 0$ the measure collapses to the headcount measure and when $\alpha = 1$ the measure is the normalized version of the poverty gap. When $\alpha = 2$, we have squared poverty gap measure.

3.8.2 Measuring Multidimensional Poverty Index

The MPI has three dimensions: education, health and living standard. Each of the dimension has different indicators. Education has two indicators - years of schooling and school attendance. The health dimension has also two indicators

Figure 3.4: Three dimensions and ten indicators of Multidimensional Poverty Index (MPI)
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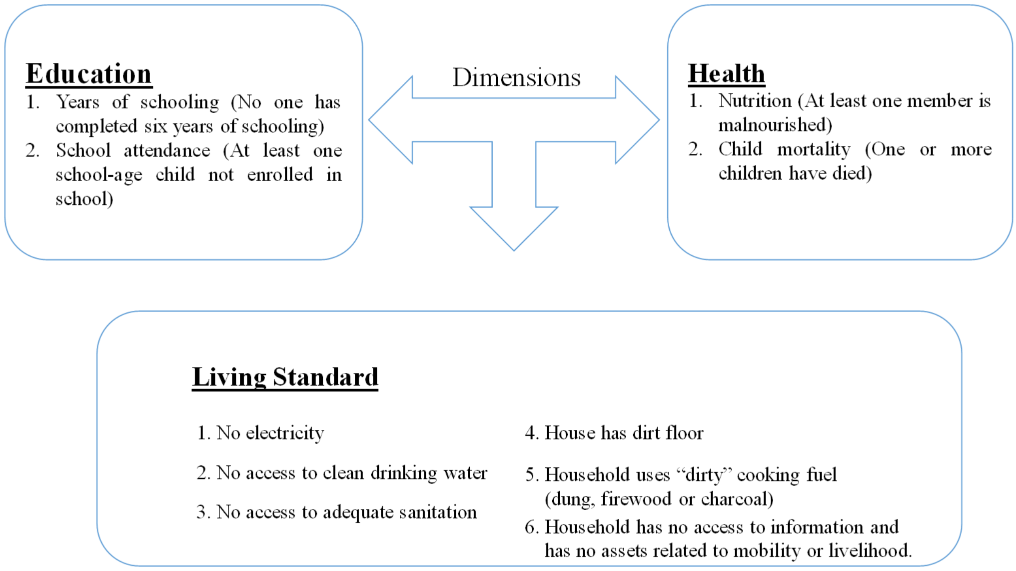

Source: https://ophi.org.uk/

- nutritional status and child mortality. The living standard dimension has six indicators covering a wide range of accesses: (i) access to electricity, (ii) access to better cooking fuel, (iii) access to better shelter, (iv) access to information, (v) ownership of vehicle and (vi) access to better means of livelihood.

We have assigned one-third weight on dimension. The weight on each indicator of the specific dimension is assigned by dividing the dimension weight by number of indicators in the dimension. Each indicator of health and education dimension of MPI has an weight of (1/6) where as each indicator of living standard dimension has an weight of (1/18).

For more technical representation of measuring MPI, let assume that MPS is the aggregation of the score of three dimensions - health, education and living standard.

$$MPS_i = \sum \lambda_i E_i + \sum \gamma_i H_i + \sum \phi_i LS_i \tag{3.2}$$

In the above equation, λ and γ represents the specific weight assigned on the specific dimension. In our case, $\lambda = \gamma = \phi = \frac{1}{3}$ and $\gamma = \frac{1}{24}$. It is noted that $\sum \lambda_i = 1/6$, $\sum \gamma_i = 1/6$,and $\sum \phi_i = 1/18$. The multi-dimensional poverty index (MPI) value will be in between 0 and 1: a zero value will imply highly secured household whereas a value of 1 will indicate perfectly unsecured household. A household is classified as multidimensional poor (MPI_{poor}) if the MPS_i value of that particular household is above 0.33, that is, a household is multidimensional poor if it is deprived in more than 33 per cent of the weighted indicators.

3.8.3 Measuring Dynamics of Poverty

Suppose that D_t represents the set of observable individual specific variables like age, gender, education, training, access to various services, and some household specific characteristics like the number of dependent, the household size, literacy rate within the household, labor force participation etc. Also assume that X_t presents the set of observable exogenous variables. This includes community level information like infrastructure, government support for anti-poverty strategies like social safety net, and other measurable indicators.

Following Osmani (2010), we can propose the income generation process over time by the following recursive system of dynamic equations:

$$Y_t = F(D_t, X_t) + e_t \tag{3.3}$$

$$D_t = G(Y_{t-1}), D_{t-1}), X_t) + \varepsilon_t \tag{3.4}$$

where F is the income generation function, with endowments and exogenous factors as its arguments; G is the vector of functions – with one function for each element of D_t, and the terms e_t and ε_t represent the stochastic disturbances.

Based on the income generation process over-time, individuals or households can be classified into major five dynamic categories:

(i) Chronic poor or chronically poor are those whose life trajectories always stay below the poverty line;

(ii) Transitory poor or churners are those whose trajectories keep fluctuating around the poverty line;

(iii) Movers are those whose trajectories start from below the poverty line but rises above it at some stage and not fall again;

(iv) Fallers are those whose trajectories start from above the poverty line but falls below at some stage and can never to rise above it again within the given time of analysis;

(v) Never poor are those whose trajectories always stay above the poverty line.

3.8.4 Construction of Water Security Index

At household level, water security implies access to safe piped water, access to safe sanitation, and better hygiene. In our case, to measure water security at the household level, we are considering water source, water quality as proxy of reliability, affordability, sanitation and hygiene indicators to measure the household level security index.

Table 3.7: Indicators and corresponding weight of water security index
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Indicators [weight]	Sub-indicators [weight]
Water Source [1/6]	Improved drinking water [1/30]
	Improved cooking water [1/30]
	Improved bathing water [1/30]
	Improved washing water [1/30]
	Accessible within 10 minutes [1/30]
Water Quality/	Drinking water is safe [1/24]
Reliability [1/6]	Drinking water is treated [1/24]
	Water storage is cleaned regularly [1/24]
	Water has no arsenic/germ/iron [1/24]
Water Affordability [1/3]	Monthly water bill is less than 120 [1/3]
Sanitation [1/6]	Improved sanitation facility [1/6]
Hygiene [1/6]	Maintain hygiene [1/6]

Source: Author

We have assigned one-third weight on water source and water quality or reliability and we have divided the weight into two and equal weight has been assigned on water source (1/6) and water quality/reliability (1/6) dimension. The water source dimension includes broadly two types of variables: (i) sources of water for household activity and (ii) distance of water source from the household. The household level water usage considers sources of drinking water, cooking water, bathing water, and water for washing utensils and clothes. It is to be mentioned here that each of the the water source variable has two states: the access to that specific water during dry season and during monsoon. The switching or dependence on unimproved water covers the state of stability of household's access to safe water for household purposes as well as drinking purposes.

The one-third weight has been assigned on affordability dimension and affordability is measured based on threshold monthly expenditure on water. We have considered the median expenditure on water as the benchmark. The third dimension considers sanitation and hygiene where a weight of (1/6) has been assigned on sanitation and a weight of (1/6) on hygiene. To measure access to safe sanitation, the variable availability and usage of improved sanitation facility has been used and hygiene dimension considers whether the household members maintain hygiene, i.e., they wash their hand before eating and after the use of latrine.

For more technical representation of measuring household level water security index, let assume that WSQR represents the sources and quality/reliability of household level water source which is the aggregation of different dimensions of water sources based on usages of water for various purposes like drinking, cooking, bathing, and washing as well as accessibility and reliability of the water source.

$$WSQR_i = \sum \lambda_i WS_i + \sum \gamma_i QR_i \tag{3.5}$$

In the above equation, λ and γ represents the specific weight assigned on the specific dimension. In our case, $\lambda = \frac{1}{30}$ and $\gamma = \frac{1}{24}$. It is noted here that $\sum \lambda_i = 1/6$ and $\sum \gamma_i = 1/6$. Therefore, the total weight assigned on $WSQR$ dimension is $\frac{1}{3}$. The second dimension of household level water security index considers the affordability which has an weight of $\frac{1}{3}$, say, this is represented by ω.

$$WA_i = \sum \omega_i WS_i \tag{3.6}$$

The third dimension - sanitation and hygiene - has two dimensions and each receives an equal weight of $\frac{1}{6}$. Let the weight assigned on sanitation is given by ϕ and the weight assigned on hygiene is given by Φ.

$$SH_i = \sum \phi_i S_i + \sum \Phi_i H_i \tag{3.7}$$

The combination of all the three equations - $WSQR$, WA, and SH will give us the aggregate score of household level water security.

$$WSI = WSQR_i + WA_i + SH_i \tag{3.8}$$

The water security index (WSI) value will be in between 0 and 1: a zero value will imply highly water unsecured household whereas a value of 1 will indicate perfectly water-secured household. A household is classified as water poor (WP) if the water security index value of that particular household is below 0.33.

3.9 Statistical analysis

To analyze the survey data both descriptive and econometric techniques were followed. In the descriptive analysis, the summary of the variables has been described. The summary statistics include the standard measures of statistics like the measures of central tendency (mean, median, quartiles, deciles, percentiles, etc.), measures of dispersion (variance, standard deviation), and some pair-wise correlation measures of the respective variables in the analysis. The univariate and bivariate frequency distributions have been described to show the incidence of specific concerned variables. The rigorous econometric techniques have been used to test the hypotheses of the study and to draw inferences based on the econometric models.

3.9.1 Determinants of open-source water and water poor

The descriptive analysis shows that households having the contact with open-source of water have higher number of ill members and the incidence of various diseases is high among them compared to alternate group. The pairwise correlation analysis suggests some associations among selective variables. Since descriptive and correlation analysis is not sufficient to find the causal relationship, we are using the regression modeling technique to find the effect of the potential variables on outcome indicators.

To do the modeling work, first we want to find the factors pushing the households to do contact with open-source of water for various purposes and then we want to know the effect of such contact on treatment expenditure. We have defined a binary variable denoting the status of the exposure to open-source of water (y_i). The variable contains a value 1 if any member of the household does have contact with open-source of water and 0 otherwise. Therefore, the chance of the contact with open-source of water can be modeled using the Logistic distribution as follows:

$$Pr[y_i = 1|X_i] = e^{X\beta} / \left(1 + e^{X\beta}\right) \tag{3.9}$$

Here, X represents the vector of explanatory variables and β is the vector of regression coefficients. The above expression shows that the probability depends on the vector of explanatory variables X and the vector of coefficients β. The single-index form with conditional probability can be written as $Pr[y_i = 1|X] = F(X_i'\beta)$ where $F(\cdot)$ is a specified function. To ensure that $0 \leq P \leq 1$ it is natural to specify $F(\cdot)$ to be a cumulative distribution function (Cameron and Trivedi, 2010).

In our case, we are dealing with an outcome variable which binary in nature. The density of y_i, or more formally its probability mass function, is $f\left(y_i|X_i\right) = P_i^{y_i}\left(1-P_i\right)^{y_i}, y_i = 0, 1$, and here $P_i = F\left(X_i^{\prime}\beta\right)$. The density function, here, will give us the following log form.

$$lnf\left(y_i\right) = y_i ln\left(P_i\right) + \left(1-y_i\right) ln\left(1-P_i\right) \tag{3.10}$$

The log-likelihood function is, therefore, given by the following form:

$$L_N(\beta) = \sum\left\{y_i lnF\left(X_i^{\prime}\beta\right) + \left(1-y_i\right) ln\left(1-F\left(X_i^{\prime}\beta\right)\right)\right\} \tag{3.11}$$

The maximum likelihood estimator of $\hat{\beta}$ can be obtained by the differentiation of the above likelihood function with respect to β as follows:

$$\sum\left\{\left(y_i/F_i\right)F^{\prime}X_i + \frac{\left(1-y_i\right)}{\left(1-F_i\right)}F^{\prime}X_i\right\} = 0 \tag{3.12}$$

where $F_i = F\left(X_i^{\prime}\beta\right)$, and $F_i^{\prime} = F^{\prime}\left(X_i^{\prime}\beta\right)$. Simplifying the expression we can write the expression below:

$$\sum\left\{\frac{y_i - F\left(X_i^{\prime}\beta\right)}{F\left(X_i^{\prime}\beta\right)\left(1-F\left(X_i^{\prime}\beta\right)\right)}F^{\prime}\left(X_i^{\prime}\beta\right)X_i\right\} = 0 \tag{3.13}$$

Since the expression does not give the explicit solution for the estimators, we can use the Newton-Raphson iterative procedure to have a converged estimator of the coefficients as the log-likelihood is globally concave. Under the assumption that the cumulative density function follows a logistic distribution, the expression in the above equation simplies to the following expression:

$$\sum y_i - \bigwedge(X_i'\beta)X_i = 0 \tag{3.14}$$

Since $\bigwedge' = \bigwedge(z)[1 - \bigwedge(z)]$

The empirical strategy to estimate the odds of contacting with open-source of water (osw), we propose the following models:

Model 1:

$$ln\left(\frac{Pr\,(osw_i = 1)}{1 - Pr\,(osw_i = 1)}\right) = \beta_1 + \beta_2 WCT_i + u_i \tag{3.15}$$

Model 2:

$$ln\left(\frac{Pr\,(osw_i = 1)}{1 - Pr\,(osw_i = 1)}\right) = \beta_1 + \beta_2 WCT_i + \beta_3 WATCOST_i + u_i \tag{3.16}$$

Model 3:

$$ln\left(\frac{Pr\,(osw_i = 1)}{1 - Pr\,(osw_i = 1)}\right) = \beta_1 + \beta_2 WCT_i + \beta_3 WATCOST_i + \gamma_k HHC_k + u_i \tag{3.17}$$

Model 4:

$$ln\left(\frac{Pr\,(osw_i = 1)}{1 - Pr\,(osw_i = 1)}\right) = \beta_1 + \beta_2 WCT_i + \beta_3 WATCOST_i + \gamma_k HHC_k + \lambda_m REGION_m + u_i \tag{3.18}$$

Here, the dependent variable as defined earlier is binary in nature. The explanatory ‘WCT’ refers to the required time to collect water from the water point, ’WATCOST’ means the average monthly spending on water which has been termed as affordability referring the capacity of the households to pay the water cost, poverty is defined as the lack of income to meet the required basic needs along with the allowances for non-food items, 'HHC' refers to household characteristics which includes the characteristics of the household head (gender, age, and education) and household size, and 'REGION' refers area characteristics which have been represented as dummy variables of the areas like dummies for upstream, middle stream, and downstream. The term u_i is the stochastic disturbance term. Since poverty is basically a multidimensional form of deprivation, affordability and poverty status could be interlinked and the models are estimated separately to understand the effect of poverty on contacting with open-source of water.

In the above model, the null hypotheses are: (i) $H_o : \beta_2 = 0$,(ii) $H_o : \beta_3 = 0$, (iii) $H_o : \beta_4 = 0$, and (iv) $H_o : \gamma_k = 0$ whereas the alternative hypotheses of the null hypotheses are: (i) $H_o : \beta_2 \neq 0$,(ii) $H_o : \beta_3 \neq 0$, (iii) $H_o : \beta_4 \neq 0$, and (iv) $H_o : \gamma_k \neq 0$ respectively. The first null hypotheses states that distance from freshwater point has no effect on the contact with unimproved water whereas the corresponding alternative hypothesis states that distance matters for access to improved water for all purposes. Similar explanation applies for other explanatory variables.

The expression e^{β} gives the odds ratio. If $e^{\beta} > 1$, then the respective independent variable will have a positive effect on the predictand, that is, if the predictor increases, the predictand will increase. If $e^{\beta} < 1$, then the respective independent variable will have an opposite effect on the predictand, that is, if the predictor increases, then the predictand will decrease.

The expression $e^{\beta StdX}$ measures the changes in odds of the predictand for a standard deviation change in predictand (Long & Freese, 2006).

3.9.2 The Effect of the Interaction with open-source Water on Illness, Diseases, Out of Pocket Expenditure, and Productivity

The modeling of economic cost of open-source water contact is relatively not easy. It depends on the nature of the dependent variable. The chapter seven focuses on assessing the effects of open-source water contact on health risks (illness and diseases), productivity, treatment expenditure, and poverty. The variable illness is continuous in nature and contains the integer value starting from zero and the variable number of diseases faced by the household members is of similar fashion of illness variable. The illness is measured by the number of ill members in the households within one months during the survey period.

The measurement of productivity is tricky and can be modeled by considering continuous variable or transformed binary variable based on specific threshold value. Treatment expenditure is also continuous in nature but it is truncated from below. Finally, poverty and poverty dynamics are being modeled considering them as binary variable.

Households which are contacting with open-source of water may be affected through various kinds of health risks like illness of the members, higher treatment expenditure to reduce the risks, and so on. The descriptive analysis and the correlation analysis show that the number of ill members (illmem) are high among the households whose members do contact with open-sources of water and incur higher treatment cost (treatcost) compared to their alternate group. Such analysis hardly reflects the causal relationship. The causal relationship is being modeled using the following regression models:

$$illmem_i = \lambda_0 + \lambda_1 osw_i + \lambda_k HHC_{ki} + u_i \tag{3.19}$$

$$numdisease_{i_i} = \gamma_0 + \gamma_1 osw_i + \gamma_k HHC_{ki} + u_i \tag{3.20}$$

$$log\,(treatcost)_i = \mu_0 + \mu_1 osw_i + \mu_2 illmem_i + \mu_k HHC_{ki} + u_i \tag{3.21}$$

To understand the relationship of number of ill members in the households with their characteristics and treatment cost with contacting the open-source water along with some characteristics of the households, we could use the ordinary least square (OLS) method but both 'illmem' and 'treatcost' are truncated from below. Therefore, to model the relationship, we used truncated regression analysis, the Tobit model.

The specification of the econometric models considers the interaction with open-source water source as the key determinants along side a set of explanatory variables from households, and locality. Since the coefficient of the contact variable measures the difference in the outcome due to the state of contacting with unimproved water or not, essentially, it represents the mean-difference between the two groups. Therefore, it will be very reasonable to make the comparison group comparable based on the potential determinants of the contact variable. We use what has come to be known as the effect of a contact with unimproved water. The assessment of the effect of such exposure requires a group affected by the event, and another group not affected by the event to compare the outcomes.

To understand how the OLS estimators are obtained in linear regression model, let assume that the data are specified as $[y, X]$, where y is the observations on the dependent variable and X is the vector of explanatory variable. The general regression model is specified as follows (Greene, 2012):

$$y = E[y|X] + u \tag{3.22}$$

In the above equation, E[y|X] is the conditional expectation of the dependent variable given X and u is the vector of unobserved errors. Let assume that there is a linear relationship between y and X and is expressed as follows:

$$E[y|X] = X\beta \tag{3.23}$$

Therefore, we can write

$$y = X\beta + u \tag{3.24}$$

If there is N observation, then we have $N \times 1$ vector of observation of the dependent variable. If there are k - variables, then X is an$N \times K$ regression matrix. In this equation, u is $N \times 1$ stochastic error vector.

The OLS estimators are the estimators that minimize the sum of squared errors.

$$u'u = (y - X\beta)'(y - X\beta) \tag{3.25}$$

Setting the derivative with respect to β equal to 0 and solving for β yields the OLS estimators,

$$\hat{\beta}_{OLS} = (X'X)^{-}X'y \tag{3.26}$$

It is assumed that the inverse of the matrix $X'X$ exists and it is nonsingular. The obtained OLS estimators will be best linear and unbiased estimators.

The truncated regression fits a model of a dependent variable on independent variables from a restricted part of a population. If x has a normal distribution with mean[1] µ and standard deviation σ, the density of the truncated normal distribution is (Greene, 2012)

$$f\left(x|a < x < b\right) = \frac{f(x)}{\Phi\left(\frac{b-\mu}{\sigma}\right) - \Phi\left(\frac{a-\mu}{\sigma}\right)} = \frac{\frac{1}{\sigma}\phi\left(\frac{x-\mu}{\sigma}\right)}{\Phi\left(\frac{b-\mu}{\sigma}\right) - \Phi\left(\frac{a-\mu}{\sigma}\right)} \quad (3.27)$$

where ϕ and Φ are the density and distribution functions of the standard normal distribution.

Let assume that $y = X\beta + u$ is the regression model where y is the continuous outcome variable either observed or not observed. Under the assumption that $u \sim (\mu, \sigma^2 I)$ and a with lower limit and b with upper limit, the log-likelihood function is

$$lnL = -\frac{n}{2}log\left(2\pi\sigma^2\right) - \frac{n}{2\sigma^2}\sum_{j=1}^{n}\left(y_j - X_j\beta\right)^2 - \sum_{j=1}^{n} log\left\{\Phi\left(\frac{a-x_j\beta}{\sigma}\right) - \Phi\left(\frac{b-x_j\beta}{\sigma}\right)\right\}$$

3.9.3 The Propensity Score Matching Model

Using the propensity score matching (PSM) technique, the average socioeconomic indicators, like expenditure, number of ill-members, number of diseases, loss of working days, and poverty etc. of households that have the interaction with unimproved water to that of other groups who do not have such exposure.

PSM can be used to balance distribution of both participating households and control households when non-experimental design is adapted (Rosenbaum & Rubin, 1983). Through balancing, it removes expected effects of exposure bias. Balanced households are also matched because it is derived based on the known characteristics of both groups of households. Because of balancing and matching of the distribution of comparison groups, differences in mean

[1] Compared with the mean of the untruncated variable, the mean of the truncated variable is greater if the truncation is from below, and the mean of the truncated variable is smaller if the truncation is from above. Moreover, truncation reduces the variance compared with the variance in the untruncated distribution.

outcomes of these groups can be estimated and statistically tested as significant or insignificant.

To measure the gap in welfare indicators between users and non-users of open-source water, following Rosenbaum & Rubin (1983), Let us consider that Y_1 be the outcome that would result if a household has contact with unimproved water and Y_0 the outcome that would result if the same household does not expose to. Let $osw = 0, 1$ denote the binary indicator of contact ($D = 1$ if there is contact, 0 otherwise). For a given household i, the observed household income is then $Y_i = Y_{oi} + osw_i(Y_{1i}–Y_{0i})$. Therefore, we can attempt to identify the effects of the interactions with unimproved water as follows:

The average effect $E(Y_1–Y_0)$ is the average difference, like, expenditure between the two groups. The average effect of the event on the exposed household is $E(Y_1–Y_0|osw = 1)$. This parameter is the one receiving most attention in assessing the effect measures the average expenditure differential between the expenditure that households exposing to unimproved water and the expenditure that they would gain if they had not exposed. The average treatment effect on the non-treated: $E(Y_1–Y_0|osw = 0)$ is the average expenditure difference between the potential or expected expenditure that the households who did not exposed to the event ($osw = 0$) would get if they had ($E(Y_1)$) and the real income that they earned (Y_0); and the net average effects (ATT) of event can be derived by taking the differences of ATT of both program participants and non-participants (Rosenbaum & Rubin, 1983).

3.10 Tools used to manage data

The data were collected using potable tablets. The questionnaires were transformed into online version and made suitable for ONA software, a tool of ODK.

Primary level of analysis was done using ONA and further statistical analyses were done in STATA, the sophisticated statistical package used in the research. For statistical analysis the data were transformed from ONA to STATA and then reorganized and processed through STATA.

3.11 Conclusion

This chapter describes the detailed methodology of selection of sample areas, sample households, survey instruments used, and the methods of analyzing quantitative data. It describes the econometric and statistical models used in chapter 5 and 6. In the subsequent chapters, we have presented the results of this study. In chapter 4, we have presented the the general charateristics of the households and members of the households along with their water use behavior. In chapter 5, and 6, the results are presented in accordance to the objectives. The results related to the first objective of the study "studying the linkage between water security, attributes of the household, and ecological attributes" has been presented in chapter 5. The results related to the second objective of the study "studying the linkage among health risks, productivity, and health expenditure in relation to the interaction with open-source water" have been discussion in chapter 6. The last chapter summarizes the results of the study, draws conclusion, and proposed recommendations.

Chapter 4

Characteristics of the Households

4.1 Introduction

The household was the unit of analysis of this study. The household survey was conducted to gather socioeconomic data of the households. The detail methodology of the survey was discussed in chapter 4. In total, 1826 households were surveyed and the data were were collected through the structured questionnaire.

This chapter dealt with different characteristics of a representative samples of the population living in the areas of the study which include (i) the water security related variables, (ii) the residence and housing, (iii) lighting and cooking fuel, (iv) durable Assets of the Households, (v) household size, (vi) characteristics of the household members, (vii) uni-dimensional Poverty Analysis, (viii) multidimensional poverty, (ix) poverty dynamics, (x) source of water, (xi) perception of the quality of water and the methods of storing water, (xii) cost and payment mode of water, and (xiii) water security index and water poor.

The results have been presented, in this chapter, either in tabular or in graphical forms. The tables or figures represented the percentage of univariate or bivariate frequency distributions, the average, and the weighted average of the respective variables.

4.2 Variables used

Various variables were generated from the survey data. The variables were made compatible for descriptive and econometric analysis in the light of the objectives of the study. The household related variables were constructed based on the previous research works and those of BBS. The study used household as the unit of analysis and it was considered as the social institutions. The households comprised of people in the dwelling place where one or more individuals having matrimonial or blood or both relations live and take food together under a common cooking arrangement. Each household was led by a specific person called household head played key decision- making roles in various socioeconomic and political activities. In this study, the permanent family members, boarders and lodgers (if any), servants and other employees who often lived in the household and took food together were considered as family members.

Household members might have different occupations. Any individual who had any income generating occupation was considered as an earner. The individuals who had no formal education was treated as illiterate and the years of schooling referred to the completion of the specific class/degree not just the attendance.

The surveyed households had residence either of own or rented to live which might be a building or tin-shed during the survey period. The household expenditure included food, clothing, all consumable items including medical, treatment and other services.

Water security was considered as the key variable in the present study. Water security constituted as the household accessing the safe water from safe water source for drinking, cooking, bathing, and washing the clothes and utensils at the affordable price. Water security considered three important components: (i) affordability, (ii) accessibility, and (iii) stability.

Table 4.1: Water security related variables

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Variable	Description
Affordability	The median expenditure on water below the burden threshold and households which needed to pay more than the median expenditure was considered as the affordability constraint
Accessibility	The accessibility was measured by using the required time to collect water from the improved water source.
Stability	The improved water source was uninterruptedly available during any change like the change in seasonality e.g., dry season and monsoon, climate change, and so on.

The key variable of this study was water security which has been presented in table 5.1.

4.3 Residence and Housing

There were 1826 number of households selected from twelve locations of Dhaka urban riparian areas (areas near to Turag river and Tongi khal) for the present study. Most of the surveyed areas were adjacent to the industrial growth centers. Therefore, households often came from various parts of the country and were involved in various economic activities and lived mostly near to their working places.

Table 4.2: Residence and Housing Structure of the households in Turag riparian areas under study design
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Variable	Description	Percentage of HHs
Years of residence	Less than 1 year	8.63
	1-4 years	15.24
	5-10 years	12.79
	More than 10 years	63.34
Current occupancy status	Owner	51.59
	Tenant	31.65
	Free accommodation	16.76
Wall materials	Brick/cement	37.35
	Tin sheet	57.83
Roof materials	Brick/cement	6.52
	Tin sheet	92.44
Floor materials	Concrete	60.19
	Earth/soil	35.49
	Wood/bamboo	3.56

Source: REACH Household Survey (2018)

The survey results (Table 4.2) showed that around 8.63 percent of the households started their living in those areas for the last one year and 15.24 percent of households were living there for around 1 to 4 years, 12.8 percent of the households living for 5-10 years and majority of the households (around 63.34 percent) were living the study places for more than 10 years.

In sum, over three-fourth of the households were living there for more than 4 years and less than 9 percent of households were newcomers. It was apparent from the study (Table 4.2) that newcomers in the urban riparian areas was estimated at 8.63 percent and over time this rate increased because of rural-urban migration, the faster urbanization, the higher opportunity for getting job, and the higher income opportunity.

Results presented in the Table 4.2 showed that around 51.59 percent of households had their own houses while around 31.65 percent of households were tenant and 16.76 percent of households lived in public land/embankment at no cost.

The housing structure also represented the state of subjective poverty. A better shelter is a fundamental human right. But the elements of housing are not well-defined. We perceived that a brick house was better than a tin-made house and a tin-made house was better than a straw-made house.

The Household Income and Expenditure Survey (BBS, 2016) showed that in urban areas, brick/cement was the key roof material of around one-fourth of the households. But in the present study areas, houses of 6.52 percent of households had brick/cement based roof. From Table 4.2 it appeared that in our study areas the most of the houses had tin/ corrugated iron-roof (92.44%) and few had brick/cement made roofs.

The HIES (2016) also showed that in urban areas, the materials of the walls of urban dwellings used were mostly brick and cement whereas in our study areas, our survey showed that the materials of the walls were mostly tin/corrugated iron sheets (57.83%) and brick and cement (37.35%) was the second major materials of wall. Few walls of the houses were made of earth/soil (3.4%). Concrete (60.19%) and earth/soil (35.49%) were the key floor materials.

4.4 Lighting and cooking fuel

The households requires cooking and lighting fuel for better living. The sources of cooking fuel and lighting varies by location such as urban, peri-urban, or rural. In some cases, the supply disruption impedes the access to those sources. As cooking fuel, households use natural gas, fire wood, straw, shrubs, grass, animal dung, and other sources. On the other hand, for lighting source, the households depend on grid supplied electricity, solar electricity, kerosene, and other sources.

Table 4.3: Sources of lighting and cooking fuel used by households under study in Turag riparian areas
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Variable	Description	Percentage of HHs
Cooking fuel	Natural gas	8.63
	Fire wood	15.24
	Straw/shrubs/grass	12.79
	Animal dung	63.34
Lighting source	Grid supply electricity	93.67
	Kerosene	3.56

Source: REACH Household Survey (2018)

Results provided in Table 4.3 showed that in the study areas, around 93.67 percent of the households had grid supply electricity connection, similar findings were reported by BBS in the report of HIES (2016). Few households (3.56%) used kerosene as lighting fuel while for cooking purpose, most of the households used fire wood/fire sticks as cooking fuel (75.6%) and 44.4 per cent households had gas connection. It appeared from the study that most of the households used multiple sources of fuel for lighting and cooking purposes.

4.5 Equipment used in the Households

The ownership of some equipment represents the relative strength of an individual or a household. Access to information equipment and accessories indeed increase the access to information, the access to vehicle increases the chance of better transportation, and access to electric equipment implies the relative better off condition of the household.

In our study, we included some specific equipment for amenities of the households. These equipment were important to determine the multi-dimensional poverty of the household.

Table 4.4: Different equipment used in the households of the Turag riparian areas
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Description	Percentage of HHs
Television	74.04
Radio/CD/DVD player	6.79
Computer/ laptop	5.15
Bicycle	8.60
Motorcycle	3.29
Auto-bike/tempo/CNG	1.10
Car/truck/micro-bus	0.77
Rickshaw/van/animal cart	3.18
Almirah/wardrobe/showcase	76.01
Electric fan	94.30
Refrigerator	46.11
Power tiller/tractor	0.71
Electric/diesel pump	5.91
IPS/ Generator	1.70

Source: REACH Household Survey (2018)

It appeared from Table 4.4 that around 74 percent of the households had TV and very few households had radio/CD/DVD player and computer/laptop, 8.6 percent of the households had bicycle and 3.3 percent had motorcycle, while 3.2 percent owned rickshaw/van for livelihood purposes. Most of the households (around 94.3 percent) had electric fan and around 46 percent owned a refrigerator in the study areas.

4.6 Household Size

The households in the study areas comprised of male, female, children, and adult. The distribution of household size by gender of household head presented in Table 4.5. The result showed that the average household size was around 3.90 which was 3.35 among the female led households, and 3.95 among the male led households.

Table 4.5: Distribution of household size in study areas during 2018

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Number of members in household	Female headed HH (%)	Male headed HH (%)	Weighted Average (%)
1	9.49	1.50	2.19
2	28.48	12.11	13.53
3	18.99	23.08	22.73
4	21.52	34.11	33.02
5	11.39	17.63	17.09
6	6.33	7.67	7.56
7	1.90	2.34	2.30
8	0.00	0.96	0.88
9	1.90	0.60	0.71
Average	3.35	3.95	3.90

Source: REACH Household Survey (2018)

There were around 2.19 percent of the households which had single member and among female led households, around 9.49 percent of the households had single member. Around 78.8 percent of female led households, the household size was below 5.

4.7 Characteristics of Household Members

Any member in a household may act as an earner or be a dependent. In the short-run, an young boy or girl may be a dependent in the family but in the long-run s/he can be an active contributor to family. The household composition has the effect on the access to various services, ownership of assets, and other resources. In a household, the characteristics of household head play important role in taking various decisions. A prudent decision can contribute to the household to achieve the desired target, otherwise, the household may face difficulties.

Table 4.6: Characteristics of household head: Gender, Age, and Education
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Description	Value
Gender of HH head: male (percent)	91.4
Average age of male HH head (Years)	42.3
Average age of female HH head (Years)	44.5
Average age of HH head (Years)	42.5
Average education of male HH head (Years of schooling)	4.47
Average education of female HH head (Years of schooling)	1.84
Weighted average education (Years of schooling)	4.24
Literate: male HH head (percent)	58.1
Literate: female HH head (percent)	31.0
Literate (percent)	55.8

Source: REACH Household Survey (2018)

From the survey data (Table 4.6), we found that around 91 percent of the households were led by male while only 9 percent by female. The average age of male head of household was 42.3 years and that of female household head was 44.5 years. The average age of female household head was higher than the male household head. This could be due to the presence of living widow and old women who used to lead the household.

The average education of female household heads (1.84 percent) was lower than that of male household head (4.47 percent) and this represented that the female headed households were lacking behind in education in the riparian areas under the study.

Among the female household heads, 31 percent was found literate while among the male household heads, 58.1 percent was literate. The Table 4.7 showed the distribution of years of schooling by gender of household head and it appeared that 21.5 percent female household heads had years of schooling in between I-V and almost similar rate was observed among the male household head.

Around 27 percent male household heads had completed within VI-X classes while it was only 6.3 percent in case of female household heads. The number of heads of the households who achieved college and higher education was very poor. It was, in case of male headed household, around 9 percent while among female household heads, it was 3.2 percent in Turag riparian areas.

The study further revealed that (Table 4.7), around 69 percent of the female household heads were illiterate whereas around 42 percent male household heads were illiterate. Female household heads were less educated compared to that of the male household heads. Likewise in higher education the female household heads were lacking behind male household head.

Table 4.7: Education standard of household heads (percent) in study areas during 2018

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Levels of education (Class)	Female head	Male head	Weighted Average
Illiterate	68.99	41.87	44.22
I-V	21.52	21.9	21.86
VI-VIII	3.8	13.2	12.38
IX-X	2.53	13.98	12.99
XI-XII	1.9	5.4	5.1
Higher education	1.27	3.66	3.45

Source: REACH Household Survey (2018)

The nature of occupation of the main earning member mostly determines the social status of the households in our society. A low earning occupation can't generate sufficient earnings for the households to lead an above standard of living: sometimes, they have to lead below subsistence or just subsistence live. In an agrarian economy, there is much option for people to engage in diversified occupations rather they have limited choices.

On the basis of location the structure of occupation was quite different such as rural-urban, business growth center, developed-underdeveloped, etc. In a rural areas, agriculture absorbs the largest share of rural labor force whereas in urban areas, the industry and service sectors absorb the largest share of urban labor force. The people may, broadly, be employed in agriculture, non-agriculture, and service sectors. The people may be employed as day labor in agriculture and non-agriculture sector or some people may be self-employed in agriculture or non-agriculture or in petty or big businesses.

Table 4.8: Participation of household heads both male and female of the study areas in different occupations during 2018
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Description	Gender of Household Head		Weighted average
	Female	Male	
Agricultural labor	3.66	4.31	4.27
Boatman	0.00	0.14	0.13
Business	10.98	25.35	24.57
Construction labor	3.66	3.40	3.42
Domestic maid	19.51	0.00	1.05
Farmer	3.66	12.01	11.56
Fisherman	0.00	5.14	4.86
Garment factory	29.27	17.78	18.4
Government services	1.22	0.97	0.99
Landlord	6.10	1.11	1.38
Non-government services	3.66	3.40	3.42
Other casual labor	6.10	8.33	8.21
Other factory	10.98	6.32	6.57
Rickshaw puller	0.00	3.75	3.55
Skilled labor	1.22	7.99	7.62

Source: REACH Household Survey (2018)

Gender-wise occupational activities of the heads of households have been presented in Table 4.8. From the study, it was revealed that in RMG sector participation of female heads (29.27 percent) were higher than that of male households (17.84 percent). In other factories female participation (10.98 percent) was higher than that of male (6.32 percent). Though in casual work male participation was higher (8.33 percent) than females (6.10 percent) as number of skill female workers was less (1.22 percent) than that of males (7.99 percent). Among female household heads, 19.51 percent worked as domestic worker and none of the male household head worked as domestic maid. As regards services in both government and non-government sectors number of males (1.22 percent and 3.66 percent) was greater than males (0.97 percent and 3.44 percent).

On the other hand, around 4.99 percent male household heads were working as fisherman/boatman and none of the female household heads were involved with these activities and around 3.75 percent of the male household head pulled rickshaw/van.

We found that 19.72 percent of the male household heads were working as casual, skilled, and construction laborer in other sectors (other than RMG and factory worker) whereas 10.98 percent of the female household heads were employed in those types of occupations. The difference seems largest in case of the self-employment in business, as 25.35 percent of the male household heads were involved with business whereas 10.98 percent of the female household heads were associated with business.

While considering the data presented in Table 4.9, a distinct economic vulnerability was revealed among the distribution of types of activities participated by male and female household head. Except fishing and boatman-ship, both male and female household heads were doing jobs according to their physical capabilities. In business and formal works, male people were in better position while in garment sector, factories, and domestic works, female people were occupying better position.

The survey results (Table 4.9) showed that around 54.5 percent of women worked as garment worker and 10.05 percent as other factory worker. We found that around 64.5 percent of women worked as factory worker. One feature was that the male members were employed in business (24.6 percent), garment factory (20.79 percent) and other factories (6.78 percent).

The nature of occupation of household members by their gender reflected the employment destination of male and female workers. It was noted that male members were more diverse as compared to female members, though in RMG sector, the participation of women was more prominent.

Table 4.9: Participation of members both male and female of the household in different types of activities (percent) in the Turag riparian areas during 2018
.

Description	Gender of Household Member		Weighted average
	Female	Male	
Agricultural labor	0.78	3.56	2.90
Boatman	0.00	0.15	0.11
Business	6.44	24.6	20.25
Construction labor	2.04	3.22	2.94
Domestic maid	11.15	0.05	2.71
Farmer	1.10	9.41	7.41
Fisherman	0.16	4.16	3.20
Garment factory	54.47	20.79	28.87
Government services	0.78	0.89	0.87
Landlord	1.73	0.89	1.09
Non-government services	3.45	4.16	3.99
Other casual labor	4.08	9.16	7.94
Other factory	10.05	6.78	7.56
Rickshaw puller	0.00	3.71	2.82
Skilled labor	3.77	8.47	7.34

Source: REACH Household Survey (2018)

The distribution of occupation by gender of household head and by gender of household member revealed some distinct differences in characteristics which may help us to explain the nature of disparity of male led and female led households. Besides occupation, education of the household members also play some important role.

The study (Table 4.10) showed that the illiteracy was low among the male members compared to the female members. The male members have higher education compared to female members.

Table 4.10: Levels of education of male and female members in the Turag riparian areas during 2018
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Education	Gender of household member		Weighted average
	Female	Male	
Illiterate	36.16	30.72	33.43
I-V	27.08	27.42	27.25
VI-VIII	17.8	15.84	16.81
IX-X	11.98	14.2	13.10
XI-XII	4.64	7.12	5.88
Higher education	2.34	4.7	3.52

Source: REACH Household Survey (2018)

The study showed that both male and female members had low level of education: one third of them were illiterate and 27.25 percent had education up to class V. About 22.5 percent of the members had education above class VIII.

4.8 Uni-dimensional Poverty Analysis

Following the method of measuring uni-dimensional poverty and using Upper Poverty Line (UPL) and Lower Poverty Line (LPL) of urban areas of Dhaka division, we have estimated the poverty headcount. The results have been presented in Figure 4.1. According to the Household Income and Expenditure Survey conducted (2016), the incidence of poverty under upper poverty line was 24.3 percent at national level which was 18.9 percent in urban areas. The incidence of poverty under upper poverty line (UPL) in urban areas of Dhaka division was 12.5 percent which was 18 percent in 2010. On the other hand, the incidence of extreme poverty in Dhaka was only 3.3 percent which was 3.8 percent in 2010. Although the incidence of poverty under UPL showed a little bit optimistic rate in reducing the incidence but the reduction of extreme poverty in urban areas of Dhaka division showed inertia.

Figure 4.1: Poverty scenario under upper poverty line (UPL) and lower poverty line (LPL) in study areas during 2018

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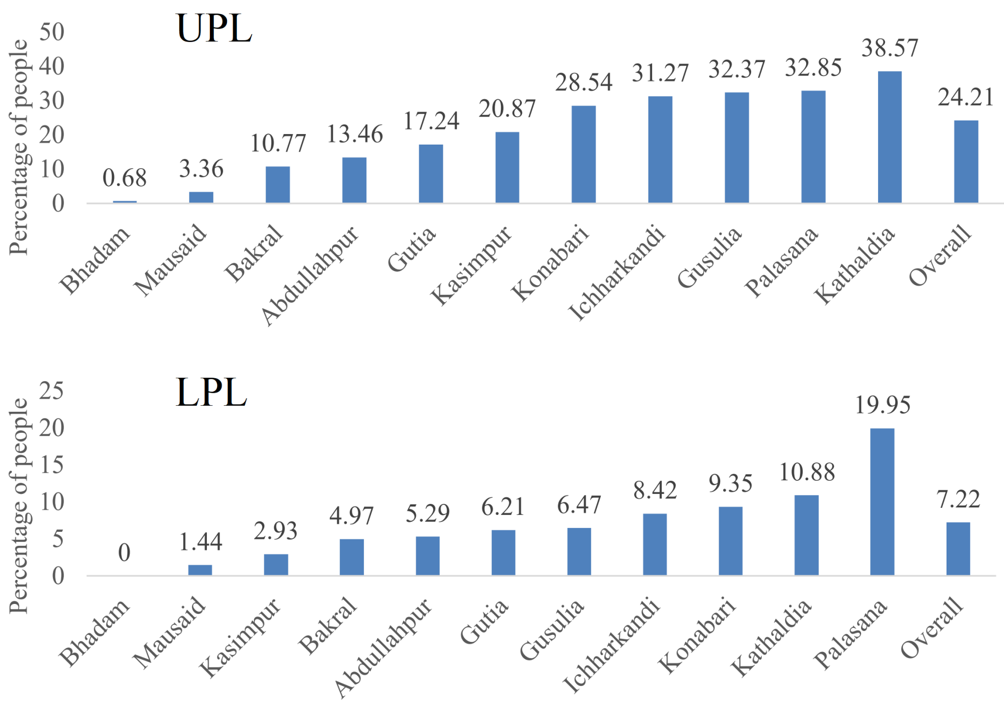

Note: The national poverty line for urban area has been updated by the author using the consumer price index and the update line is considered as the poverty threshold.

The headcount rate (HCR) of poverty in the study area was found 24.2 percent which was nearly close to the national level headcount rate of poverty. The poverty headcount rates in Konabari, Gusulia, Ichharkandi, and Palasana were higher than the national HCR of poverty. Except in Bhadam, Mausaid and Bakral, the HCR of poverty in other survey areas is higher than district level HCR of poverty. The HCR of extreme poverty was lower in all survey areas except Palasana compared to national HCR of incidence of extreme poverty.

4.9 Multidimensional Poverty

Following the methodology of measuring multidimensional poverty (as described in methodology chapter), we estimated the incidence of multidimensional poverty. The incidences were estimated for the households which used open-source water as well as for the households which did not use open-source water. We also estimated the overall scenario of the multidimensional poverty in the Turag riparian areas. The state of multidimensional poverty of those households was dis-aggregated by the location of the households: upstream, middle stream, and downstream.

The results of multidimensional poverty were presented in Table 4.11. We found that 35.4 percent of the people were multi-dimensional poor. The multidimensional poor households had higher deprivation score in education compared to health and living standard indicator.

Table 4.11: Incidence of multidimensional poverty in the urban riparian areas (%)
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	Down stream	Middle stream	Upstream	Weighted average
Overall	49.28	25.22	42.24	35.42
Non-user of open-source water	40.98	21.37	38.59	29.46
Among open-source water user	62.59	39.95	48.71	50.02

Source: REACH Household Survey (2018)

In the upstream, the incidence of multidimensional poverty was 42.24 percent. The incidences were 25.22 percent and 49.28 percent in middle stream and down stream respectively. Among the open-source water user households, the incidence of multidimensional poverty incidence was around 50 percent which were 38.59 percent, 21.37 percent, and 40.98 percent in upstream, middle stream and downstream respectively. Among the non-user of open source water, the incidence of multidimensional poverty was around 30 percent and in upstream, middle stream and downstream, the incidences of multidimensional poverty were 38.59 percent, 21.37 percent, and 40.98 percent respectively.

The incidence of multidimensional poverty was the highest in the downstream areas compared to the other areas among both users and non-users of open-source water. More importantly, the incidences of multidimensional poverty were higher among the users of open-source water than the non-users in all areas. The gap in the incidence of multidimensional poverty was the highest in the downstream compared to middle stream and upstream.

4.10 Poverty Dynamics

In studying the poverty dynamics of the households in Turag riparian areas, the perception of the respondents was inquired about their welfare situation i.e. their poverty condition almost five years ago and current condition of their households. Comparing those two states, the households were classified as chronic poor, movers, fallers, and always better off. The measurement of multidimensional poverty was theoretically discussed in chapter 4 (4.8.5).

The incidence of multidimensional poverty situation in households of Turag riparian areas under study has been presented in Table 4.12. The results were prepared for both male led and female led households.

It was found (4.12) that around 33 percent of the households were enjoying a better life now as were enjoying before five years. Male headed households were relatively more stable in terms of enjoying better livelihoods before five years of the study period and during study period, around 34 percent of the households. Among the female led households, the rate was 25 percent. Around 23 percent of the female headed households were chronic poor and that of male led households were 16 .27 percent.

Table 4.12: Poverty dynamics of the Turag riparian areas under study by gender of household head during 2018
.

Classification of households	Gender of household head		Weighted average
	Female	Male	
Chronic	23.08	16.27	16.86
Movers	27.56	38.57	37.62
Fallers	24.36	11.09	12.24
Always better off	25.00	34.06	33.28

Source: REACH Household Survey (2018)

The percentage of households moving out of the worse situation to better off situation was high (around 38.6 percent) among the male headed households compared to the female headed households (around 27.6 percent) whereas the percentage of fallers was low among the male headed households (11.1 percent) compared to the female headed households (around 24.4 percent).

The results suggested that the female led households were in the vulnerable and chronically poor compared to the male led households. From the Table 4.12, it appeared that around 47 percent of the female led households were transient and chronically poor whereas among male led households that was around 27 percent.

Table 4.13: Incidence of multidimensional poverty in the Turag riparian areas
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Multidimensional Poverty	Down stream	Middle stream	Upstream	Weighted average
Chronic	13.95	19.91	13.18	16.86
Movers	31.68	46.25	25.00	37.62
Fallers	16.08	10.17	12.95	12.24
Always better off	38.30	23.66	48.86	33.28

Source: REACH Household Survey (2018)

The survey results presented in Table 4.13 that around 17 percent of the people in the survey areas were chronically poor and the incidence of chronic poverty is the highest in middle stream areas and lowest in the upstream areas. Around one-third of the people in the study area were leading always better off lives. About 48.86 percent of the people in the upstream areas were always better off whereas in down stream areas, 38.3 percent of the people were always better off.

4.11 Source of water

Water is an indispensable part of human life. In the daily routine of a household water is used for toilet, shower, bath, wash, ablution, watering the plants, drinking, cooking and many more purposes. The modern households collect[1] water from different sources like water supplies by local bodies, deep tube-wells, tube-wells, and open-sources like river, canal, lake, pond, etc (Table 4.14). For drinking purposes, households were very much cautious of the source of water. They tried mostly to collect from safe sources of water.

[1]Customarily, women and children are mostly the water bearer in Bangladesh. But adult males also sometimes collect water.

Table 4.14: Sources of drinking water and its distance

.

Purposes of water use	Source	Percent of HHs
Drinking water source	Supply water by local bodies	21.25
	Tube-wells	4.11
	Deep tube-wells	73.82
	open-source (river/canal/Lake/pond)	2.47
	Others	1.25
Distance from main water source	Within 5 minutes	69.82
	5-10 minutes	18.51
	Above 10 minutes	11.67

Source: REACH Household Survey (2018)

According to HIES (2016), around 60 percent of the urban households used tube-well water for drinking purposes and around 37 percent used water supplied by local authorities throuh pipe lines. Our survey results showed that around 74 percent of the households used tube-well water for drinking and few households used drinking water from tube-well (4.11 percent).

The points of distribution of drinking water supplied by local bodies were mostly at the yard from where the members of the households of the community collected water. Only 21.25 percent of the households had water-pipe connection at their dwelling places.

The results further showed that around 70 percent of the households were able to collect water within 5 minutes, and 18.5 percent of the households required 5-10 minutes to collect improved water for drinking purposes. Nearly 11.7 percent of the households required above 10 minutes to access improved water for drinking.

4.12 Quality and Storage of Drinking Water

The access to improved water source is one side of water security and the quality of drinking water and its management at the household level is another issue. The results of the present study showed that around 93 percent of the respondents of the survey had the perception that they used to drink safe water. The testing of the quality of drinking water was not of much concern among the members of the households in the study areas.

The presence of various types of heavy metals and micro organisms in water is not new. The arsenic problem is well-known for its deleterious effects on human bodies in some parts of the world and for that matter in Bangladesh also. Knowing well that there was the problem of arsenic and some other heavy metals, out of 1826 respondents, a few perceived the presence of iron (53 respondents), micro organisms (24 respondents) in water, and of different taste (18 respondents) of water which made them concern if drinking water was not unsafe.

Only 2.9 percent of the households (only 53 of the sample households) used to treat their water before drinking. Among those households, 60 percent used to boil the drinking water, 26 percent used to water filtering technique (sand/ composite/ ceramic filter), 7.5 percent used to strain the water through the clothes, 3.8 percent used solar disinfection system, and the rest followed other techniques.

Figure 4.2: Water storage time distribution (percent of HH)

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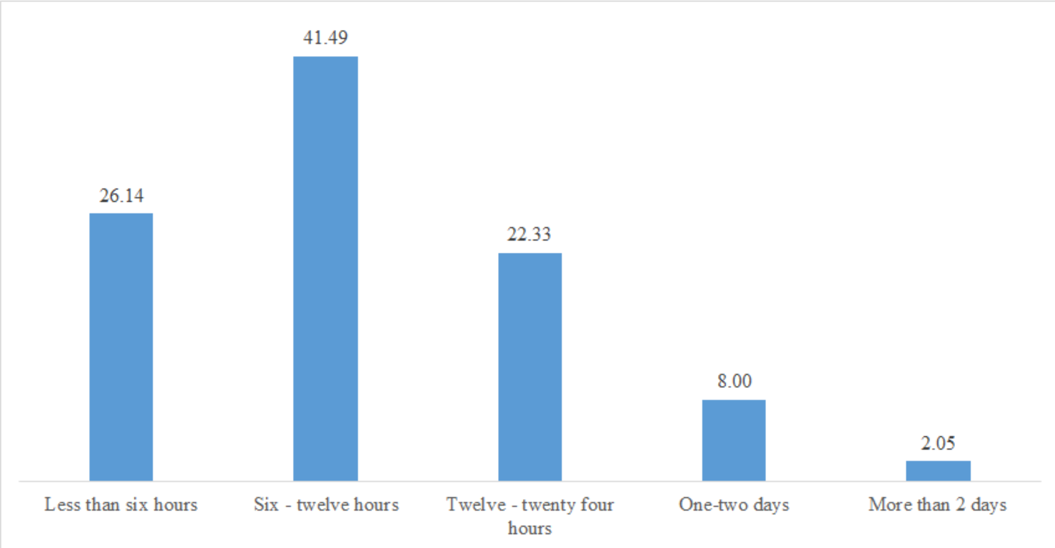

Source: REACH Household Survey (2018)

Around 59 percent of the households reported that they stored water[2] at their premises. Among them, 26 percent stored water less than 6 hours, 41.5 percent stored water for the period between six-twelve hours, and 22.3 percent stored water for 12-24 hours. In total, around 90 percent of the households stored water for one day and 10 percent stored water for over one day.

4.13 Cost and payment mode of water

From the present study it appeared that around 30 percent of the households did not have to pay for water while 70 percent of the households had to spend a certain amount of money on water. The average monthly expenditure on water was around BDT 195 (USD 2.4) whereas the median cost of water was found BDT 100 (USD 1.21). The average expenditure on water was around 1.24 percent of total monthly household expenditure whereas the median expenditure

[2]By storage we mean of holding large quantities of water for at least a few hours due to difficulties in fetching water as and when needed.

on water was around 1 percent of the total monthly household expenditure.

Households which collected water from vendors make their payment at various places. Around 40.14% households paid for water mostly at the place where water was fetched from or delivered to.

Around 58 percent of the households paid their water bill at the utility office like WASA office or bank or to tariff collector (25.5 percent) and at rented houses sometimes the owners used to collect bill with house rent (32.3 percent). Around 99 percent of the households paid the bill on monthly basis.

4.14 Water Security Index and Water Poor

Since water security implies access to safe piped water, access to safe sanitation and better hygiene following the method of calculation described in chapter 4 (4.8.4). In the present study to measure the water quality at household level water source, reliability, affordability, sanitation, and hygiene were considered and the formula in 4.8 has been used to calculate the WSI value. In this section, the basic description of the calculated WSI value has been presented.

The kernel density of WSI has been plotted in Figure 5.3 along with some statistical values like percentiles, deciles, mean, and variance etc. We found the calculated WSI value had a range of 0.03 to 0.96 whereas the theoretical range was zero to one. The 95% sample households had WSI value over 0.41 and the 90% sample households had WSI value above 0.51. The first quartile value of WSI was calculated at 0.65 and that of the third quartile value of WSI was 0.88 giving an inter-quartiles range value of 0.23. The top 10 percent sample households had WSI value above 0.92.

Figure 4.3: Density plot of WSI values

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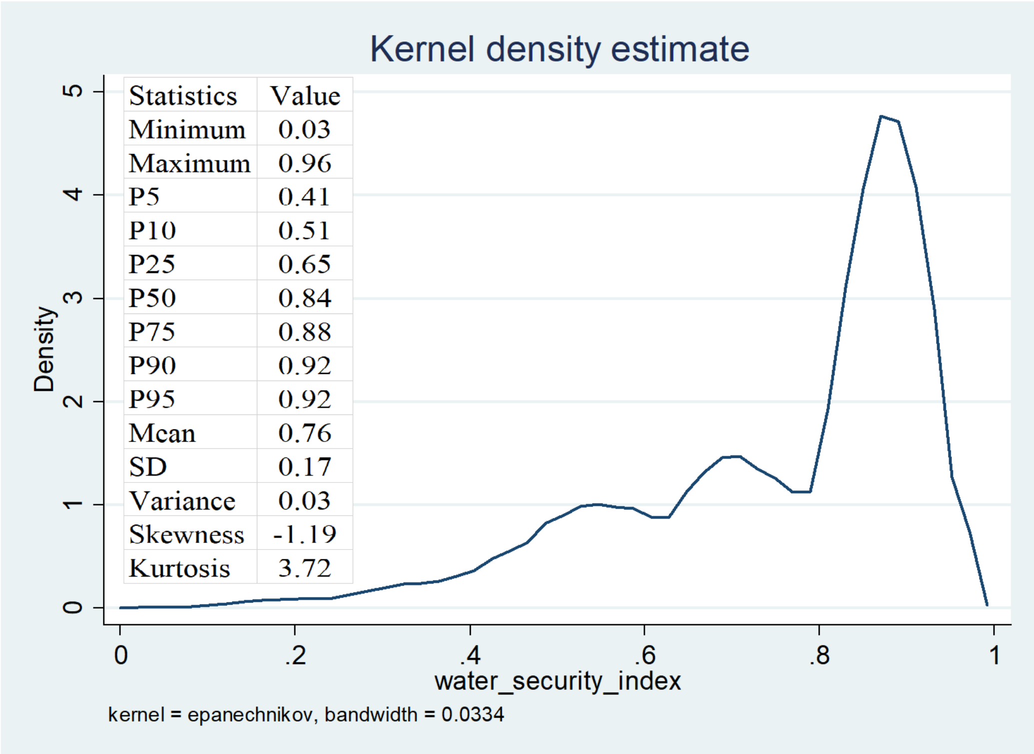

Source: REACH Household Survey (2018)

The average WSI value was around 0.76 with a standard deviation of 0.17 whereas the median WSI value was around 0.84. The median of WSI value was higher than the mean WSI value suggesting a negatively skewed distribution of WSI values and estimated skewness. The kurtosis measure gave a positive value of kurtosis statistics.

The average WSI value of non-poor household was estimated at 0.76 which was equal to the average WSI value whereas the moderate poor households had an average WSI value of 0.74 and that is estimated at 0.71 for the extreme poor households. The result showed that the poorest have the least average WSI value compared to other two groups - non-poor and moderate poor. The difference in the average WSI value between non-poor and extreme poor was around 0.05 with a standard deviation of 0.017 and this gap was found statistically significant at 1 percent level, at two tail test the estimated p-value was 0.0017.

Figure 4.4: State of water security by poverty status (percent of HH)

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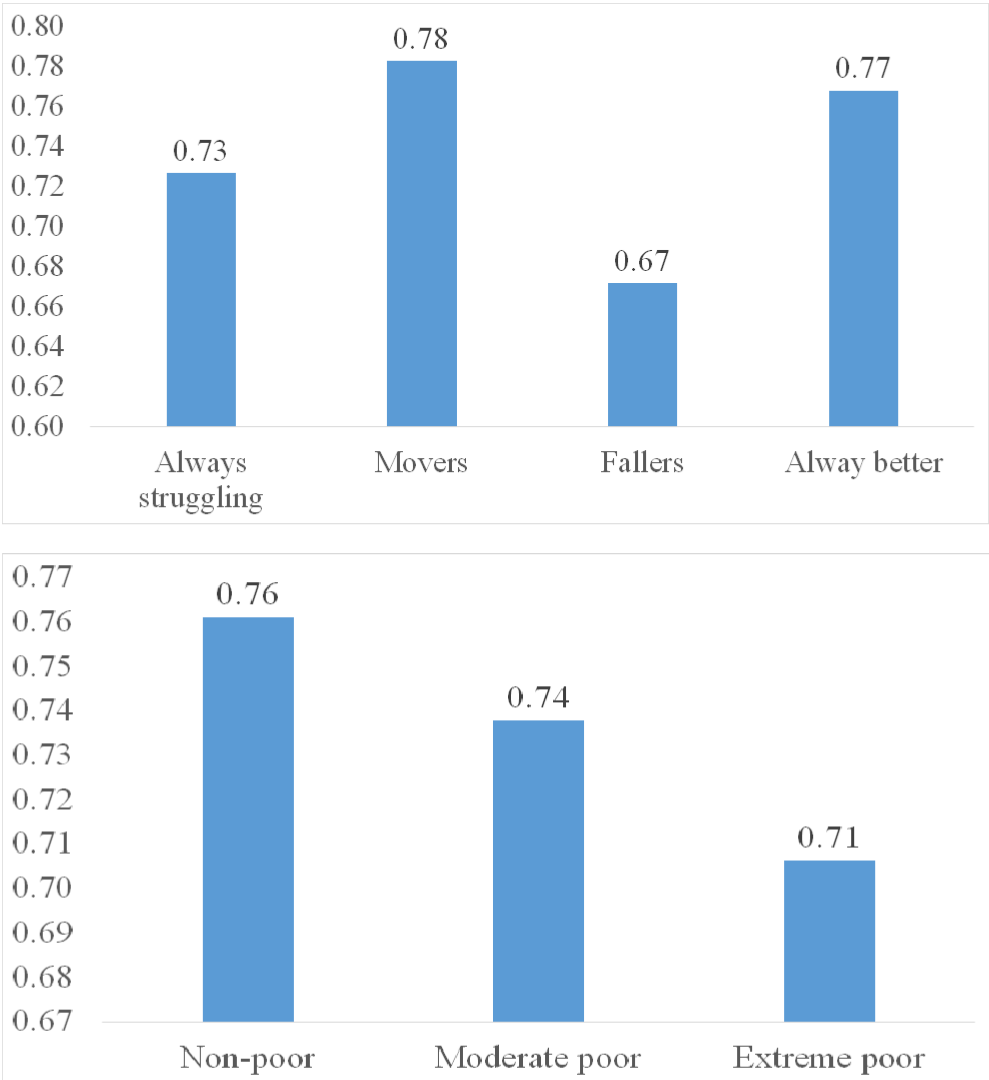

Note: The vertical axis shows the water security index value.
Source: REACH Household Survey (2018)

The always better off households had an average WSI value of 0.77 and the movers had an average WSI value of 0.78 whereas the fallers had an average WSI value of 0.67 which was even lower than the average WSI value of the chronic group. The analysis showed that the households who had lost their social and economic status over the course of time were more water unsecured compared to the chronic and always better off groups - always better and movers. The estimated difference in the average WSI value between fallers and movers was around 0.11 with a standard deviation of 0.013 whereas that was 0.10 with a standard deviation of 0.014 between fallers and always better off households.

4.15 Summary of the Results

Among the households under study in Turag riparian areas 8.63 percent started living in those areas for the last one year, and 15.24 percent for 1 to 4 years, 12.8 percent for 5-10 years and 63.34 percent for more than 10 years. The result showed that the average household size was around 4. Among the female led households, the average household size was 3.35 and that for the male led households was 4.

We found that around 91 percent of the households were led by male while only 9 percent were led by female. The average age of male head of household was 42.3 years and that of female head of the household was 44.5 years. The average education of female household heads (1.84 percent) was lower than that of male household heads (4.47 percent).

Among the female household heads, 31 percent was found literate while that of male heads of the household, 58.1 percent was literate, 21.5 percent of the female household heads had years of schooling in between I-V and similar rate was observed among the male household head. Around 27 percent of the male household heads had education within 6-9 years of schooling whereas only 6.3 percent of the female household heads had that level of schooling. Very few of male and female household heads had college and higher education (about

11.0 and 3.2 percent respectively).

Among the selected households, 51.59 percent had their own houses, 31.65 percent were tenants, and 16.76 percent lived in public land/embankment at no cost. It was also found that 6.52 percent of the households had concrete based roof, 92.44 percent of the houses had tin/iron-roof, and few had brick/cement made roofs.

The connection of electricity had in 93.67 percent of the households, and 3.56 percent of the households used kerosene as lighting fuel. For cooking purposes, 75.6 percent of the households used wood/sticks as cooking fuel, and 44.4 per cent households had gas connection. Some households used multiple sources of fuel for lighting and cooking purposes.

The households of the study areas had various types of modern equipment like TV (74 percent), electric fan (94.3 percent), and refrigerator (46 percent). Very few of the households had radio/CD/DVD player and computer/laptop, 8.6 percent of the households had bicycle and 3.3 percent had motorcycle, and 3.2 percent owned rickshaw/van for livelihood purposes.

Regarding employment RMG sector was very important where the participation of female household heads (29.27 percent) was higher than that of the participation of male household heads (178.4 percent). In different factories, the participation of female members of the households (10.98 percent) was also higher than that of the participation of male heads of the households (6.32 percent). Around 20 percent of female members of the households worked as in domestic workers and none of the male heads of the households worked as domestic maid. As regards services in both government and non-government sectors number of male employees (1.22 percent and 3.66 percent) was greater than female employees (0.97 percent and 3.44 percent).

Around 5 percent of the male heads of the household were working as fisherman/boatman and 3.75 percent of the male heads of the households worked as rickshaw/van puller. Around 20 percent of the male heads of the household had been working as workers (casual, skilled, and construction) in other sectors (excluding RMG and factory worker) whereas 10.98 percent of the female heads of the household were employed as casual, construction and skilled worker. The differences seemed largest in case of the self-employment in business: 25.35 percent of the male heads of the household were involved with business, and 10.98 percent of the female heads of the households had business.

The headcount rate (HCR) of poverty in the survey area was found 24.3 percent which was as per with that of the national level. The poverty incidences in Konabari, Gusulia, Ichharkandi, and Palasana were higher than the national level of poverty. Except in Bhadam, Mausaid and Bakral, the incidence of poverty in other survey areas was higher than the poverty incidence rate of Gazipur district. The also revealed that 35.4 percent of the people were multidimensional poor.

It was found that around 33 percent of the households in the study areas were enjoying better life during the survey and five years prior to the study period. Of the male led households, 34 percent had better life five years prior to study and during study period, and The male led households compared to female led households were relatively more stable in terms of better lives before five years of the survey and the lived now (around 34 percent of the households report this) whereas this rate was 25 percent among the female headed household. Around 23 percent of the female headed households were chronic poor and that of male led households were 16 .27 percent. The percentage of households moving out of the worse situation to better off situation was high (around 38.6 percent) among the male headed households compared to the female headed households (around 27.6 percent) whereas the percentage of fallers was low among the male headed households (11.1 percent) compared to the female headed households (around 24.4 percent).

Our survey results showed that around 75 percent of the households used tube-well water for drinking (73.82 percent used motorized tube-well water) and few households used drinking water from deep tube-well (4.11 percent). Of the supply drinking water, the water point was mostly at the yard from where the households of the community collected water. Only 21.25 percent of the households had water-pipe connection at their dwelling. The results showed that majority of the households, around 70 percent, were able to collected water within 5 minutes, and around 18.5 percent of the households required 5-10 minutes to collect improved water. Nearly 11.7 percent of the households required above 10 minutes to access improved water.

Around 59 percent of the households used to store water at their premises of which 26 percent stored water less than 6 hours, 41.5 percent stored for six-twelve hours, and 22.3 percent stored for 12-24 hours. Among the water storing households, 90 percent stored water up to one day and 10 percent of the households stored water for above one day.

The analysis showed that around 30 percent of the households did not have to pay for water while 70 percent of the households had to spend a certain amount of money for water. The average monthly expenditure on water was around BDT 195 (USD 2.4) whereas the median monthly cost of water was BDT 100 (USD 1.21). The average expenditure on water was around 1.24 percent of total monthly household expenditure whereas the median expenditure on water was around 1 percent of the total monthly household expenditure.

4.16 Conclusion

The results presented in this chapter showed that the households in the study areas were mostly poor and lived near to or on the Turag riverbank or the bank of the Tongi Khal. Most of them were living there above two years and few were newcomers. They lived in poor houses, the roof of which were mostly made of corrugated iron sheet with tin sheet fence. They used different types of fuel to cook and had access to electricity. Motorized/ deep tube-well was the major sources of fresh and drinking water and the second important source of water was supplied through local bodies at the yard. Most of the households collect drinking water from the main source of water within 5 to 10 minutes. Adult women mostly collect the water for various purposes. Other than drinking purposes, some households collected water from open-source of water like lake, river, canal, pond, etc for domestic purposes. The study revealed that although the quality of water of open-source perceived as poor, around 28 percent of the members of the households used open-source water within a year on regular or occasional basis.

Chapter 5

Dynamics of Water Insecurity and Water Poverty of the Households

5.1 Introduction

Water, the most indispensable natural resource for humans (Solomon, 2010: 3; Koehler, 2008; Ashton, 2002) and in fact, indispensable for all forms of lives (Bates et.al., 2008, Young et.al, 2004), hence, is called life. Water is an input, mostly acts as natural capital, to almost every production process. Agricultural production and industries use the major share of freshwater, and maintaining good ecosystem requires water.

It is commonly acknowledged that access to safe water is essential to lead a better life. WHO (2017) iterated that access to safe drinking water, the basic human right, and a component of effective policy for health protection, is essential to health. WHO and UNICEF (2017) reported that 71 percent of the global population (5.2 billion people) used safely managed drinking water services and 5.8 billion people used improved sources of water available when needed in 2015. They mentioned that around 1.9 billion rural people used a safely managed drinking water services. Gleick (1998) pointed out that access to the required basic water, implicitly or explicitly, is the fundamental human right which has to be ensured by the local, national, and international organizations.

In the post-MDGs[1], on 25 September 2015, the member countries of the United Nations adopted the 2030 agenda titled sustainable development goals (SDGs) addressing the wider aspects of development: social, economic and environment to end poverty, protect the planet and ensure prosperity for all. Water and sanitation took important attention and is set as goal 6, relating to "Ensure availability and sustainable management of water and sanitation for all" with specific targets addressing all aspects of the freshwater cycle and more specifically, improving the standard of WASH services (6.1 and 6.2); increasing treatment, recycling and reuse of wastewater (6.3); improving efficiency and ensuring sustainable withdrawals (6.4); and protecting water-related ecosystems (6.6) as part of an integrated approach to water resources management (6.5).

Riverbanks were the major growth centre at the early stage of Bangladesh and now cities become the new growth centres. Dhaka, the capital of Bangladesh, is surrounded by four major rivers: Turag, Buriganga, Shitalakkha, and Dhaleshari. With the growing urbanization, the poor and vulnerable people are choosing the least cost living areas as their living location for example slums, riverbanks, and areas having limited access to utilities and roads.

According to the World Bank report (2018), Bangladesh witnessed around 843,000 deaths in 2015. Of those, nearly 27.7 percent were caused by environ-

[1]The eight Millennium Development Goals are: (i) To eradicate extreme poverty and hunger, (ii) To achieve universal primary education, (iii) To promote gender equality and empower women, (iv) To reduce child mortality, (v) To improve maternal health, (vi) To combat HIV/AIDS, malaria, and other diseases, (viii) To ensure environmental sustainability, and (viii) To develop a global partnership for development[

mental pollution, the highest among South Asian nations, on average nearly 26 percent while it was 16 percent worldwide. The same report continued that the economic cost of the deaths and disability in terms of labour output was estimated at USD 1.4 billion in all urban areas of Bangladesh and it was at 310 million in Dhaka city alone, equivalent to 0.6 percent and 0.1 percent of the country's GDP in 2015. The rapid growth of the ready-made garment industry and increase in urban population from less than 40 million in 2006 to more than 55 million in 2015 were exposing to environmental hazards. The overall pollution had generated an economic loss of USD 6.52 billion in 2015 which was equivalent to 3.4% of GDP of that year and encountered an annual productivity loss of RMG workers, approximately USD 90 million, and the treatment as well as time costs of illness of USD 130 million a year.

Water security is very important for growth and development (Grey and Connors, 2009; Grey and Sadoff, 2007; Brown et.al., 2013) and in particular for sustainable development (Beck and Walker, 2013). Globally, 80% of the population faced a high-level water security risk (Bakker, 2012). Water is critical to the ecological services on which many of the poor depend (Soussan & Arriëns, 2004). Water security, hence, plays an important role in alleviating poverty (Barker and Kappen, 1999; Barker et.al., 2000; Ahmad, 2003; Rijsberman, 2003; Ünver et.al., 2012).

Contamination of drinking water is a threat to human health (Smith et.al., 2000; Pandey, 2006; Azizullah et.al., 2011) and the presence of arsenic exacerbates the scenario (Berg et.al., 2001). Over 900 industries in Bangladesh are polluting various rivers through the disposal of industrial wastes (Nouri et.al., 2009). The presence of heavy metals in fish of contaminated rivers of Bangladesh like Buriganga, Turag, Bangshi, etc. is causing a deleterious effect on human health through the food chain (Rahman et.al., 2013; Ahmed et.al., 2016). The people living near to Turag river, suffered from a variety of health problems including skin, diarrhoea, dysentery, respiratory illnesses, anemia and complications in childbirth, yellow fever, cholera, dengue, and malaria (Halder and Islam, 2015). Poor water quality, sanitation and hygiene accounted for some 1.7 million deaths a year world-wide mainly through infectious diarrhoea (Ashbolt, 2004).

The analysis of the previous chapter showed that some of the people of study areas used open-source water for drinking and domestic purposes. The study showed that people contacted with open-source of water for various purposes like bathing, cleaning utensils, fishing, irrigating agriculture land, and so on. The bivariate analysis showed that the tendency of using the open-source water varied by socioeconomic variables. While there was a water point and safe source of water near to the household, why did people interact with the open-source water for domestic purposes? The aims of this chapter was to investigate the significance and relative magnitudes of the the effects of the respective explanatory variables within a given model.

The results of this chapter were presented in two forms: (i) the descriptive statistics explaining the nature of the contact with open-source water and some socioeconomic characteristics of the households, and (ii) the econometric results explaining the casual relationship among the socioeconomic variables and the contact with open-source water. The descriptive statistics were also compared and tested using the classical mean test to see whether the differences between groups (if there any existed) were statistically significant or not.

Table 5.1: Contact with open-source water by seasons

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Purposes	Dry season		Monsoon	
	%	SD	%	SD
Cooking	2.14	14.46	0.99	9.88
Washing	23.82	42.61	11.61	32.04
Bathing	27.05	44.44	13.31	33.98
Overall		28.37		

Source: REACH Household Survey (2018)

5.2 Descriptive Analysis

5.2.1 Nature of open-source water contact (OSWC)

Since the sample households were living adjacent to the river/lake/canal, they may have the high chances of contacting with these open-source water for various purposes during crisis or for daily personal uses. The contact with open-source water was constructed based on the nature of contact during dry season and monsoon season. During dry season, the natural flow water was scarce and water scarcity increased due to lack of sufficient water supply and during monsoon, the natural flow water was available and was close to near hand. People contacted with open-source water for various purposes like bathing, recreation journey by boat, fishing, and daily household chores.

The survey results showed that none of the households contacted with open-source water for drinking purposes but around 28 percent of the household's members sometimes contacted with open-source water. The household members mostly contacted the open-source water for washing, and bathing purposes (Table 5.1). Water scarcity during dry season, mostly due to the interruption of electricity, was the important causes of contacting with open-source water. This implied that the lack of available freshwater forced them to contact with open-source water.

5.2.2 OSWC by Poverty Status and Gender of Household Head

Poverty and vulnerability of the households also played important role in contacting open source water. We identified the households were extreme poor, people living the lower poverty line, moderate poor, people living the upper poverty line. The classical mean-difference test between who contacted with open-source water - poor or non-poor. The classical test assumed that there was no difference between the comparison group in term of contacting open-source water.

Table 5.2: Contacting with open-source water by household characteristics
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	Obs.	Percent of HHs having contact with OSW	Difference compared to base	t-stat
Upper Poverty Line				
Non-poor	1,489	27.40	Base	
Poor	337	32.64	-5.24	-1.93
Lower Poverty Line				
Non-poor	1,721	27.83	Base	
Poor	105	37.14	-9.31	-2.06
Gender of HH Head				
Female	158	29.75	Base	
Male	1,668	28.24	1.51	0.40

Note: t-statistics calculated to test whether the difference is statistically significant or not.

The results in Table 5.2 showed that among the non-poor households, the incidence of contacting with open-source water was around 27.4 percent whereas among the moderate poor, the incidence of the contact with open-source water was around 32.64 percent and hence, the incidence was found higher among the poor compared to the non-poor households.

The difference in the incidence of contact with open-source water was found statistically significant at 10 percent. The results also revealed that the incidence of contacting with open-source water among the extreme poor was much more higher, around 37.14 percent, compared to the comparison group and the difference was this time statistically significantly different at 5 percent level of significance.

Table 5.3: Contacting with open-source water by long-term poverty dynamics
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	N	Percent of HHs having OSWC	Difference compared to base	z-value
Chronic	303	39.6	9.33	2.67
Movers	676	18.49	-11.78	-5.15
Fallers	220	39.55	9.28	2.37
Always better	598	30.27	Base	

Source: REACH Household Survey (2018)

5.2.3 OSWC by poverty dynamics

Based on the perception of the households by themselves, we categorized the households into four groups: (i) struggler, (ii) movers, (iii) fallers, and (iv) always better off. We found that the incidence of the contact with open-source water was high among the chronic and fallers group whereas it was very low among the movers group. The result showed that around 39.6 percent of the chronic poor contacted with open-source water and similarly incidence was observed among the fallers households.

Among the movers, the incidence was estimated at around 18.5 percent which was 30.3 percent among the never poor households. There was visible differences among these households in terms of the incidence of contacting with open-source water. The classical mean test showed that compared to never poor group, the incidence of contacting with open-source water was high by 9.33 percent among the struggling group and the statistical test-statistic rejected the hypothesis of no differences in the incidence among these two groups (Table 5.3).

Similarly, the fallers group had higher incidence of contacting with open-source water compared to the never poor group by 9.28 percent and the gap was also statistically significant. We found that the incidence of exposing to open-source water was high among the extreme poor and female led households compared to the non-extreme poor and male led households. The incidence of exposing to open-source water was high among the households who were struggling for better life every time and had fallen down below the poverty line (Table 5.3).

Table 5.4: Contacting with open-source water by water collection time

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	N	Percent of HHs having OSWC	Difference compared to base	z-value
Within 5 minutes	1275	22.59	Base	
5-10 minutes	338	31.66	9.07	3.43
10-15 minutes	141	56.74	34.15	8.23
15-30 minutes	61	60.66	38.07	6.15
Above 30 minutes	11	54.55	31.96	2.32

Source: REACH Household Survey (2018)

5.2.4 OSWC by time required to collect improved water

Water collection time and water collection point also determined the incidence of contacting with open-source water. The water collection time variable was categorized into five groups: (i) households collecting water within 5 minutes, (ii) households collecting water within 5-10 minutes, (iii) households collecting water within 10-15 minutes, (iv) households collecting water within 15-30 minutes, and (v) water collection requires over 30 minutes.

The water collection focused on the collection of freshwater from the reliable source. We found that the incidence of the contact with open-source water was high among the households which required more times to collect freshwater from the main freshwater point whereas it was very low among the households which can access to water within 5 minutes.

The results in Table 5.4 showed that around 31.66 percent of the households which collected water within 5-10 minutes contacted with open-source water and the incidence increased to 56.74 percent among the households which required 10-15 minutes to access freshwater and the incidence was much higher (60.66 percent) for the households which required 15-30 minutes to collect good quality water from safe water point.

We observed that among the households who were relatively far away from the safe water point, were contacting with open-source water. The visible differences among these households in terms of the incidence of contacting with open-source water based on the water collection time suggested us that distance from the safe water point was an important determining factor of contacting with open-source water.

The classical mean test showed that compared to the households which collected water within 5 minutes, the incidence of contacting with open-source water was high by 9.07 percent among the households which required 5-10 minutes to collect water, 34.15 percent among the households which required 10-15 minutes, 38.07 percent among the households which required 15-30 minutes. Again, the statistical test-statistic rejected the hypothesis of no differences in the incidence among these comparison groups. The gaps were statistically significant at one percent level of significance (Table 5.4).

Table 5.5: Contacting with open-source water by pattern of water cost
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	Obs.	Percent of HHs having OSWC	Difference compared to base	z-value
Water cost below 120	1,543	26.38	Base	
Water cost above 120	283	39.22	-12.85	- 4.43

Source: REACH Household Survey (2018)

5.2.5 OSWC by price of improved water

In urban areas, water is not mostly freely available. The households have to pay individually per month for water consumption. Some households have their own tube-well and get water after for long time at free of cost by just making the installation cost. However, some households are forced to pay for water. Sometimes, the cost of water of the poor household becomes a burden as the water cost share in total expenditure becomes relatively large.

We constructed the the dummy of water cost variable and termed it as affordability based on the median water cost of the households. The median water cost was estimated at 120 per month. The survey results showed that around 15.5 percent of the households had affordability constraint.

The result showed that the affordability constrained households had an incidence of contacting with open-source water of 39.22 percent whereas among affordability unconstrained households had the lower incidence of the contact with open-source water of 26.38 percent and hence, the incidence was found higher among the constrained households compared to the unconstrained households. The difference in the incidence of contact with open-source water was found statistically significant at one percent level of significance.

Table 5.6: Contacting with open-source water by occupation of household head
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Occupation of Household Head	N	Percent of HH having OSWC	Difference compared to base	Z-value
Agriculture Worker	65	36.92	4.03	0.64
RMG Worker	280	16.79	-16.1	-4.57
Other Factory Worker	100	10	-22.89	-4.23
Casual Worker	125	46.4	13.51	2.7
Skilled Worker	116	32.76	-0.13	-0.03
Construction Worker	52	26.92	-5.97	-0.86
Domestic Worker	16	18.75	-14.14	-1.16
Boatman/fisherman	76	46.05	13.16	2.18
Farmer/Landlord	197	34.52	1.63	0.39
Non-govt. Service	52	15.38	-17.51	-2.48
Rickshaw/van puller	54	33.33	0.44	0.07
Business	374	32.89	Base	
Others	152	26.97	-5.92	-1.33
Unemployed	152	20.39	-12.5	-2.83

Source: REACH Household Survey (2018)

5.2.6 OSWC by occupation of household head

The incidence of contacting with open-source water varied by the nature of the principal occupation of the households. The occupation of the household heads were classified into thirteen group. The groups contained workers (agriculture, RMG, factory, casual, skilled, and construction), boatman, fisherman, business, self-employment activity like vehicle driving, and others.

The Table 5.6 showed that the incidence of the contact with open-source water was high among the household heads who were working as workers in agriculture (36.92 percent) or as casual workers (46.4 percent) and the incidence was the second highest among the fisherman and boatman (46.05 percent). The differences among these households in terms of the incidence of contacting with open-source water based on the water collection time suggested us that the nature of the occupation of household head determined the incidence of contacting with open-source water.

The classical mean test showed that compared to the households whose head was engaged with business, the households whose heads were working as workers in agriculture or as casual workers, fisherman/boatman, and vehicle drivers had the higher incidence of contacting with open-source water. Again, the statistical test-statistic rejected the hypothesis of no differences in the incidence among these comparison groups. The gaps were statistically significant at one percent level of significance.

The households whose heads were the RMG workers, factory worker, and non-govt service holder, had low incidence of contacting with open-source water compared to the households whose heads were running a small business. The government service holders had no incidence of contacting with open-source water. But the households whose heads were employed in any sector have some sort of incidence of contacting with open-source water.

Table 5.7: Contacting with open-source water by education of household head
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Education level	N	Percentage of HHs having OSWC	Difference compared to base	Z-value
Illiterate	807	34.08	26.14	3.79
I-V	399	30.08	22.14	3.36
VI-VIII	226	24.34	16.4	2.68
IX-X	237	21.1	13.16	2.3
XI-XII	93	13.98	6.04	1.14
Higher education	63	7.94	Base	

Source: REACH Household Survey (2018)

5.2.7 OSWC by education of household head

Education helps people to take right decision. It increases awareness among people. Education not only improves well-being but also helps managing risks properly and efficiently. The level of education of household head plays an important role in every decision making process. An illiterate individual may be unaware of some malicious effects of various events which they overlook and an educated individual is relatively aware of various risks.

We classified the years of schooling of household head into six categories: (i) illiterate group, (ii) head completed I-V classes, (iii) head completed VI-VIII, (iv) head completed IX-X, (v) head completed XI-XII, and (VI) heads have higher education.

The survey results showed that the incidence of the contact with open-source water is high among the households led by illiterate head whereas it is very low among the households led by highly literate head . The result showed that around 34.08 percent of the households led by illiterate head contacted with open-source water and the incidence was 30.08 percent among the households led by heads who completed I-V classes. The incidence was much lower (24.34 percent) for the households led by heads having education VI-VIII and it was the lowest among the households (7.94 percent) whose head completed higher education.

We observed that among the households whose heads were relatively more educated, had less contact with open-source water. The differences among these households in terms of the incidence of contacting with open-source water based on the level of education of household head suggested us that it significantly determined the choice of contacting with open-source water. The gaps were statistically significant at one percent level of significance for the first four groups and the incidence was similar among the household heads who completed college education and the higher education.

5.3 Econometric Results

5.3.1 Factors affecting the interaction with open-source water

The results of three models were reported in Table 5.8. Model 1 contained single explanatory variable 'water collection time from main source'. Model 2 was an extension of the simple version of model 1 where one additional variable was included. Model 3 was a comprehensive model containing the variables of model 2 as well as new variables. The last model contained the poverty variable only.

Table 5.8: Determinants of open-source water contact (Logit coefficents based on Logit model)

.

Model	Explanatory variable	Coefficient	Z-value
Model 1	Water collection time	0.096***	9.081
Model 2	Water collection time	0.096***	8.963
	Monthly water cost over 120	0.575***	4.128
Model 3	Water collection time	0.09***	8.352
	Monthly water cost over 120	0.549***	3.902
	Gender of HH head (Male =1)	0.23	1.17
	Age of HH head (years)	-0.006	-1.319
	Schooling years	-0.078***	-5.809
	Household size	0.066	1.65

Note: β= raw coefficient, Z=Z-score for the test of $\beta = 0$. * indicates significance at 10 percent level, ** indicates significance at 5 percent level, and *** indicates significance at 1 percent level.
Data Source: REACH Household Survey (2018)

The distance from the main source of water was an important factor determining the choice of contacting the open-source water for various purposes. The model 1 showed that if the distance of the main source of water required 5 minutes more, the odds of contacting with open-source water increased by a factor of 1.1 or by 10 percent, holding all other variables constant. The z-value of the coefficient was found over 9 and the p-value was approximately zero suggesting that the effect of higher distance from the main source of water significantly pushed the households to contact with open-source of water. The marginal effect showed that distance of households from main source water taking additional five minutes to collect water increased the chance of the contact with open-source water by around 0.02.

If we included the affordability variable in the model, as given by model 2 in the Table 5.8, we found that lack of affordability forced the household to contact with open-source water. The result showed that holding the effect of distance of households from the main source of water constant, the lack of affordability increased the odds of contacting with open-source water by the factor 1.78 or by 78 percent. The probability of contacting with open-source water increased by around 0.12, holding the effect of distance constant. The relationship was found statistically significant even at one percent level of significance.

Table 5.9: Unstandardized, standardized, and marginal effect of the coefficients of Logit models of finding determinants of open-source water contact
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Model	Explanatory variable	e^{β}	$e^{\beta StdX}$	Marginal Effect
Model 1	Water collection time	1.101	1.599	0.019
Model 2	Water collection time	1.101	1.598	0.019
	Monthly water cost over 120	1.778	1.232	0.115
Model 3	Water collection time	1.094	1.553	0.018
	Monthly water cost over 120	1.732	1.22	0.108
	Gender of HH head (Male =1)	1.259	1.067	0.045
	Age of HH head (years)	0.994	0.927	-0.001
	Schooling years	0.925	0.697	-0.016
	Household size	1.068	1.097	0.013

Note: e^{β}= factor change in odds for unit increase in X, $e^{\beta StdX}$=change in odds for SD increase in X. The coefficients are estimated using Logit model.
Data Source: REACH Household Survey (2018)

The characteristics of the household and household head were also important factors in determining the choice of contacting with open-source water. The model 3 showed that the odds of contacting with open-source water was inversely related with the level of education of the household head while it was positively and significantly related with the number of members in the households. The result showed that every incremental years of schooling of the household head reduced the odds of contacting with open-source water by around 7.5 percent, holding the effects of other variables constant. On the other hand, every additional member in the household increased the odds by a factor of 1.07, other things remaining the same.

The probability of contacting with open-source water increased by around 0.12, holding the effect of distance constant. The relationship was found statistically significant even at one percent level of significance. The characteristics of the household and household head were also important factors in determining the choice of contacting with open-source water.

The model 4 was expanded by taking a set of dummy variables explaining accessibility, ownership of water-point, status of sharing water-point, social problems faced during the collection of water from improved water-point. Moreover, the age of household heads were categorized and set as dummies and with similar fashion, a set of occupational dummies were added. A set of education dummies were also added. The downstream and upstream dummies were also included into the model. The results were reported in Table 5.10.

Table 5.10: Determinants of open-source water contact (unstandardized, standardized, marginal effects of the Logit coefficients based on Logit model)
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	Coefficient	SE	Z-value	Marginal Effect	e^{β}	$e^{\beta stdX}$
5-10 minutes	0.570***	0.162	3.51	0.114	1.769	1.248
10-15 minutes	1.229***	0.236	5.21	0.273	3.418	1.389
15-30 minutes	1.209***	0.33	3.67	0.272	3.349	1.243
Above 30 minutes	0.484	0.664	0.73	0.099	1.622	1.038
Water cost above 120	0.599***	0.164	3.64	0.121	1.821	1.242
Own water point	-0.174	0.169	-1.03	-0.031	0.84	0.923
Shared water point	0.460**	0.196	2.34	0.092	1.584	1.152
Faced social problem during water collection	0.624***	0.175	3.56	0.125	1.866	1.271
Gender of head (male=1)	-0.369	0.241	-1.53	-0.073	0.691	0.901
Below 20	-0.061	0.629	-0.1	-0.011	0.941	0.993
21-25	0.31	0.344	0.9	0.061	1.363	1.08
26-30	0.3	0.294	1.02	0.058	1.349	1.106
31-35	0.563**	0.279	2.02	0.113	1.756	1.224
36-40	0.213	0.275	0.78	0.041	1.237	1.082
41-45	-0.082	0.286	-0.29	-0.015	0.921	0.973
46-50	0.343	0.281	1.22	0.067	1.409	1.114
51-55	-0.178	0.308	-0.58	-0.031	0.837	0.952
56-60	-0.077	0.299	-0.26	-0.014	0.926	0.979
Agriculture Worker	0.293	0.312	0.94	0.057	1.341	1.056
RMG worker	-0.792***	0.224	-3.54	-0.124	0.453	0.752
Other factory worker	-1.149***	0.377	-3.05	-0.156	0.317	0.77
casual worker	0.211	0.239	0.89	0.041	1.235	1.055
Skilled worker	-0.354	0.254	-1.39	-0.059	0.702	0.917
construction worker	-0.585	0.359	-1.63	-0.092	0.557	0.907
Domestic worker	-1.958***	0.739	-2.65	-0.201	0.141	0.833
Boatman/fisherman	0.536*	0.286	1.87	0.109	1.709	1.113
Farmer/landlord	0.312	0.212	1.47	0.061	1.366	1.102
Non-govt. service	-0.946**	0.433	-2.19	-0.134	0.388	0.854
Rickshaw/van puller	-0.395	0.347	-1.14	-0.065	0.674	0.935
Others	-0.595**	0.243	-2.45	-0.095	0.552	0.848
Unemployed	-0.700**	0.278	-2.52	-0.109	0.496	0.825
Illiterate	1.357***	0.501	2.71	0.256	3.885	1.963
I-V	1.190**	0.505	2.36	0.249	3.287	1.635
VI-VIII	1.066**	0.517	2.06	0.229	2.905	1.421
IX-X	1.095**	0.515	2.13	0.238	2.988	1.445
XI-XII	0.641	0.579	1.11	0.133	1.898	1.151
Downstream	1.229***	0.158	7.78	0.257	3.419	1.684
Upstream	1.128***	0.149	7.59	0.233	3.09	1.623
Constant	-2.865***	0.62	-4.6			

Data Source: REACH Household Survey (2018)

Table 5.11: Collinearity Diagnostics of the Logit Model

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Variable	VIF	$\sqrt{VIF}$	Tolerance	R^2
OSWC	1.21	1.1	0.8259	0.1741
Extreme poor	1.06	1.03	0.9478	0.0522
Gender of head (male=1)	1.4	1.18	0.7152	0.2848
5-10 minutes	1.12	1.06	0.8941	0.1059
10-15 minutes	1.12	1.06	0.8893	0.1107
15-30 minutes	1.09	1.04	0.9179	0.0821
Above 30 minutes	1.03	1.01	0.9726	0.0274
Water cost above 120	1.1	1.05	0.9065	0.0935
Below 20	1.23	1.11	0.812	0.188
21-25	2.09	1.45	0.4786	0.5214
26-30	2.84	1.69	0.3517	0.6483
31-35	3.01	1.73	0.3324	0.6676
36-40	3.06	1.75	0.3267	0.6733
41-45	2.59	1.61	0.3862	0.6138
46-50	2.45	1.56	0.409	0.591
51-55	2.04	1.43	0.4898	0.5102
56-60	2.04	1.43	0.4899	0.5101
Agri. Worker	1.19	1.09	0.8438	0.1562
RMG worker	1.71	1.31	0.5862	0.4138
Other factory worker	1.28	1.13	0.7831	0.2169
casual worker	1.31	1.14	0.7648	0.2352
Skilled worker	1.27	1.12	0.7905	0.2095
construction worker	1.16	1.08	0.8624	0.1376
Domestic worker	1.2	1.1	0.8304	0.1696
Boatman/fisherman	1.22	1.1	0.8196	0.1804
Farmer/landlord	1.47	1.21	0.6803	0.3197
Government service	1.07	1.03	0.9368	0.0632
Non-govt. service	1.16	1.08	0.8586	0.1414
Rickshaw/van puller	1.15	1.07	0.8717	0.1283
Others	1.34	1.16	0.7454	0.2546
Unemployed	1.67	1.29	0.5994	0.4006
Illiterate	8.7	2.95	0.115	0.885
I-V	6.23	2.5	0.1606	0.8394
VI-VIII	4.25	2.06	0.2351	0.7649
IX-X	4.32	2.08	0.2314	0.7686
XI-XII	2.42	1.55	0.4136	0.5864
Downstream	1.37	1.17	0.731	0.269
Upstream	1.25	1.12	0.8	0.2

Data Source: REACH Household Survey (2018)

Table 5.12: Eigenvalues and condition index for measuring collinearity of the explanatory variables

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	Eigenvalues	Condition index
1	6.1349	1
2	1.6514	1.9274
3	1.4088	2.0868
4	1.342	2.1381
5	1.2065	2.255
6	1.19	2.2705
7	1.1631	2.2967
8	1.114	2.3467
9	1.0854	2.3774
10	1.08	2.3834
11	1.0651	2.4
12	1.0441	2.424
13	1.0291	2.4416
14	1.0228	2.4491
15	1.0165	2.4567
16	1.0106	2.4639
17	0.9963	2.4815
18	0.9898	2.4896
19	0.9821	2.4993
20	0.953	2.5372
21	0.9369	2.5589
22	0.9265	2.5733
23	0.9198	2.5826
24	0.9108	2.5954
25	0.8934	2.6205
26	0.8775	2.644
27	0.8183	2.7382
28	0.7812	2.8024
29	0.7365	2.886
30	0.7019	2.9564
31	0.6783	3.0074
32	0.6146	3.1594
33	0.5906	3.223
34	0.5	3.5028
35	0.3399	4.2483
36	0.1682	6.0401
37	0.0685	9.4659
38	0.0414	12.1797
39	0.0103	24.421

Data Source: REACH Household Survey (2018)

Table 5.13: Model's statistics of the determinants of open-source water contact (Logit model)
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	Value
Number of covariate patterns	1273
Number of groups	10
Hosmer-Lemeshow chi2 (8)	6.59
Prob > chi2	0.5815
Pearson chi2(1236)	1292.49
Prob > chi2	0.1287
VIF	2.03
Maximum eigenvalue	6.13
Minimum eigenvalue	0.0103
Condition Number	24.4
Sensitivity	31.85%
Specificity	93.42%
Positive predictive value	66.00%
Negative predictive value	77.37%
Correctly classified	75.80%

Data Source: REACH Household Survey (2018)

The expanded model 4 showed that the probability of OSWC risen with the increasing time to collect freshwater from the main source of water. The price risk also induced the probability of OSWC significantly. Households which had to share water points had more chances of OSWC and the probability of OSWC was intensified when the households faced social problems in collecting water.

The results showed that the river based livelihood increased the probability of OSWC. The probability of OSWC was quite high among the illiterate group compared to the literate group. We also found that in the downstream and upstream areas compared to the middle stream, the probability of OSWC was high.

Based on model 4, the predicted probabilities were estimated. The predicted probabilities were represented using kernel density to see the distribution pattern of the probability of OSWC. The kernel density plot of probability of OSWC was almost similar to the normal density plot of probability of OSWC.

Figure 5.1: Kernel density of probability of open-source water contact

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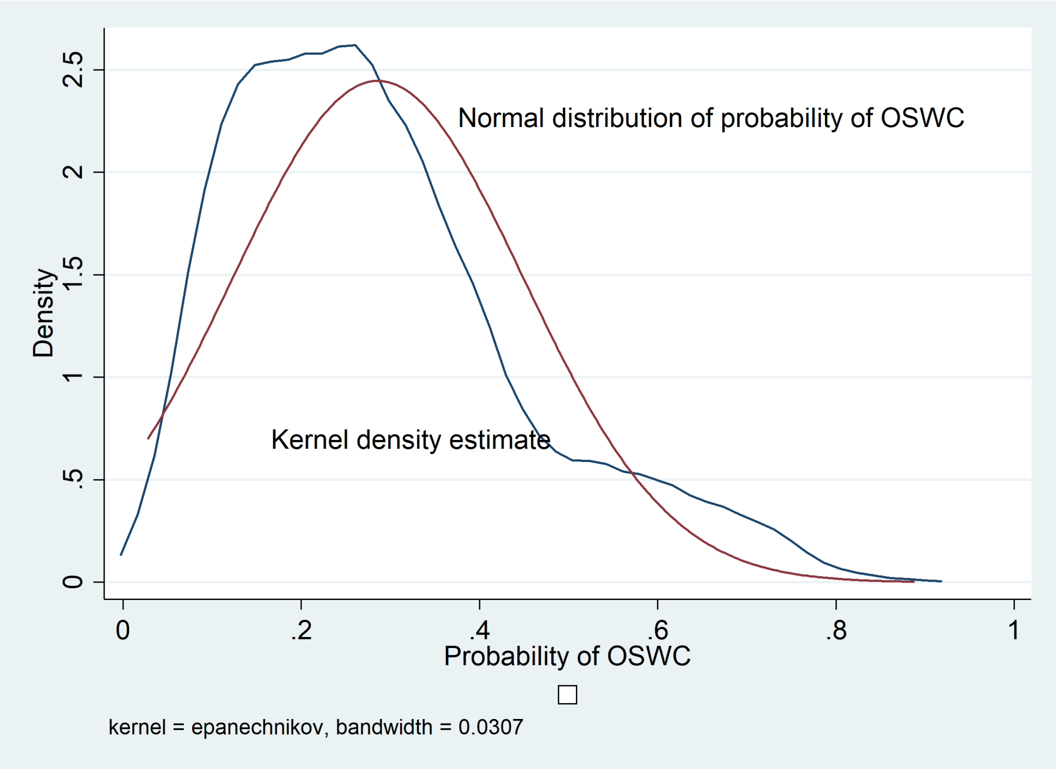

Source: REACH Household Survey (2018)

The goodness of fit of Logit model showed that how much well the current model fitted the data well. The Hosmer and Lemeshow Goodness-of-Fit Test was used to test the goodness of fit of the model. The estimated $\chi 2$ value was 6.59 with 8 degrees of freedom and the associated calculated p-value was 0.58. The high p-value suggested that the null hypothesis of zero fitting of the model was rejected. The number of covariate patterns was 1273, and the Pearson $\chi 2$ was 1292.49.

The model did not suffer from multicollinearity as the average variance inflating factor (VIF) value 2.03 was lower than the threshold value 10 suggesting very minimal multicollinearity among the variables. Similarly the condition index value, the square root of the ratio of the maximum eigenvalue of 6.13 and the minimum eigenvalue of 0.0103, estimated at 24.4 were suggesting a low level of moderate level of multicollinearity among the variables. The results are very much consistent with our previous results. The extended model lucidly revealed that the water security was influenced by the accessibility, affordability, ownership and shared nature of water-points, the characteristics of the households, and location of the households. We foundthat Water insecurity raises among the households which is constrained by affordability and accessibility as well as live in the upstream and downstream.

Figure 5.2: Relationship among probability of OSWC, affordability and availability of improved water

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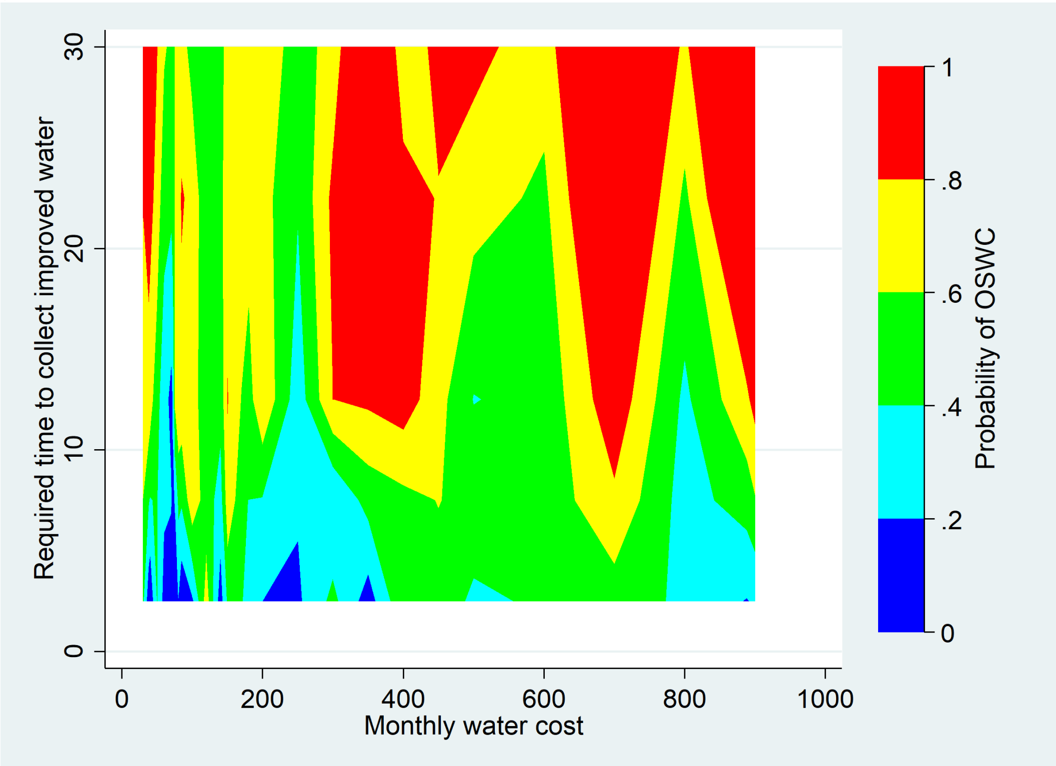

Source: REACH Household Survey (2018)

Now, we wanted to see the joint effect of affordability and availability of improved water on probability of OSWC. We used a contour plot to see the relationship. The plot showed that availability mattered: as even at low level of expenditure on water, the chance of OSWC was high and the chances increased for higher water cost and higher required time to collect water from improved water source. Therefore, among the constrained households, constrained by affordability and availability of water, the chance of exposing to open-source water was very high.

Table 5.14: Probability of OSWC with respect to availability and affordability (Logit model based results)
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Explanatory variable	Downstream	Middle stream	Upstream
Availability			
Below 5 minutes	33.3%	12.8%	30.9%
5-10 minutes	54.0%	22.3%	46.8%
10-15 minutes	76.3%	44.6%	70.0%
15-30 minutes	74.0%	50.8%	73.8%
Above 30 minutes	57.1%	36.7%	63.4%
Affordability			
Yes	36.9%	18.4%	36.3%
No	50.6%	25.9%	41.4%
Total	41.1%	19.2%	36.8%

Data Source: REACH Household Survey (2018)

The estimated probability showed that the probability of the contact with open-source was the highest among the households who are relatively far away of improved water source and who were relatively constrained by financial affordability.

Table 5.15: Water security score by various group and attributes

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	Average	Difference	SE	t-stat
Never poor	0.761	Base	0.004	171.31
Moderate poor	0.738	-0.023	0.012	-1.92
Extreme poor	0.706	-0.055	0.017	-3.16
Poverty dynamics				
Chronic	0.727	-0.041	0.012	-3.47
Movers	0.783	0.015	0.009	1.54
Fallers	0.672	-0.096	0.013	-7.24
Always better off	0.768	Base	0.007	111.68
Gender of HH Head				
Female	0.728	Base	0.014	2.06
Male	0.757	0.029	0.014	53.28
Education of HH head				
Illiterate	0.731	-0.092	0.022	-4.15
I-V	0.741	-0.083	0.023	-3.6
VI-VIII	0.778	-0.045	0.024	-1.86
IX-X	0.796	-0.027	0.024	-1.12
XI-XII	0.814	-0.010	0.028	-0.35
Higher education	0.823	Base	0.021	38.55
Accessibility				
Below 5 minutes	0.778	Base	0.005	168.2
5-10 minutes	0.744	-0.034	0.010	-3.36
10-15 minutes	0.653	-0.125	0.015	-8.55
15-30 minutes	0.630	-0.148	0.022	-6.84
Above 30 minutes	0.433	-0.345	0.050	-6.89
Affordability				
Unconstrained	0.809	Base	0.008	-45.67
Constrained	0.462	-0.347	0.003	270.45
Area Type				
Downstream	0.666	-0.116	0.010	-12.11
Middle stream	0.784	0.002	0.009	0.23
Upstream	0.782	Base	0.005	146.39

Data Source: REACH Household Survey (2018)

5.3.2 Factors affecting the water insecurity and water poverty

The contact with unimproved water source was one dimension of water security. Such contact was influenced by affordability, availability, and stability of water sources. It was also influenced by some household and regional attributes. We constructed a general water security score based on the technical formulation as discussed in chapter 2.

The average water security score was 0.755 with a standard deviation of 0.172. We compared the average water security score across various groups and various attributes of the households.

The study results showed that the non-poor household had an average water security score of 0.761 while the moderate and extreme poor household had an average water security score of 0.738 and 0.706 respectively. We found a gap in average water security score by the state of poverty. The extreme poor was the most vulnerable compared to the moderate poor and non-poor. The differential water security score between non-poor and moderate poor was found significant at 10 percent level while the differential water security score between non-poor and extreme poor was found significant at one percent level.

We also found the similar pattern of water security score by the various state of poverty of the household. The result showed that the average water security score of the better off household was around 0.768 whereas that was around 0.727, ar0und 4.1 percent lower than the average of the better off household. The differential water security score between these two groups was found statistically significantly different from zero at one percent level of significance. The household who had improved their economic condition over the course of time had the higher water security score - around 0.783 which was around 1.5 percent higher than average water security score of a random better off household.

We found that male led household was more water secured compared to the female led household: the average water security score of male led household was 0.757 while the average water security score for female led household was

0.728 and the difference in average water security score was found statistically significant at 5 percent. The schooling of household head and water security score was positively related implying an increase in years of schooling decreases the water insecurity or improved water security.

We found that among the households led by illiterate head, the average water security score was around 0.731, and among households led by a head having education over HSC, the average water security score was estimated at 0.823. Compared to the highest schooling group, the average water security of other group was found lower and the gap was found significant for the first three groups at various level of significance.

Water security score was low among the households living far away of the main source of water compared to the households adjacent to the main source of water and households who was financially constrained was more water unsecured compared to the non-constraint household. The households living in the downstream areas were more water unsecured compared to the households living the upstream and middle-stream.

The Logit based estimates showed that water poor was significantly influenced by the distance of the main source of water, low level of literacy of household head, the residence of the households in the downstream and middle-stream. Ownership of water source also significantly determined the state of water poverty.

Table 5.16: Factor determining probability of water poor

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	Coefficient	P-value	Marginal Effect	e^{β}	$e^{\beta stdX}$
5-10 minutes	-0.033	0.167	-0.005	-3.200	-1.300
10-15 minutes	0.804***	0.234	0.151	123.500	24.000
15-30 minutes	0.867***	0.330	0.168	138.000	16.900
Above 30 minutes	1.170	0.740	0.242	222.300	9.500
Own water point	-2.120***	0.216	-0.260	-88.000	-62.100
Shared water point	-0.675***	0.219	-0.089	-49.100	-18.800
Faced social problem during water collection	0.128	0.181	0.020	13.700	5.000
Gender of head (male=1)	0.016	0.249	0.002	1.600	0.400
Below 20	0.115	0.568	0.018	12.100	1.300
21-25	0.320	0.357	0.054	37.800	8.300
26-30	0.195	0.320	0.032	21.600	6.800
31-35	0.106	0.312	0.017	11.100	3.900
36-40	0.059	0.309	0.009	6.100	2.200
41-45	0.016	0.319	0.002	1.600	0.500
46-50	0.422	0.318	0.073	52.600	14.300
51-55	0.203	0.344	0.033	22.600	5.700
56-60	0.371	0.336	0.063	44.900	10.900
Agriculture Worker	0.245	0.352	0.041	27.700	4.600
RMG worker	-0.056	0.220	-0.009	-5.500	-2.000
Other factory worker	-0.979***	0.366	-0.115	-62.400	-20.000
casual worker	0.087	0.252	0.014	9.100	2.200
Skilled worker	0.010	0.274	0.002	1.000	0.300
construction worker	0.252	0.341	0.042	28.600	4.300
Domestic worker	0.168	0.628	0.028	18.300	1.600
Boatman/fisherman	0.078	0.328	0.012	8.100	1.600
Farmer/landlord	-0.279	0.278	-0.041	-24.400	-8.300
Non-govt. service	-0.742*	0.448	-0.092	-52.400	-11.600
Rickshaw/van puller	-0.536	0.358	-0.071	-41.500	-8.700
Others	0.184	0.243	0.030	20.200	5.200
Unemployed	-0.202	0.290	-0.030	-18.300	-5.400
Illiterate	0.707*	0.429	0.113	102.800	42.100
I-V	0.760*	0.433	0.134	113.900	36.900
VI-VIII	0.158	0.452	0.026	17.100	5.300
IX-X	0.276	0.455	0.046	31.800	9.700
XI-XII	0.460	0.519	0.081	58.500	10.700
Downstream	1.534***	0.159	0.294	363.700	91.600
Upstream	0.501***	0.163	0.084	65.100	24.000
Constant	-1.960***	0.580			

Data Source: REACH Household Survey (2018)

5.3.3 Multi-dimensional, Uni-dimensional and Water Poor: An Analysis of the Relationship

Conceptually, multidimensional and water poor (WSI) have some connection as the multidimensional poverty index (MPI) includes health component. On the other hand, the uni-dimensional poverty has no direct link with MPI and WSI but it pronounces the overall deprivation measured in terms of expenditure per capita.

The three poverty incidences - MPI, UPI and WSI - are well connected. A pairwise correlation analysis among these variables showed that the coefficient of correlation between MPI and UPI is 0.14, and that was 0.24 between MPI and WSI while that was 0.07 between WSI and UPI.

Figure 5.3: Distribution of poor by nature of poverty

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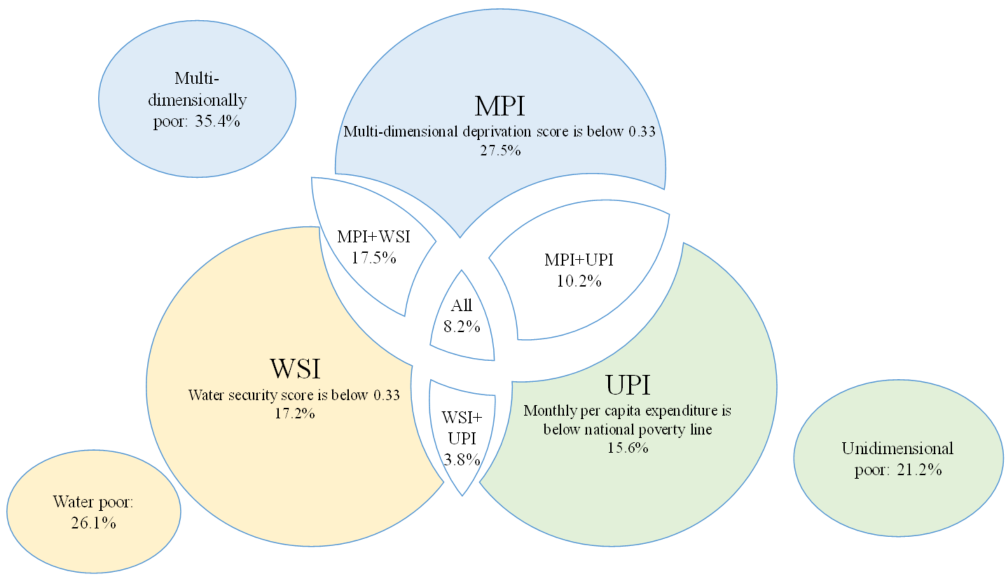

Source: REACH Household Survey (2018)

We found that around 35.4 percent people were multi-dimensional poor among which 17.5 percent were both water poor and multi-dimensional poor, 10.2 percent was both multi-dimensional and uni-dimensional poor, and 8.2 percent was poor in all type of poverty. Around 27.5 percent of the people were only multi-dimensional poor while 17.2 percent of the people were water poor only and 15.6 percent of the people were uni-dimensional poor. We found that the incidence of multi-dimensional poverty was 35.4 percent, the incidence of uni-dimensional poverty was 21.2 percent and the incidence of water poor was 26.1 percent.

Although the overlap of the incidence of water poor and uni-dimensional poor, multi-dimensional and uni-dimensional poverty was relatively low while the interaction between multi-dimensional poverty and water poverty was relative well-pronounced.

5.4 Summary of the Results

The survey results showed that during dry season, members of around 27 percent of the households had interactions with open-source water for bathing purposes, 23.8 percent for washing purposes (clothes and cooking utensils) and the interaction was a little bit lower during monsoon. Such an exposure to unsecured water for domestic purposes increased the household's overall water insecurity.

The results showed that among the non-poor households, the incidence of contacting with open-source water was around 27.4 percent whereas among the moderate poor, the incidence of the contact with open-source water was around 32.64 percent and hence, the incidence was found higher among the poor compared to the non-poor households and the difference was found statistically significant at 10 percent. The results also revealed that the incidence of contacting with open-source water among the extreme poor was much more higher, around 37.14 percent, compared to the comparison group and the difference was this time statistically significantly different at 5 percent level of significance.

Among the movers (the social status had improved compared to 5 years ago during the survey), the incidence was estimated at around 18.5 percent which was 30.3 percent among the never poor households. The classical mean test showed that compared to never poor group, the incidence of contacting with open-source water was high by 9.33 percent among the struggling group and the statistical test-statistic rejected the hypothesis of no differences in the incidence among these two groups. Similarly, the fallers (the social status had degraded compared to 5 years ago during the survey) group had higher incidence of contacting with open-source water compared to the never poor group by 9.28 percent and the gap was also statistically significant. We found that the incidence of exposing to open-source water was high among female led households compared to the non-extreme poor and male led households. The incidence of exposing to open-source water was high among the households who were struggling for better life every time and had fallen down below the poverty line.

The econometric results showed that the interactions with unimproved water was influenced by the affordability (the price risks), availability, and time required to collect the improved water. The simple two variable model showed that the lack of affordability increased the chance of the interactions with unimproved water by around 11.5 percent and after allowing the chances in some of the household characteristics, the chance of the contact with unimproved water slightly reduces and stands at 10.8. Adding the variables related to the ownership of water infrastructure and the status of the sharing the water in the model, the complete model showed that the chance of being exposed to unimproved water increases by 12.1 percent, holding the effects of other variables constant.

5.5 Conclusion

The concern of improving water security is increasing due to population growth, rapid urbanization, industrialization, persistence poverty, natural calamities and climate change as water stress can constrain social and economic development through jeopardizing the health and livelihoods of the vulnerable population. Urban water security needs to markedly progress and accelerate, because risks are increasing. There is a need to focus on strong governance, education, innovation, policy development, and adaptability. The assurance of water security requires enabling environment (policies and legislation), institutional framework, and management instruments (assessment, information, and allocation instruments) (ADB, 2016).

Moreover, addressing the urban water security needs the existing state of water security, nature, and indicators to stimulate policy formulation and to enhance effectiveness of interventions. This chapter described the state of access to water and water use behavior in urban riparian areas and identified some factors that were inducing or deterring of the exposure to the unimproved water.

The incidence of the contact with unimproved water was high among availability and affordability constrained households. Along sides, some household characteristics also determined the state of the interactions with unimproved water like the incidence of the interactions was high in downstream, and upstream areas compared to the middle stream. The study showed that although the quality of water of open-source water as perceived by the respondents was very poor, despite that around 28 percent of the households had the contact with such kind of water.

The poor households more likely had contact with unimproved water. In sum, the lack of availability of water from main source due to distance and time constraint, the affordability of buying the good quality of water, and social marginality were inducing the households to contact with unsecured water. Therefore, water should be available to the households at minimum distance and at minimum cost. The water security required the provision of safe water for drinking, sanitation and hygiene, the assurance of healthy rivers and ecosystem, the prevention of water-related disasters and a resilient communities which can adapt the changes.

Chapter 6

The Impact of use of Poor Water on Health Risks, Out-of-Pocket Expenditure, Productivity and Poverty

6.1 Introduction

The dynamics of water insecurity and the plausible factors affecting the interaction of the households with unimproved water sources for various purposes have been discussed in chapter six. The results showed that people of the nearby community of the riparian areas had some exposure to unimproved water for non-drinking purposes. The interaction with unimproved water was not only due to the price risks but also due to a set of socioeconomic factors. The second objective of this study was to assess the effects of such interactions on various economic indicators of the households and aimed at assessing the impact of water poverty on human health, illness, out-of-pocket expenditure, productivity, and overall poverty.

In an agrarian economy, the interaction of the people with the water body is normal and if the water body is not polluted, such exposure is not much deviant. However, with increasing the dominance of the manufacturing sector in the urban economy, the dependence of industrial growth is very much related to the environmental concerns in the industrial areas. Therefore, it is very much pertinent to ask what is the marginal external cost of the interaction with polluted water bodies. The answer to the question necessitates the measurement of the economic burden of such interaction.

The literature suggested that the interaction with unimproved water increased the chance of water-borne diseases. The health risks ultimately transformed into productivity risks and welfare risks. In labor economics, the trade-off between leisure and labor (hours) is well-discussed where it is assumed that the available time is defined as the gap between 365 days and the sum of the number of working days and the number of leisure days. But the human has to face some unanticipated realities. Sometimes, they suffer from diseases that have a direct and an indirect effect on total available days of work and leisure. Human enjoys the pleasant leisure and income from the work. The unpleasant leisure, time spent due to ill health, affects the labor-leisure constraint. The ill-health not only has an implication on labor-leisure choice but also has an implication on income and the well-being of the individual, hence, on poverty. Access to safe, reliable, and affordable water supply is important for good health (Hunter et.al., 2010). However, the magnitude of the effects depends on the economic loss or economic costs of illness, its dynamics, and the coping mechanisms.

In this chapter, we have discussed the impact of poor water i.e. unimproved water which is responsible for health risks, that is, illness and diseases of household members. Indeed this has direct impact on income of the household. The higher rate of illness and diseases reduces the available working hours, the effective working hours, income, and these may ultimately move the household under the poverty line or keep them under the poverty line for a longer time.

In the sustainable development goals, by 2030, it was set the target of eradicating extreme poverty for all people everywhere and of ensuring good health and well-being. Health and poverty are interlinked. Poor health of the family members may create income constraints or intensify the economic hardship through the low income earning or through the economic burden to be borne. On the other hand, good health is the source of happiness and good capital of earning.

Therefore, it is very much pertinent to assess the cost of the interaction with unimproved water on, health, health expenditure, income, and the overall well-being of the household. In particular, this chapter aimed to study the following causal relationships:

- Interaction with open-source water and illness/ diseases
- Interaction with open-source water and productivity
- Interaction with open-source water and out-of-pocket expenditure
- Interaction with open-source water and poverty.

In analyzing the results, we used pairwise correlation among selective variables related to explain the effects of the interaction with unimproved water on health and well-being. We also used the descriptive measures like frequency distribution and mean comparison among the comparison groups. The econometric techniques were followed after the descriptive analysis of the respective variables. The detailed theoretical discussions of the econometric modeling were done in the methodology section.

6.2 Correlation Analysis

To understand the association among the interaction with open-source water, illness, disease, productivity, out-of-pocket expenditure, and poverty, a pairwise correlation analysis among some related variables was done and the results have been presented in Table 6.1. The table contained the value of correlation coefficient, the p-value of testing zero correlation between the variables, and the test results (significant or insignificant).

Since the outliers affect the measure of correlations, the analysis was done at two levels: (i) without controlling the outliers, and (ii) with controlling outlier. The outlier was measured using the 99th percentile value of the respective variables, that is, we considered above the 99 percentile values as the outliers and were restricted in case of getting the correlation under a controlled scenario.

The pairwise correlation showed that the interaction with open-source water was positively associated with the selected outcome variables. The Pearson correlation coefficient between the interaction with open-source water and treatment expenditure was found 0.0667 with a p-value of 0.004 of this relationship. Similarly, the Pearson correlation coefficient between the interaction with open-source water and the number of ill members in the household was found at 0.1505 level and this relationship was found statistically significant. The pairwise correlation coefficient between the interaction with open-source water and productivity loss was estimated at 0.1681 which was 0.0481 between the interaction with open-source water and poverty.

Table 6.1: Correlation analysis among open-source water contact, different variables related to health risks, and some other related variables
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Pairwise correlation	Correlation Coefficient	P-value	Remarks
Interaction with open-source water and treatment expenditure	0.0667	0.004	Significant
Interaction with open-source water and number of ill people	0.1505	0.000	Significant
Interaction with open-source water and productivity loss	0.1681	0.000	Significant
Interaction with open- source water and poverty	0.0481	0.040	Significant
Treatment expenditure and number of ill member	0.1186	0.000	Significant
Productivity loss and number of ill member	0.1696	0.000	Significant
Controlling the outliers (99th percentile value)			
Interaction with open-source water and treatment expenditure	0.108	0.000	Significant
Interaction with open-source water and number of ill people	0.1471	0.000	Significant
Interaction with open -source water and productivity loss	0.1479	0.000	Significant
Interaction with open-source water and poverty	0.0456	0.053	Significant
Treatment expenditure and number of ill member	0.1347	0.000	Significant
Productivity loss and number of ill member	0.1511	0.000	Significant

Source: REACH Household Survey (2018)

The Pearson correlation coefficient revealed that ill members and treatment expenditure was positively correlated and the estimated correlation coefficient between these two variables was 0.1186.

Under the outlier controlled scenarios, it was found that the estimated correlation coefficient between the interaction with open-source water and treatment expenditure was 0.108 which was 0.0667 in the case of non-controlling the outliers. Similarly, the correlation coefficient between the interaction with open-source water and the number of ill people was found 0.1471 in the controlled case which was 0.1505 in case of uncontrolled outliers.

Therefore, after controlling the outlier of the treatment cost variables, we found lower correlation coefficients of the above-discussed relationship except for the correlation coefficient between the interaction with open-source water and treatment expenditure. However, the values of correlation coefficients of the bivariate association did not change much and the correlation coefficients were found still significant.

The pairwise correlation values were positive, though small in magnitudes, suggesting that there was a positive association between contacting open-source water and the number of ill people, contacting with open-source water, and treatment expenditure. The associations were statistically significant even at less than one percent level.

6.3 Effects of Poor Water on Health Risks: Illness and Diseases

In developing countries, about 80% of illnesses were attributed to unsafe drinking water and waterborne diseases (Abedin et.al., 2019). The chapter five of this study showed that members of the households had the interaction with the open-source water not for drinking purposes but for other domestic uses like bathing, washing utensils, and other household chores. Such an exposure to open-source water could have deleterious effects on health and might increase health risks if the contacted water was polluted.

To understand the water-related health risks, we have focused on household level health risks and, in particular, individual level water related health risks along with other non-water related health risks.

The effects of exposing to open-source water on illness, the number of ill members within the specific period of time, and the effects on out-of-pocket expenditure have been measured in this section. The effects are shown by areas: upstream, down stream, and middle-stream.

The Table 6.2 showed the distribution of the number of ill members in the household, the average ill members per household, and the gap in the average ill members between the households having the contact with the unimproved water or not. The results were shown for upstream, middle stream, and downstream areas.

It appeared from the Table 6.2 that 44.27 percent of the households whose members had no interaction with open-source water had no ill members whereas 27.22 percent of the households whose members had the interaction with open-source water had no ill members. So, 72.78 percent of the households having interaction with open-source water had ill members.

The results further showed that of the non-exposing households, 28.75 percent of the households had single ill member, 17.13 percent had two ill members and 9.85 percent had more than two members whereas that of the exposing households, 33.59 percent had single ill member, 23.17 percent had two ill members, and 16.02 percent had more than two ill members.

On an average, households exposing to open-source water had more average number of ill people (1.35 persons per household) compared to the households who were not exposed (0.97 per household). The incidence of illness was high among the households exposing to open-source water and the difference was 0.38 which was significant at 1 percent level (Table 6.2).

Table 6.2: Number of ill members in the households due to the contact with open-source water in various areas of Turag Riparian during the study period .

Description	Contact with open-source water		Weighted average
	No ($n_1 = 1308$)	Yes ($n_2 = 518$)	$N = 1826$
0	44.27	27.22	39.43
1	28.75	33.59	30.12
2	17.13	23.17	18.84
More than 2	9.85	16.02	11.61
Average	0.97	1.35	1.08
Mean Difference	0.38		
Test statistics (t-stat)	6.5		
Upstream			
0	38.87	20.25	32.06
1	27.92	31.90	29.37
2	19.79	28.22	22.87
More than 2	13.42	19.63	15.70
Average	1.13	1.54	1.28
Mean Difference	0.41		
Test statistics (t-stat)	3.48		
Middle stream			
0	53.64	44.51	51.89
1	29.48	36.81	30.88
2	13.12	13.74	13.24
More than 2	3.76	4.94	3.99
Average	0.68	0.81	0.70
Mean Difference	0.13		
Test statistics (t-stat)	1.86		
Downstream			
0	21.96	15.61	19.39
1	27.45	31.79	29.21
2	26.27	28.32	27.10
More than 2	24.32	24.28	24.30
Average	1.66	1.75	1.70
Mean Difference	0.09		
Test statistics (t-stat)	0.65		

Source: REACH Household Survey (2018)

In the upstream areas, among the households whose members had no interaction with unimproved water, around 38.87 percent had no ill-members whereas among exposing groups, around 20.25 percent had no ill-members. In the upstream areas, among the users of open-source water, 60.12 percent households had 1-2 ill members and among the non-users of open-source water, 47.71 percent had 1-2 ill members.

Table 6.3: Percent prevalence of different diseases due to contact with open-source water by members of the households in Turag Riparian areas under study in 2018
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Description	Contact with open-source water		Weighted Average
	No ($n_1 = 1308$)	Yes ($n_2 = 518$)	$N = 1826$
Dysentery/diarrhoea	7.8	16.22	10.19
Cholera	0.76	0.58	0.71
Typhoid	5.66	7.34	6.13
Jaundice	7.49	12.36	8.87
Skin diseases	8.18	18.34	11.06
Gastric/ulcers	25.08	35.91	28.15
Mosquito borne	6.8	10.42	7.83
Respiratory disease	4.13	7.72	5.15
Other	24.39	27.22	25.19

Source: REACH Household Survey (2018)

The results in 6.2 revealed that the averages of the number of ill-members among users and non-user of open source water were 1.54, and 1.13 in upstream; in middle stream, that were 0.81, and 0.68; and in downstream, that were 1.75, and 1.66 respectively. The result revealed that in the upstream and downstream areas, the average number of ill members among both users and non-users of open source water were larger than the areas in the middle stream. It was found that in all areas, the number of ill members were higher among the users of open-source water than the non-users of open-source water.

The mean-differences were 0.41, 0.13, and 0.09 in upstream, middle stream, and downstream respectively and these difference were found significant in upstream areas but insignificant in other areas.

The illness was prevalent among the members of the households in the survey areas. The data presented in Table 6.3 showed that among the households having the interaction with open-source water, there were prevalence of diarrhoea (16.22 percent), typhoid (7.34 percent), jaundice (12.36 percent), skin diseases (18.34 percent), gastric ulcer (35.91 percent), mosquito borne (10.42 percent), and respiratory diseases (7.72 percent).

Among the non-user of open-source water, there were the prevalence of diseases too. The prevalence of various diseases among those groups were diarrohea 7.8 percent, typhoid 5.66 percent, jaundice 7.49 percent, skin diseases 8.18 percent, gastric/ulcers 6.8 percent, mosquito borne 6.8 percent, and respiratory disease 4.13 percent. The results revealed that gastric/ulcer was the major disease faced by male and female members of the households. Skin disease and diarrhoea were second and third most (excluding other category) diseases among the members of the households.

The comparative analysis of the prevalence of the diseases by the nature of the use of open-source water showed that among the members of the households who used open-source water, the prevalence of various diseases, except cholera, was higher than the members of the households who did not use open-source water.

Since the association between variables did not guarantee the causal relationship among the variables and the two-way bivariate analysis were not enable to control more than two or three variables, an econometric model has been used to find the relative effects of selective household characteristics.

Based on the OLS and Tobit methods the effects of the use of open-source water on number of ill members of the study have been presented in Table 6.4.

Table 6.4: A comparative analysis of OLS and Tobit Models of determining the number of ill members of the households under study in relation to open-source water contact
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Explanatory variable	OLS	TOBIT
Contact with open-source water (yes=1)	0.361***	0.610***
	(0.059)	(0.093)
Gender of household head	-0.057	-0.076
	(0.095)	(0.152)
Age of household head	0.004*	0.008**
	(0.002)	(0.003)
Education of household head	-0.004	-0.009
	(0.006)	(0.01)
Household size	0.153***	0.207***
	(0.019)	(0.031)
Constant	0.272*	-0.589***
	(0.141)	(0.228)
Sigma		1.675***
		(0.039)
Number of observations	1,825	1,825
F	24.832	

Source: REACH Household Survey (2018)
Note: The figures in parentheses show standard errors. * indicates significance at 10 percent level, ** indicates significance at 5 percent level, and *** indicates significance at 1 percent level.

The results showed that the contact with open-source water increased the number of ill members in the households and the relationship was found statistically significant at one percent level. The results also revealed that among the users of open-source water, the average number of ill member was around 0.36 person which was higher compared to those households whose members had no contact with open-source water.

The coefficient of household size variable was found positive meaning that an incremental number of member in the households increased the number of ill members in the households. This result was quite practical as the additional member in the household lowers average resource allocation per individual.

The other coefficients of the variables gender of household head and years of schooling of household heads (education) were negative suggesting an inverse relationship between the number of ill members in the household and the corresponding independent variable. However, the OLS results may be theoretically biased as the dependent variable had biasness toward zeros. Therefore, a truncated model would be more appropriate.

The TOBIT model was used to handle this problem and the results were reported in the last column of the Table 6.4. The TOBIT coefficients were different than the OLS coefficients and hence told us that OLS estimates were biased and the directions of the biasness were downwards. The TOBIT model showed that the intensity of ill members in the households who contacted with open-source water increased by 0.61 holding other things remaining same compared to the households whose members did not contact with open-source water other things remaining same.

The coefficient of the variable open-source water contact was 0.25 point higher in TOBIT model compared to the OLS model. The effect of the incremental household members on number of ill members in the household also intensified in TOBIT model. Moreover, the relative significance of the age variable also increased in TOBIT model.

The result presented in Table 6.5 showed that the contact with open-source water increased the number of diseases of the members of the households and the relationship was found statistically significant. The results showed that

Table 6.5: A comparative analysis of OLS and Tobit Models of finding the effects of open-source water contact on the number of diseases faced by members of the households under study in 2018
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Explanatory variable	OLS	TOBIT
Contact with open-source water (yes=1)	0.448***	0.703***
	(0.058)	(0.092)
Gender of household head	-0.138	-0.168
	(0.095)	(0.15)
Age of household head	0.004*	0.008**
	(0.002)	(0.003)
Education of household head	0.001	-0.003
	(0.006)	(0.01)
Household size	0.104***	0.152***
	(0.019)	(0.031)
Constant	0.448***	-0.380*
	(0.14)	(0.226)
Sigma		1.658***
		(0.039)
Number of observations	1,825	1,825
F	20.832	

Source: REACH Household Survey (2018)
Note: The figures in parentheses show standard errors. * indicates significance at 10 percent level, ** indicates significance at 5 percent level, and *** indicates significance at 1 percent level.

among the open-source water contacting households, the average number of diseases was 0.45 higher compared to the households which have no contact with open-source water.

The coefficient of household size variable was found positive meaning that an incremental number of members in the households would increase the occurrence of the number of diseases in the households. The other coefficients of the variables gender of household head and years of schooling of household heads (education) in Tobit model were negative suggesting an inverse relationship between the number of diseases of the members of the households and the corresponding independent variable.

The TOBIT model showed that the intensity of number of diseases in the households whose members contacted with open-source water increased by 0.703 holding other things remaining the same compared to those who did not contact with open-source water . The coefficient of the variable open-source water contact was 0.25 point higher in TOBIT model compared to OLS model. The effect of the incremental household member on number of diseases in the household was also intensified in TOBIT model.

6.4 Effects on Productivity

From the study, it was found that 22.6 percent of adult women and 72.6 percent of adult men were employed in various occupations. The rest of the men and women were either unemployed or actively engaged with learning or incapable to work. The average age of the working female was 31 years whereas the average age of the male workers was 37 years. Around 21 percent of female workers were below 21 years whereas less than 11 percent of male workers were below 21 years. Around 60 percent of female workers had age below 31 and around 75 percent of male workers had age below 41 years.

Table 6.6: Participation of members of the households (male, female, and both) of different age groups in different productive activities and levels of education attained in Turag Riparian areas under study.
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Variables (%)	Female worker (22.6%)	Male worker (72.6%)	Weighted Average (47.6%)
Age (average year)	31	37	37
Below 21	20.57	10.99	13.29
21-25	18.37	11.83	13.4
26-30	20.09	15.94	16.94
31-35	15.38	14.7	14.87
36-40	9.42	13.07	12.19
41-45	6.75	9.6	8.92
46-50	4.4	8.66	7.64
Above 50	5.02	15.19	12.75
Schooling years (average)	3.7	5.1	4.8
Illiterate	42.39	34.5	36.39
I-V	31.4	23.71	25.56
VI-VIII	14.29	15.84	15.47
IX-X	8.16	15.1	13.44
XI-XII	2.35	6.88	5.8
Above XII	1.41	3.96	3.35

Source: REACH Household Survey (2018)

Among the female workers, 42.39 percent were illiterate and very few of them had education above HSC (1.41 percent) whereas among the male workers the illiteracy rate was 34.5 percent and 3.96 percent of them had education above HSC. The results revealed that the illiteracy was low among the male workers compared to the female workers. The average years of schooling of female workers was around 3.7 and that of male workers was 5.1 (Table 6.6). The distribution of workers by the level of education showed that the female workers had mostly primary level of education whereas the male workers had a little bit higher education.

Table 6.7: Participation (percent) in different types of productive activities by members of the households in Turag Riparian areas during 2018
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Occupation	Female worker (22.6%)	Male worker (72.6%)	Weighted Average (47.6%)
Agricultural labour	0.78	3.56	2.9
Boatman	0	0.15	0.11
Business	6.44	24.6	20.25
Construction labour	2.04	3.22	2.94
Domestic maid	11.15	0.05	2.71
Farmer	1.1	9.41	7.41
Fisherman	0.16	4.16	3.2
Garment factories	54.47	20.79	28.87
Govt. service	0.78	0.89	0.87
Land owner	1.73	0.89	1.09
Non govt. service	3.45	4.16	3.99
Casual labour	4.08	9.16	7.94
Other factories	10.05	6.78	7.56
Rickshaw/van puller	0	3.71	2.82
Skilled labour	3.77	8.47	7.34

Source: REACH Household Survey (2018)

It was revealed from the study (Table 6.7) that more than half of the working women (54.47%) were employed in Garment factories, 10.05 percent in other factories, and very few were casual workers. Domestic work was the second most service of the female workers. Involvement of female members of the households in the study area was 6.44 percent.

There was variation in occupancy among the male workers. One-fifth of the male workers of the households were employed in RMG sector, 9.16 percent were employed as casual workers, and 6.78 percent were employed in other factories.

Business was the major occupation of the male workers: 24.6 percent were running their business. Labor selling was another important occupation of the male workers: 8.47 percent of male workers were working as skilled labor, 3.56 percent as agriculture labor, and 3.22 percent as construction workers. Around 4.16 percent of male workers were involved with fishing, 3.71 percent as rickshaw/van pullers, and few of male workers were employed in government services.

Table 6.8: Productivity loss due to illness and diseases among male and female workers and the treatment cost in Turag Riparian areas during 2018
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	Female worker (22.6%)	Male worker (72.6%)	Total (47.6%)
Lost working days in last two weeks during study period (% of workers)	21.04	16.68	17.73
Average days in last two weeks during study period	4.3	4.5	4.5
Per month average treatment cost (BDT) (Among the households having positive treatment expenditure)	2132	2145	2142

Source: REACH Household Survey (2018)
Note: According to LFS (2016-17), the average monthly salary/wage of female and male workers was BDT 13321 and BDT 17106 respectively. The weighted average of the salary/wage was BDT 15912.

Results presented in Table 6.8 described the productivity loss of the working members of the households in Turag riparian areas under study. The loss of working days due to illness was obtained by the aggregation of number of working days lost by male and female workers of the households. The survey result showed that around 21.6 percent of households lost a positive number of working days due to illness of the working members of the households.

On an average, among female workers, 21.04 percent of female workers and 16.68 percent of male workers had lost effective working days. In total, among both male and female workers, around 17.73 percent of workers had lost effective working days due to illness.

The number of diseases faced by the members of the households and the total number of ill members in the households might have an effect on the number of working days of the households.

Figure 6.1: Percent of households having lost working days due to illness and diseases under study during 2018

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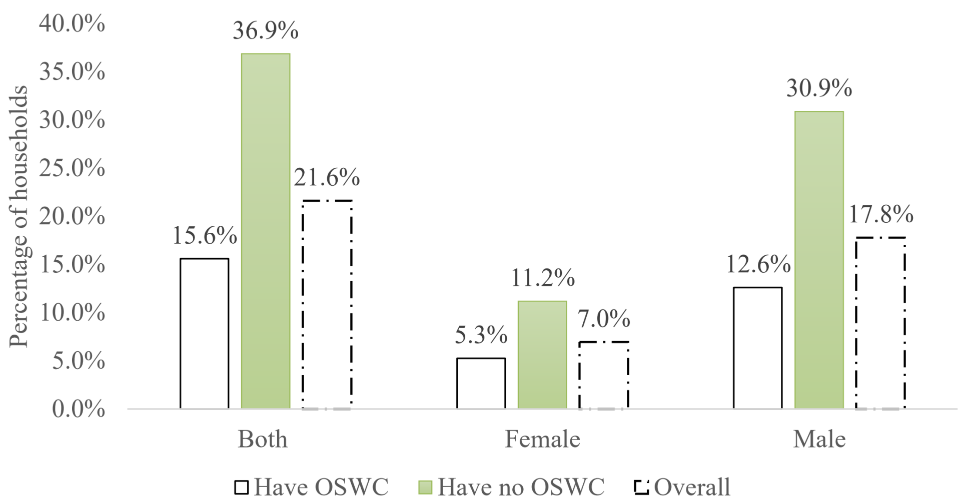

Source: REACH Household Survey (2018)

The results presented in Figure 6.1 was the percent of the household whose working members lost working days due to illness in relation to the contact with open-source water during the study in Turag riparian areas. The results showed that 21.6 percent of the households had members who lost positive amount of working days due to illness, 15.6 percent of the households whose members had no OSWC lost a positive number of working days and among the households whose members had OSWC, the incidence of loss of working days within the same period was 36.9 percent. We observed that the difference in incidence of losing working days by the status of OSWC was more than double among the households whose members had OSWC compared to non-users of open source water.

The dis-aggregation of the incidence by gender, we found that around 11.2 percent of the households with OSWC had female workers who lost some working days due to illness and the incidence was 5.9 percent point lower among the households whose members had OSWC. The gap in incidence of lost working days of male workers due to illness between the households who had OSWC and who had no OSWC was substantial, 12.6 percent for the households having no OSWC and 30.9 percent for the households having OSWC.

It was clear from Table 6.8 and Figure 6.1 that the OSWC increased the productivity loss and the associated loss was borne either by the workers or the employers, or both. The incidence of loss of working days in work places was one side of the effect of OSWC but the other side of the effect of OSWC was the average number of loss of working days by the workers in the households. We estimated the average loss of working days within the group (the households which had members losing working days due to illness, and among all samples which were classified based on OSWC) as well as that of whole samples and the estimated results were presented in Table 6.9.

Table 6.9: Average productivity loss in days due to illness of working members of the households during last two weeks during the survey in 2018
.

Productive Groups	Have OSWC? No	Have OSWC? Yes	Overall	Difference	t-stat
Both male and female					
Within groups	4.25	4.48	4.36	0.23	0.8
All Samples	0.67	1.69	0.96	1.02	8.8
Female					
Within groups	3.56	4.01	3.77	0.45	0.8
All Samples	0.19	0.45	0.26	0.27	4.4
Male					
Within groups	4.21	4.12	4.74	0.09	0.3
All Samples	0.54	1.3	0.75	0.76	7.5

Source: REACH Household Survey (2018)
Note: In estimating the average, the variables has been restricted to 99 percentile value so that the effects of the outliers can be avoided.

The results showed that within the groups, the average loss of working days among the households having OSWC was around 4.48, and the gap compared to the households having no OSWC (4.25 percent) was positive but not significant. Among all of the samples having OSWC, the average loss of working days was 1.69 whereas for the sample households which had no OSWC, the average lost working days was 0.67.

This result showed that, on an average, the households having OSWC lost one additional working day (approximately) compared to the comparison group, and the gap was found statistically significant at one percent level of significance. The gap of loss of working days between users and non-users of open-source water was found high if we considered male workers and was low if we considered the female workers.

Table 6.10: A comparative analysis of the effect of open-source water contact on treatment cost (log) in OLS and Tobit model
.

Explanatory variable	OLS	TOBIT
Contact with open-source water (yes=1)	0.771***	4.667***
	(0.127)	(0.817)
Gender of household head	-0.078	-0.275
	(0.203)	(1.335)
Age of household head	-0.003	-0.014
	(0.005)	(0.031)
Education of household head	-0.011	-0.064
	(0.013)	(0.088)
Household size	-0.026	-0.346
	(0.042)	(0.291)
Number of ill members	0.377***	2.189***
	(0.05)	(0.33)
Constant	0.722**	-12.570***
	(0.301)	(2.157)
Sigma		10.522***
		(0.569)
Number of observations	1,825	1,825
F	19.194	

Source: REACH Household Survey (2018)
Note: The figures in parentheses show standard errors. * indicates significance at 10 percent level, ** indicates significance at 5 percent level, and *** indicates significance at 1 percent level.

6.5 Effects the use of open-source water on out of pocket treatment expenditure

The previous result presented in Table 6.2 to 6.5 showed that the contact with open-source water had deleterious effects on health: increased illness and diseases. Such effects might exacerbate household out-of-pocket expenditure because of getting treatment and of purchasing medicine and medical services to recover from illness and diseases.

The average monthly health expenditure among the households exposing to open-source of water was around BDT 582 (USD 7.1) whereas the households whose members had no contact with open-source water had an average monthly health expenditure of BDT 261 (USD 3.2). The households exposing to open-source of water had to spend BDT 321 ($3.9) more as treatment cost compared to their comparable group. Annually they had to spend additional BDT 3852 to take care of the health of the household members. The effect of OSWC on out-of-pocket treatment expenditure was reported in the Table 6.10.

A comparative analysis was done on the average monthly treatment cost of the users and non-users of open source water in Turag riparian areas during the study in 2018. According to both OLS and Tobit model, the coefficients of the open-source water contact variable were positive suggesting that treatment cost was high among the users of open-source water than the non-users holding other things constant and the result was statistically significant at 1 percent level in both of the models. The increase of the number of ill-members of the households by one unit holding the effects of other variables constant, the log of monthly treatment expenditure increased by 0.377 in OLS model and 2.189 in Tobit model. The OLS estimates underestimated the effect while the Tobit model showed higher effect of the contact with open-source water on the number of ill members in the households and the number of diseases faced by the household members. The results confirmed that the contact with open-source water increased illness and diseases among the household members.

6.6 Effects on Poverty

The previous analysis clearly showed that the use of open-source of water increased illness and diseases of the members of the households and also increased the loss of working days among the working members of the households. These effects might increase the probability of poverty among the users of open-source water. In this case, the environment-health-poverty trap can be mentioned: (i) pollution might increase water insecurity, (ii) water insecurity might increase the chance of being or remaining poor, and (iii) the poverty, in turn, might increase water insecurity. The answer was not straightforward as both were interlinked in both directions: (i) water insecurity could be due to poverty, and (ii) water insecurity could exacerbate poverty condition.

The results of the analysis of the effects open-source water contact on poverty of the household caused by different factors in Turag riparian areas under study following Logistic regression model have been presented in Table 6.11.

It was evident that water insecurity increased the probability of poverty. The results revealed that the households having contact with open-source water had 1.005 times higher chance of probability. The results further showed that an increase of the standard deviation in water insecurity increased the chance of poverty by around 0.26 keeping the effects of other variables constant. This results suggested that the successful initiative for the reduction of water insecurity would reduce the poverty.

Table 6.11: The effects of the use of open-source water and a set of exogenous variables on poverty in Turag Riparian areas during 2018 (Results were based on Logit model)

Explanatory variable	Coefficient	P-value	Marginal Effect	e^{β}	$e^{\beta stdX}$
Contact with open-source water (water insecurity)	0.005***	0.001	0.005	1.005	1.2659
Gender of household head	-0.090	0.209	-0.090	0.914	0.975
Age of household head	0.003	0.005	0.003	1.003	1.0431
Education of household head: years of schooling	-0.438***	0.024	-0.438	0.645	0.1335
Household size	-0.211***	0.047	-0.211	0.810	0.7444
Downstream	1.641***	0.170	1.641	2.005	2.005
Upstream	1.033***	0.156	1.033	1.558	1.5582
Constant	0.648**	0.328			
Number of observations	1,825				
Pseudo R2	0.353				

Note: The figures in parentheses show standard errors. * indicates significance at 10 percent level, ** indicates significance at 5 percent level, and *** indicates significance at 1 percent level.

6.7 Results from Propensity Score Matching Model

The non-matched comparison between the households with or without the interactions with open-source water sometimes may be questioned on the plea that the differences between the groups in some indicative variables may be due to the differences in the attributes of the households and hence, the findings could be incredible and not reliable. Therefore, it was warranted to check whether the findings in the non-matched case were supported by the matched comparison. The similarities of the findings between those two methods will not only increase the credibility of the findings but also will reveal the robustness of the findings and thereby will increase the reliability of the estimates.

Table 6.12: Effects of open-source water contact of members of the households on lost working days, illness during two weeks in Turag Riparian areas in 2018 (Results were based on Propensity Score Matching Model)
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Variable	Results without controlling PSCORE		
	Observed	Bias	Bias corrected CI
Average lost working days in last 2 weeks			
Working days (both male and female)	1.04***	-0.018	0.79 - 1.47
Working days of female workers	0.21***	0.023	0.07 - 0.40
Working days of male workers	0.77***	0.015	0.51 - 1.01
Average number of ill members in the HHS			
Ill members in the household	0.40***	-0.011	0.27 - 0.60
Female ill members in the household	0.15***	0.11	0.03 - 0.25
Male ill members in the household	0.25***	-0.03	0.19 - 0.34
	Results with controlling PSCORE		
Average lost working days in last 2 weeks			
Working days (both male and female)	1.00***	0.006	0.73 - 1.26
Working days of female workers	0.26***	0.003	0.11 - 0.40
Working days of male workers	0.76***	-0.033	0.58 - 1.03
Average number of ill members in the HHs			
Ill members in the household	0.39***	-0.004	0.25 - 0.57
Female ill members in the household	0.18***	-0.004	0.13 - 0.30
Male ill members in the household	0.21***	-0.003	0.16 - 0.38

Data Source: REACH Household Survey (2018)
Note: * indicates significance at 10 percent level, ** indicates significance at 5 percent level, and *** indicates significance at 1 percent level.

Based on the propensity score matching model, as discussed in chapter 4, we found the results represented in Table 6.12. The results were (i) without controlling PSCORE and (ii) with controlling PSCORE. Three measures of each outcome variable were reported: observed mean effect, estimated bias, and bias corrected confidence interval. The outcome variables included broadly three issues: (i) lost working days in last two weeks, (ii) the number of ill members in the household, and (iii) treatment expenditure. The first outcome variables had also been dis-aggregated by gender of the household members.

Comparing the results (i) with and (ii) without controlling PSCORE, it was found that without the control of PSCORE, on an average one working day more was lost due to illness among the water unsecured households within two weeks during the study, that is, in a year, approximately 27 (1.04×26) more working days lost among the households having the contact with unimproved water sources. Of this loss of working days, around 74 percent was due to the loss of working days of male working members of the household and 26 percent was due to the illness of female working members of the household. With controlling the PSCORE, that is, using PSCORE as weight in estimating the average effect, it was found that the average lost of working days slightly reduced from 1.04 to 1 day within two weeks or from 27 to 26 days within a year during the study.

The estimate of average number of ill members in the households having contact with unimproved water compared to their comparison group was found 0.4 more individuals in the household in the case where PSCORE was not controlled and was found 0.39 more ill members in the households in the case where PSCORE was controlled. A closer look at the average number of ill members by gender dis-aggregation showed that the average number of male members was high whereas the average number of female members was low. This might be reason that the male members of the households used to use more open-source water compared to the female members of the households.

6.8 Summary of the Results

In chapter six, it was shown that there were 28 percent of the households whose members had contact with open-source water or unimproved water for non-drinking purposes during dry or monsoon seasons. The current chapter critically investigated the impact of such exposure to open-source water by the members of the household on health risks, out-of-pocket expenditure, and poverty in descriptive as well as econometric methods. In particular, the effects of the exposure on human health and health induced shocks was assessed and it further assessed the economic cost of the exposure to open-source water on illness, number of diseases faced by the household members, number of loss of working days due to illness, the treatment cost, and on incidence of poverty. The present study was undertaken in Turag riparian areas and there were sample 1826 households from twelve areas of the study areas.

To understand the association among illness, lost working days, and treatment cost involved due to the contact with open-source water, the pairwise correlation analysis was done and the pairwise correlation coefficient values were determined. The correlation coefficients were positive, though small in magnitudes, suggesting that there was a positive association between contacting open-source water and number of ill people; and contacting with open-source water and treatment expenditure. The associations were statistically significant even at 1 percent level of significance.

The results showed that around 44.27 percent of the households having no interaction with open-source water had no ill members while 27.22 percent of the households having interaction with open-source water had ill members in the household. So, 72.78 percent of the households having interaction with open-source water had ill members. Among the non-exposing households, 28.75 percent had single ill member, 17.13 percent had two ill members, and 9.85 percent had more than two members whereas that of among the exposing households, 33.59 percent had single ill member, 23.17 percent had two ill members, and 16.02 percent had more than two ill members. On an average, households exposing to open-source water had more average number of ill people (1.35 persons per household) compared to the households who were not exposed (0.97 per household). The difference in the average number of ill members in the households between these types of households was 0.38 and the difference was statistically significant at 1 percent level of significance.

In the upstream areas, among the households having no contact with open-source water, 38.87 percent of households had no ill-members whereas among those having such contact with open-source water, 20.25 percent of the households had no ill-members. The overall results suggested that the presence of ill-members in the households was high among those having the contact with open-source water compared to those who had no contact with open-source water in upstream areas.

The prevalence of diarrhoea (16.22 percent), typhoid (7.34 percent), jaundice (12.36 percent), skin diseases (18.34 percent), gastric ulcer, mosquito borne and respiratory diseases were higher among the households using open-source water compared to the non-users of open-source water. Gastric/ulcer was the major disease faced by the household's members who are exposing to open-source water. Skin disease was also prevalent among the households. The econometric models showed that the marginal effect of the exposure to unimproved water on number of ill members and number of diseases faced by the household members was positively significant.

The illness and the diseases of the working people had directly and indirectly effect on productivity. On an average, among female worker, 21.04 percent of the workers had lost effective working days and 16.68 percent of male workers had lost effective working days. In total, among the workers without allowing the gender dimension, around 17.73 percent of workers had lost effective working days due to illness. The survey results showed that around 21.6 percent of the households lost a positive number of working days due to illness of the working members of the households.

The results showed that within the groups, the average lost working days among the households having OSWC is around 4.48 days in two weeks during the study, and the gap compared to the households having no OSWC (4.25 percent) was positive but not significant. Among the all samples having OSWC, the average lost working days was estimated to be 1.69 days in the last two weeks during the survey whereas for the sample households having no OSWC, the average lost working days was 0.67. This result showed that, on an average, the households having OSWC lost around one additional working days in two weeks during the survey compared to the group having no open-source water contact, and the difference was found statistically significant at 1 percent level. The difference was found higher among male workers compared to the female workers.

Using the shadow wage for the lost working days, the direct cost of the lost working days was calculated. The net loss in a monthly due to the nature of the exposure to open-source water was BDT 1061 per month per household (BDT 12730 annually). The inclusion of the indirect loss due to illness would intensify the loss by a factor above one.

The average monthly health expenditure among the households exposing to open-source water was around BDT 582 (USD 7.1) whereas the opposite group had an average monthly health expenditure of BDT 261 (USD 3.2). The households having the contact with open source water had to spend BDT 321 ($3.9) more as treatment cost compared to their comparable group. Annually they had to spend additional 3852 BDT to take care of the health of the household members.

6.9 Conclusion

The member of the poor households were more likely contacted with open-source water. Household characteristics also played important roles. The exposure was not costless. The number of ill persons of the households were high among the households having the contact with open-source water and the number of ill member increased due to the increased number of diseases of the members of the households compared to the households having no contact with open-source water. As regards of cost, the household having contact with open-source water had to bear an extra treatment cost of BDT 321 (USD 3.9) per month compared to the households having no contact with open-source water. It was found that in a month the difference in number of loss of working days was higher among the households having contact with open-source water than the households having no contact with open-source water.

Chapter 7

Summary and Conclusion

Bangladesh, after a long nine months war of liberation in 1971, started the journey in 1972 with numerous social, political, and economic problems. The country had to fight against poverty from the beginning. In 2000, Bangladesh took a stand with the Millennium Development Goals and put poverty alleviation first on the national development strategy. Bangladesh got success in achieving some of the goals like poverty alleviation targets, and child mortality. In 2015, the journey of MDGs stopped but Bangladesh shifted to achieving the Sustainable Development Goals along with the globe.

During the shift of national growth wheels, cities/urban areas played important roles in Bangladesh. Industries were mostly urban-centric and mostly Dhaka centric. Riverbanks were the business centers at the early stage and subsequently became important sources of environmental capital and important sources of growth of various industries. The labor-intensive agrarian economy shifted to labor-intensive manufacturing and service economy. The industrialization strategy, shifting from exuberant dependence on agriculture or a shift from an agrarian economy to a small-scaled manufacturing economy, is often considered to be the development strategies for better economic growth and human welfare.

Some specific industries often directly use some environmental capital like water in their production process directly and dispose of the industrial wastewater in the environment like water bodies or air and such disposal alters the nature of water bodies causing water pollution, hampering human welfare and the ecosystem. The urban-centric industrialization process has accelerated the sector-specific and overall economic growth and increased the contribution of urban people in various economic indicators like GDP, national savings, employment, and so on. The process has lifted many people out of poverty but putting significant stress on the environment to supply fresh air, water and hence forced to absorb pollution.

Notwithstanding the notable success in alleviating poverty and hunger, locally and globally, through the improvement of health and sanitation facilities during the last couple of decades, the people are still now facing exorbitant socioeconomic problems and the challenges of sustainability of the achievements. The sustainable alleviation of poverty necessitates the productive people having equitable access to sufficient quality food, water, and hygienic sanitation facilities. Access to safe water is necessary for drinking, cooking, and hygiene and also for the productivity of ecosystems and all lives in producing food, energy, and daily materials.

A balanced water supply has a boon effect on the people, environment and excessive water may be a cause of flood. Therefore, a balanced water supply is necessary for economic development, and building healthy and wealthy nation.

7.1 Summary

The current study [1] measured the extent of the contact of people with unimproved water which may affect the welfare of the population like health, productivity, and poverty. The study covered 12 areas of Gazipur districts and the areas were adjacent to the Turag river and Tongi Khal. The study focused on urban water security at the household level and households were considered as the sampling units. The members of the households in Turag riparian areas constituted the population of the study.

The study incorporated systematic random sampling strategies. The strategy keenly considered representative, accuracy, sample size, time, and budget constraints. In determining the sample size, the team considered the nature of the samples, the degree of homogeneity, and the level of analysis. The samples were from the newly growing industrial zones, the upstream of the Turag River, as well as from the downstream areas. The survey covered the areas between the endpoint of Bongshai river and the connection points of Turag and Balu river, a distance of around 49 kilometers by road. The areas in between those points have some distinct different characteristics: at the Bongshai-Turag points, mostly in the part of Konabari and Kashimpur areas, there are industrial settlements on one side and on the other side, there is low land mostly undergo flood water during monsoon, and dwellers lived mostly in scatter form but mostly attached with the river because of irrigation pur-

[1]The current research was a part of the project REACH. The project was sponsored by University of Oxford. Bangladesh University of Engineering and Technology (BUET) was responsible for the hydro-logical modeling and to assess the water quality of the Turag river. The economic and gender aspects of water use behavior, and human welfare were done by University of Dhaka. The qualitative and gender dimension of the study was done by the MPhil candidate of Institute of Disaster Management and Vulnerability Studies (IDMVS), University of Dhaka. The economic part was led by Dr. M. Abu Eusuf, Professor, Department of Development Studies, and Director, Centre of Budget and Policy, University of Dhaka. The qualitative and gender part was led by Dr. Mahbuba Nasrin, Director, IDMVS, University of Dhaka. The hydro-logical modeling was led by Dr. Mohammed Abed Hossain, Professor, Institute of Water and Flood Management (IWFM), BUET.

poses and low-cost dwelling. Limited people live on the banks of the river. In total, 1826 households were selected from the twelve survey points. For ethical consideration, all selected participants were informed about the purpose of the study and we took their consent. As many of the participants were illiterate, the information noted in the consent form were read out and took verbal consent.

People use water for various purposes in their daily life. In the rural areas of Bangladesh, the households collect water, mostly, from tube-well whereas, in urban areas, tap-water is the major source of water. The latest Household Income and Expenditure Survey (2016) showed that around 60 percent of the urban households used tube-well water for drinking purposes and around 37 percent used the supply water whereas, in rural areas, 95 percent of the households used tube-well water and 2.14 percent used tap water. The present study results showed that around 75 percent of the households used tube-well water for drinking of which 73.82 percent used motorized tube-well water and few households used drinking water from deep tube-well (4.11 percent). According to HIES (2016), around 2.92 percent of the rural households and about 2.54 percent of the urban households used unimproved water for drinking purposes. Our survey results also showed that around 3.72 percent of the households used unimproved water for drinking purposes: 2.47 percent used water from open-source water like river, lake, canal, pond, etc., and 1.25 percent from other sources.

Local authorities usually supplied water through pipelines and the water point was mostly at the yard. Only 21.25 percent of the households had a water-pipe connection at their dwelling places. The present survey results showed that around 70 percent of the households were able to collect water within 5 minutes, and around 18.5 percent of the households required 5-10 minutes to collect improved water. Nearly 11.7 percent of the households required over 10 minutes to access improved water. The study, though showed that very few households collected drinking water from unimproved sources, showed that members of 28 percent of the households had contact with open-sources of water during the dry season or monsoon for domestic purposes like bathing, cooking, washing utensils, and for domestic chores.

The patterns of accessing different water for different purposes were different indeed. In a crowded area with the limited opportunity of freshwater point, the people often bounded to use unimproved water for domestic uses. In slum areas, there were limited number of water points and during the morning when the people rushed to go to their working places almost within the same duration of time, they had to use the alternative, mostly unimproved, source of water for some domestic purposes. Our survey analysis showed that the probability of accessing open-source water increased by around 10 percent when the households had to share improved water sources. The participants of the focused group discussion mostly agreed that since they did not have sufficient water points, they often used open-source water for bathing, and cleaning their goods.

It was also found that the social discrimination or social problems hindered significantly to ameliorate the access to improved water. The probability of contact with open-source water increased by around 12.5 percent when the members of the households faced social problems. The social problems included the discrimination of using the improved water by gender, priority users, and social status. The adult males mostly used the common water point during morning peak time to go to their workplace on time. At the same time, the children who had to be ready for their academic institutions had to take their bath in unimproved sources of water.

The results varied by location of the households. It was found that the tendency of using open-source water was high in the upstream and downstream areas compared to the middle stream. The difference was mostly due to the distance of the households from the open-source water: the surveyed households in the upstream and downstream areas were mostly relatively close to the open-source water whereas, in middle stream areas, the households were relatively a bit away from the open-source of water.

The education, gender, and occupation of the household head in accessing open-source water for whatever the purposes played significant roles. So, it was suggested that the contact with open-source water was not due to a single factor rather that was influenced by a set of socioeconomic factors. Similar factors were mentioned by Peter et.al. (2019). They listed technical factors (variability in water supply, quality, and maintenance requirement), economic factors (construction cost, public support, maintenance cost, and transportation costs), social factors (discrimination, number of users, misinformation, etc.), and environmental factors (prevalence, distance, and resilience).

The quality of drinking water might differ from the quality of water used for domestic purposes which might also depend on the availability, affordability, and sufficiency of fresh and improved water. The access to improved water was largely determined by economic, social, and political factors. The scarcity of water, the price, the water management system, and water governance were among the important factors.

The study revealed that the people of the households adjacent to the open-source water like the river, lake, canal, and others used water from those sources for various purposes for drinking, bathing, washing utensils, cleaning clothes, and doing the household chores. The households often experience the adverse effect on health and health expenditure due to the use of open source water. Bosch et.al. (2001) also reported that lack of water reduced income, productivity, and consumption. It increased illness.

It was found that the majority of the households had access to improved drinking water and few of them used unimproved water and the use decision was influenced by socioeconomic reasons. The economic costs of the use of such unimproved water was, indeed, high. It was found that the incidence of diseases like skin disease, gastric, ulcers, dysentery/diarrhea was high among the households members having contact with open-sources of water. The number of diseases faced by the members of the households and the number of ill-members were high among the households using the open-source water compared to the households which were using improved water. The diseases and ill-health members of the household reduced the working days by around 4.48 days per month among those used the unimproved water source.

So, the exposure to open source water was not costless. It increased the out-of-pocket health expenditure of the households and increased illness among the households who had contact with open-source of water. In sum, the lack of availability of water from the main source due to distance and time constraint, the affordability of buying the good quality of water, and social marginality were inducing the households to contact with open-source of water which increased illness and reduced productivity of the workers. The increased out-of-pocket health expenditure and productivity loss reduced the income for consumption and consequently deter the households to come out of poverty.

7.2 Policy Implications

Considerable improvement in terms of water infrastructure has been made in Bangladesh. The study showed that in urban and semi-urban areas where the main source of water was shared by a group of people where the use of unimproved water was high and there was a dearth of sufficient water connection in the areas. It appeared from the study that the use of unimproved water was high in the middle and downstream, the water infrastructural development initiatives needs special focus on the communities located in those areas.

From the study, it was evident that that among the male people, the tendency of using unimproved water compared to female was high because culturally male people had more chance of taking bath in open-source water in Bangladesh and in case of scarcity of water for bathing, the intensity of taking bath in unimproved water was high. Such exposure in some areas was not so much as harmful as it occurred in the heavy polluted open-source water. Such exposure to unimproved water was increasing the burden of treatment costs to the affected households. Consequently, the economic and health cost augmented. Awareness among the community people not exposing to open-source water even for bathing and washing utensils and clothes needs to be intensified.

Another problem was the odor of the river water polluted from different point and non-point sources which has been increasing day by day affecting air quality and creating air pollution and related problems. The overall environmental condition was becoming a great concern to communities specifically living in the middle and downstream. The scenic beauty of the river and open water body has already reduced to a great extent which needs steps to improve the health of the nearby water bodies. This study affirmed the reason of the reduction of water cost and availability of improved water for all purposes and making water available to the households at a minimum distance and at minimum cost which might expedite poverty reduction in the study areas, extreme poverty. Improved water should be available for all and everywhere. Attention at policy level in these issues is an utmost urge of the day.

7.3 Contributions

From the study undertaken, the following conclusion can be drawn: the exposure to open-source water or unimproved water sources due to various purposes was high among the inhabitant of the Dhaka urban riparian areas compared to the national scenario. The plausible factors of pushing the households of the communities to interact with unimproved water sources and the factors covered household and local attributes, and the the health of the river nearby water bodies. The study showed the economic costs of the interaction with an unimproved water source in terms of the incidence of diseases, the number of ill-health members, the productivity loss due to absenteeism, and showed the linkage between water security and poverty. The study further revealed that the reasons of water insecurity at the urban riparian areas which were the lack of affordability, the price risk, accessibility, availability, and stability of freshwater sources. The lack of affordability and lack of sufficient stable water availability worsened the water security and this increased the out-of-pocket health expenditure of the households. This study specifically contributed in (i) constructing the water security index at household level, (ii) modeling water insecurity, and (iii) finding the significant determinants of water insecurity using the econometric models.

7.4 Recommendations

The study has brought some quantitative estimates of water insecurity, the cost of water insecurity, and the overall welfare and water security relationship, but it had some limitations like sample size representing the overall scenario of Dhaka Urban Riparian areas, the long-term dynamics of household water insecurity, and the overall likelihood scenario of river-dependent urban people like boatmen, fishermen, and others. The complex relationship between economic growth, river health, and human welfare within the whole riparian areas in Dhaka needs to be deciphered further which can be pointed out in the following way.

- To find out the variation of the household water insecurity by seasons (monsoon and dry season) and by time in whole of Dhaka urban riparian areas. This will bring the long-term state of water insecurity-poverty relationship in urban riparian areas. This will particularly focus on two issues: (i) the two or more period panel analysis based on panel data and (ii) at least two periods of cross-sectional survey analysis.

- The sample size and survey areas should be extended so that the whole scenario of Dhaka Urban riparian areas can be explored. This will help the analysis of some important queries about water insecurity and poverty and the cost of water insecurity on the urban households as a whole.

- To compare the differences, if any, between the water insecurity in slums and riparian areas. This is because the urban poor live mostly in low-cost areas like slums. The slum dwellers often live near some water-bodies like rivers. Therefore, to increase the coverage of the poverty-water-insecurity relationship, inclusion of some analysis of water security in urban slums is needed.

- To assess the role of institutions, the local bodies, other institutions, industries, households, business establishments, etc, about water security in urban areas.

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Unsafe Water Usages in Urban Riparian Areas: Causes and Consequences

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Outline

- Background
- Motivation
- Research Objectives
- Research Questions
- Brief literature review
- Conceptual Framework
- Research Methodology
- Findings
- Discussion and conclusion.

Background

- Water is the most indispensable natural resource for human (Solomon, 2010: 3; Koehler, 2008; Ashton, 2002) and in fact indispensable for all forms of lives (Bates et.al, 2008, Young et.al, 2004).
- Water is an important element of human body and human activity.
- Water is an input, mostly acts as natural capital, to almost every production process: agricultural production is almost impossible without water, industry uses water for various purposes, and maintaining good ecosystem requires water.

Background

- Water is abundant but fresh water is a finite resource (Kahrl, 1979; Al-Jayyousi, 2003).
- Globally, less than three percent water is fresh and 2.5 per cent out of 3 per cent is frozen and locked up in Antarctica, the Arctic and glaciers, and only 0.5 per cent water is available for drinking purpose (UNESCO, 2003).
- According to the United Nations Conference on Environment and Development (UNCED, 1992), there are four principles of water.
  - First, fresh water is a finite and valuable resource,
  - Second, fresh water is essential to sustain life
  - Third, water is essential for development and
  - Fourth, water is important for the environment

Background

- Globally usages of fresh water
  - 8 per cent for domestic purpose
  - 92 per cent for industrial (22%) and agricultural (70%) purposes.
  - The industrial usages of water is around 59 per cent in high income countries while it is 10 per cent in low and middle income countries.
- Ponds, rivers, lakes, and streams are important sources of available fresh water.
- Albeit it is commonly acknowledged but WHO (2017) iterated that access to safe drinking-water, the basic human right and a component of effective policy for health protection, is essential to health.

Background

- WHO and UNICEF (2017) reported that in 2015, 71 percent of the global population (5.2 billion people) used a safely managed drinking water services and 5.8 billion people used improved sources with water available when needed.
- Around 1.9 billion rural people used a safely managed drinking water services.

Background

- In Bangladesh, the contribution of manufacturing is estimated to be near about 20.7 per cent and that of agriculture, forestry and fishing at about 16 percent.
- The shift in production techniques: from labor-intensive agrarian economy to labor-intensive manufacturing and service economy.
- The economic growth strategy has shifted from exuberant dependence on agriculture to small scaled manufactured economy, is often considered to be the development strategies for better economic growth and human welfare.
- In setting the economic growth strategy, urban centers are playing the hub roles: creating employment opportunities, and lifting people out of poverty and at the same time creating pressure on environment.

Background

- Dhaka, the major manufacturing hub lies on the lower reaches of Ganges Delta, has a population over 20 million and the urban population is growing at the rate of 4.2 per cent (McGee, 2006).
- The greater Dhaka is bounded by the rivers like Buriganga, Meghna, Dhaleshwari, Sitalakhya, and Turag. The urban based especially Dhaka based, strong export oriented garment industries flourished in 20th century. The recent statistics show that the garments of Dhaka contributed over 19 billion USD in the export volume.
- With plans to double annual revenue to USD 50 billion by 2021 the sector relies heavily on protecting the river systems as do many of the families of the four million workers who live by and interact with these river systems.

Background

- The industry contributes over 80 per cent of Bangladesh's foreign export earnings and has already helped lift millions of families out of poverty with future growth likely to provide employment for another two million workers by 2021, the year Bangladesh will celebrate its 50th anniversary of independence.
- Beyond the factory gate, water security will influence progress to this ambitious target in terms of (1) the reliability of water resources for industry, (2) the returning effluent impacts on the aquatic environment, and (3) the implications for neighboring communities sharing the same water resources, particularly for drinking water, cooking water, and bathing water.

Background

- The continued rapid urban growth and expansion of Dhaka neighborhoods raises questions about long-term water security for new communities with increased exposure and dependence to the river systems.
- How Dhaka's dynamic and complex river systems respond to changing flow regimes, bulk abstraction and contamination from untreated sewerage, industrial effluents or upstream/downstream impacts is poorly understood.
- In turn, how river quality affects neighboring communities' health and productivity is an increasingly important question for government and the enterprises which rely on healthy workers to be productive and competitive in highly competitive markets.

Background

- People living near the rivers, having no other alternatives, are forced to use polluted river water for various purposes. This causes spread of water borne and skin diseases.
- Solid waste and different effluents dumped into the rivers make it difficult for fishes and other sub-aquatic organisms to live (DoE, 2017).
- As the dissolved oxygen (DO) content of the river water is decreased below the critical level of four milligrams per litre it is posing threats to bio-diversity in and around the rivers (DoE, 2017).
- Pollution is so severe in the Buriganga, Sitalakhya and Balu rivers that it is almost impossible to treat the water for making it suitable for human use.

Background

- Sources of Drinking Water in Bangladesh

		Supply	Tube well	Others
2016	National	12.01	85.18	2.81
	Rural	2.14	94.94	2.92
	Urban	37.28	60.18	2.54
2010	National	10.62	85.37	4.01
	Rural	1.47	94.97	3.56
	Urban	35.57	59.18	5.25

Source: HIES 2016

- In 2010, around 5.25 percent of the households were exposed to unsafe water and in 2016, that has declined to 2.54 percent.
- People are facing the threat of water-borne diseases like Diarrhea, and mosquito borne (originated from water source) like Dengue, Malaria, Chikungunya, etc.

Background

- Data on sources of cooking water, bathing water, and washing are not available. Surely, sources of drinking water are crucial but sources of water for household purposes (cooking, bathing and washing) are also important.
- Using unsafe water for any purpose could be deleterious for health and hence, may affect the welfare of the households.
- Water Security and SDG

Motivation and Objectives

- The key motivation of this research is to understand the linkage between the usages of unsafe water and likely impacts on household welfare.
- Two key areas will be deciphered:
  - Exploring water use behavior in urban riparian areas.
  - The consequences of exposing to unsafe/contaminated water on household's welfare.

Research Questions/Hypothesis

- To know the urban water use behavior, we are trying to know the answers of the following questions:
  - What the key sources of water of urban riparian residents?
  - If the urban riparian residents are exposed to contaminated water, which factors are causing such exposure: marginality, affordability, accessibility, and household/local level factors.
- Second, to understand the impact of exposing to unsafe water on household welfare, we are trying to answer the following questions:
  - Is there any significant differential effect of being exposed to unsafe water on out of pocket health expenditure of the households?
  - Is there any differential effect on being exposed to unsafe water on productivity?

Relevance

- The study primarily deals with industry, households, and environmental issues. Therefore, the study has policy relevance for those organizations or institutions governing households, industry, and environment.
- The DoE and MoEF will directly be the policy stakeholders of this study. The findings of this study will directly contribute in formulating environmental policy especially the policies related to water management.

Literature Review

- Access to safe water for all people and development strategy: MDG and SDG
- Sufficient clean water is the most significant resource for reducing poverty and disease and improving the lives of the poor (Reid and Vogel, 2006; UN, 2006).
- Poor access to water could be due to political or economic policies. People who do not have access to water are mostly geographically, economically, institutionally and socially marginalized (Mukheibir, 2010).

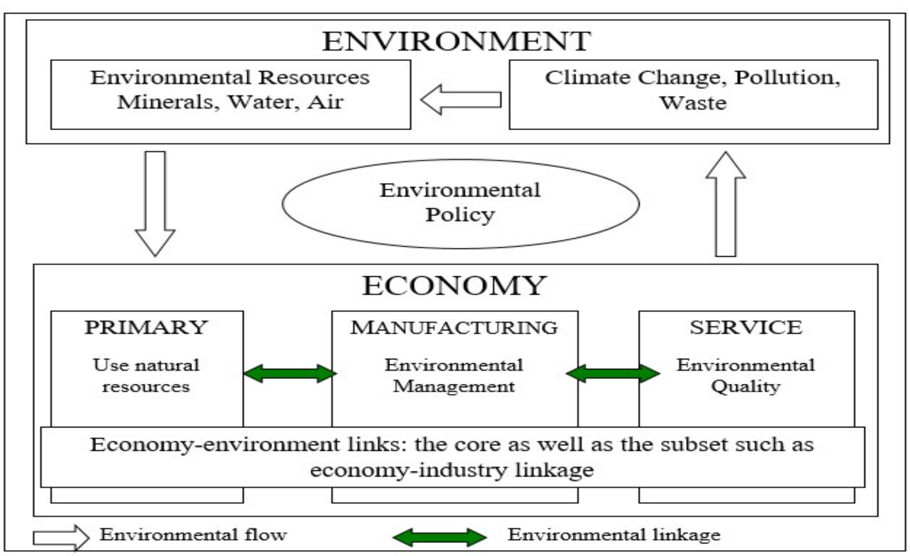
Literature Review

- The pollution in urban natural water bodies is increasing due to wastewater irrigation in developing countries (Drechsel, 2009; Jiménez & Asano 2008; Scott et.al., 2004).
- Wastewater irrigation is posing risks to health through various routes as it contain excreta-related pathogens (viruses, bacteria, protozoan and multicellular parasites), skin irritants and toxic chemicals (WHO, 2006)
- Certain occupational groups, like farmers (Bayrau et.al., 2009) and fishermen, directly affected by contact to polluted water bodies (Blumenthal and Peasey, 2002; WHO, 2006) and thereby, more likely to be affected by water-related diseases, for example, high prevalence of hookworm infection (over 80 percent) in Haroonabad, Pakistan (Ensink et.al., 2002).
- The poor is mostly affected by the natural resource degradation as the poor are tightly linked to the common-property resources (Bucknall et.al. 2000: 10) but the ways, poverty and environment is related, is not universal (Bucknall et.al. 2000: 8).

Conceptualization and Construction of the Relation/Association among concepts

- . The conceptual framework has been here developed to serve the following purposes:
- (i) To clarify the concepts related to the discussion.
- (ii) To understand what is role of the environment and environmental resources in industrial production or industrial growth, and environmental quality or damages, and
- (iii) To understand how the industry – environment interactions influence population welfare, the dynamics of poverty, in a comprehensive setup.
- (iv) To set up the way of analyzing the associations/relations.

Conceptual Framework: broad understanding



Source: Adapted from GHK (2007)

Conceptual/ Theoretical Framework

- Employment opportunity is created by economic sectors (industry, agri.)
- Both benefit recipients and non-recipients may be affected due to environment unfriendly production.
- Households or economy can be affected through health risks/productivity loss ….

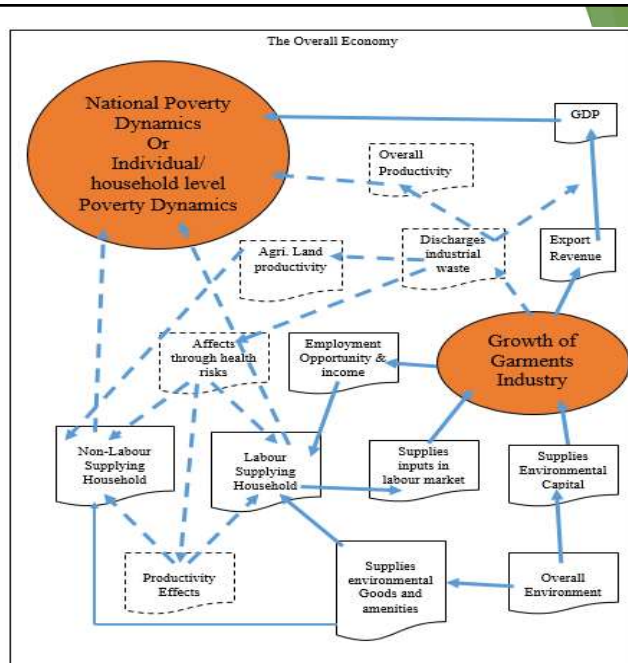


Figure: Conceptual Framework
Source: Author (2016)

Analytical Conceptual Framework

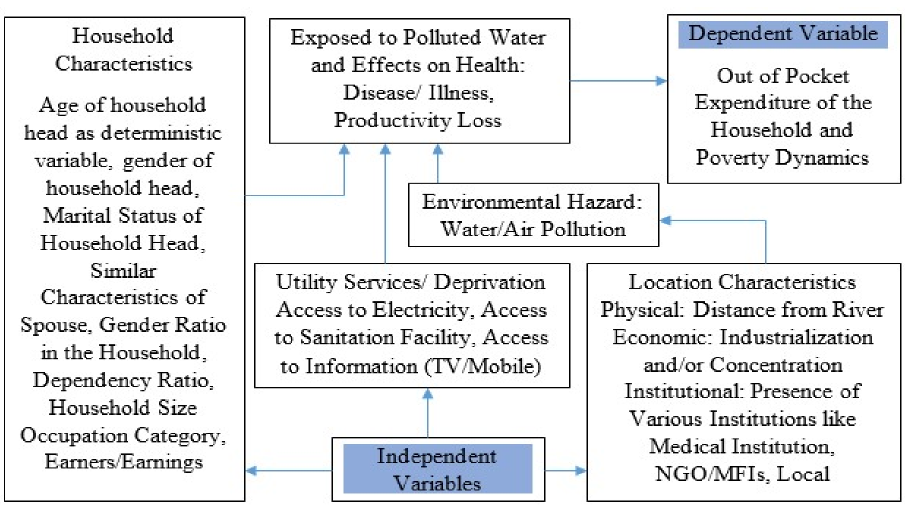


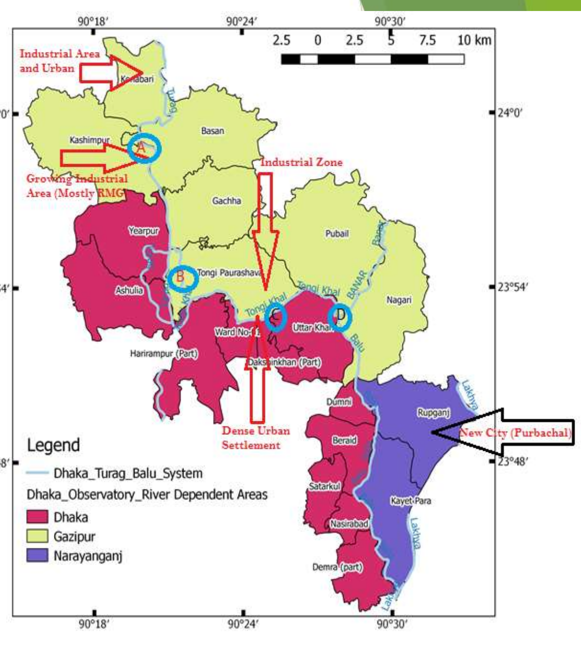
Figure: Analytical Conceptual Framework

Research Methodology

- **Approach:** The study is mostly quantitative in nature. Some qualitative techniques have also been used to compliment the quantitative analysis.
- **Sources of Data:** The data has been collected from both primary (household level interviews) and secondary sources (various publications of BBS, WHO, and World Bank).
- **Sampling Method:** Selection of Primary and Secondary Sampling Units – PSUs and SSUs.
- **Sampling Design:** The study follows a probability sampling technique in drawing the sample household, the unit of analysis. The samples are selected following the strategy of systematic random sampling.
- **Population:** The study population will cover the households living near the banks or canals of Turag River. It will cover the samples from the newly growing industrial zones, the upstream of the Turag River, as well as from the downstream areas.

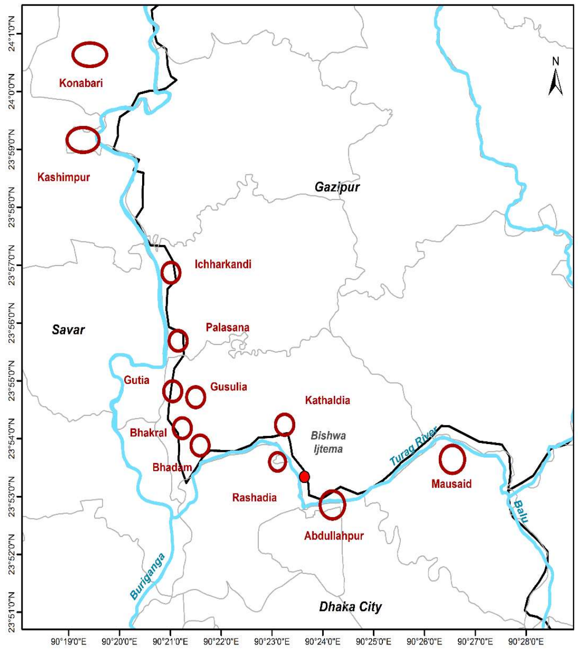
Research Methodology

- Study Areas: The water quality survey points of BUET covers the areas between the end point of Bongshai river and the connection points of Turag and Balu river, a distance is of around 49 kilometers by road (Joydevpur-Tangail Highway to Dhaka-Sylhet Highway to Tarabo to Rupganj).
- The areas in between those points have some distinct characteristics: at the Bongshai- Turag points, mostly in the part of Konabari and Kashimpur areas, there are industrial settlements on one side and on the other side, there is low land mostly undergo during monsoon, and dwellers lived mostly in scatter form but mostly attached with the river.



Research Methodology

- A household level survey has been conducted in 12 points on the areas adjacent to Tongi Khal/Turag River: 1. Rasadia, 2. Mausaid, 3. Bhadam, 4. Bakral, 5. Kasimpur, 6. Konabari, 7. Ichharkandi, 8. Gusulia, 9. Palasana, 10. Kathadia, 11. Gutia, and 12. Part of Abdullahpur
- In total 1826 households are interviewed during the survey.
- The survey has been completed within December 2017-February, 2018



Research Methodology

- **Sample Size Determination:** The sample size is determined following the sample size determination template of MICS (Multiple Indicators Cluster Survey).

Input Values				Output Values	
Parameter		Value		Estimate	Value
Predicted value of indicator (in target/base population)	r	0.500		Predicted r	0.5
Design effect	deff	1.5		Confidence limits (at 95% confidence)	
Relative margin of error at 95% confidence	RME	0.0996		Upper	0.5498
Proportion of target/base population in total population	pb	0.08		Lower	0.4502
Average household size	AveSize	4.2		Number of households (Sample size): n	2000
Household response (or completion) rate	RR	0.90		Standard error (se)	0.0249

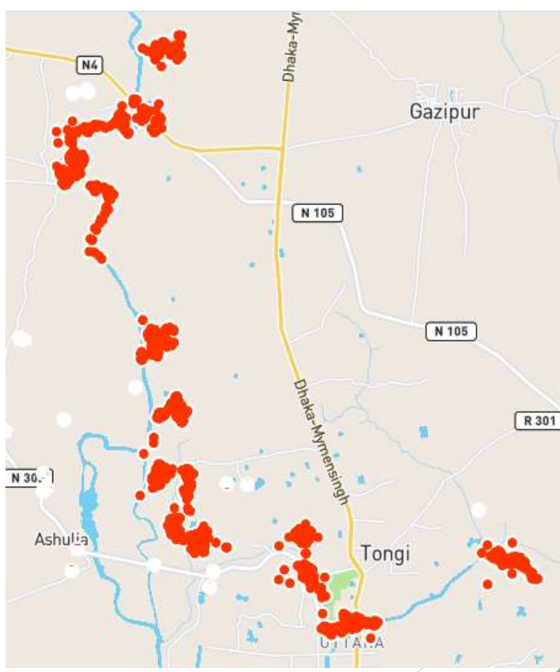
Research Methodology

- **Distribution of Samples:** In total 2000 samples were supposed to be drawn from 12 areas.

	HHs	Population	Water Source other than tap and tube-well	Proposed Samples	% of total samples	% of HHs of the areas	HHs weight
1. Rasadia	193	705	12.1	72	1.1	37.1	22
2. Mausaid	466	2332	4.9	139	2.6	29.9	53
3. Bhadam	863	2850	0.6	221	4.9	25.6	97
4. Bakral	239	1068	11.5	87	1.3	36.5	27
5. Kasimpur	4065	13957	1.2	211	22.9	5.2	459
6. Konabari	7976	30176	0.2	335	45.0	4.2	901
7. Ichharkandi	423	1845	14.2	166	2.4	39.2	48
8. Gusulia	172	789	15.7	70	1.0	40.7	19
9. Palasana	471	2038	0	118	2.7	25.0	53
10. Kathadia	613	2640	14.6	243	3.5	39.6	69
11. Gutia	372	1818	5.4	113	2.1	30.4	42
12. Abdullahpur part	1860	8289	0	225	10.5	12.1	210
Total	17713	68507		2000			

Research Methodology

- **Location of Samples and their concentration:** In total 1826 samples were interviewed in 12 areas.



Research Methodology

- Reconnaissance, Scoping Visit and the Primary Scenarios

Research Methodology

- Reconnaissance, Scoping Visit and the Primary Scenarios

Research Methodology

- **Survey Instruments:** Structured closed-end questionnaire has been used to collect the household data.
  - Household head (male or female) was the respondent.
  - The questionnaire contains several modules: the household demographics, domestic water use and sanitation, household expenditure, productivity and illness, poverty, and priority concern.
  - Both Bangla and English version of questionnaire is used but the data is preserved in English format only.
  - Data has been collected by 15 enumerators. The enumerators collected data from the households through Tab. The ONA software were used to collect and store the data.

Research Methodology

- **Survey Monitoring:** Three layers survey monitoring system has been followed. The enumerators collected the data, the supervisors (research associate/ Mphil Candidate) supervise the overall data collection, and the top management monitor the overall activity.
- **Ethical Consideration:**
  - Respect for all participants: The consents of the participants were taken before starting the survey.
  - Respect for all enumerators
  - Non-judgement

Research Methodology

- **Analytical Methods**
- The data has been analyzed using frequency distributions, measures of central tendency like mean and median, measures of dispersion like standard deviation.
- The significance of the differential effects by group is tested using the classical tests.
- The pairwise correlation analysis
- The multiple regression model
  - The logit model for binary variables
  - The Tobit model

Findings

Characteristics of Households

- Around 63 percent of the households are living over 10 years in their areas. Less than 9 percent of households are newcomers.
- Most of houses have tin/iron-roof (92.44%) and few have brick/cement made roofs.
- The walls are mostly made of tin/iron (57.83%) and brick/cement (37.35%). Few walls of the houses are made of earth/mud (3.4%).
- Brick/cement and earth/mud are the key floor materials.

Years of residence	Percent
less_1yr	8.63
1_2yr	7.8
3_4yr	7.44
5_10yr	12.79
more_10yr	63.34

Roof materials	Percent
Brick/cement	6.52
Leaves/ straw/ plastic	0.66
Other	0.16
Tin/iron	92.44
Wood/bamboo	0.22

Wall materials	Percent
Brick/cement	37.35
Earth/mud	3.4
Leaves/straw/plastic	0.11
Other	0.66
Tin/iron	57.83
Wood/bamboo	0.66

Floor materials	Percent
Brick/cement	60.19
Earth/mud	35.49
Other	0.27
Tiles/mosaic	0.49
Wood/bamboo	3.56

Characteristics of Households

- Around 93.7 percent of the households have grid supply electricity connection.
- Most of houses use wood/fuel sticks as cooking fuel (75.6%) and around 44.4 per cent households have gas connection.
- Households use multiple sources of fuel for lighting and cooking.

Lighting fuel	Percent
Grid supply electricity	93.65
Solar panel	0.77
Kerosene	3.56
Other (specify)	11.61

Cooking fuel	Percent
Electricity	0.33
Natural gas (piped supply/ cylinder)	44.41
Animal dung	5.53
Kerosene	0.71
Wood/fuel sticks	75.63
Straw/shrubs/grass	34.78
Other (specify)	0.55

Characteristics of Households

- Around 31 percent of the households have at least one RMG worker.
- Among male led households, a little over 31 percent has at least one RMG worker while among 28 percent female led households has at least one RMG worker.
- On average, out of 3, one household is reaping benefit from RMG.
- Around 22 percent households has one RMG worker and 9 percent households has multiple RMG works.

Any member is employed in RMG	Gender of HH Head		Total
	Female	Male	
No	72.15	68.76	69.06
Yes	27.85	31.24	30.94

Number of RMG workers	Gender of HH Head		Total
	Female	Male	
None	72.15	68.76	69.06
One	20.89	22	21.91
Two	5.7	7.67	7.5
Above two	1.27	1.56	1.53

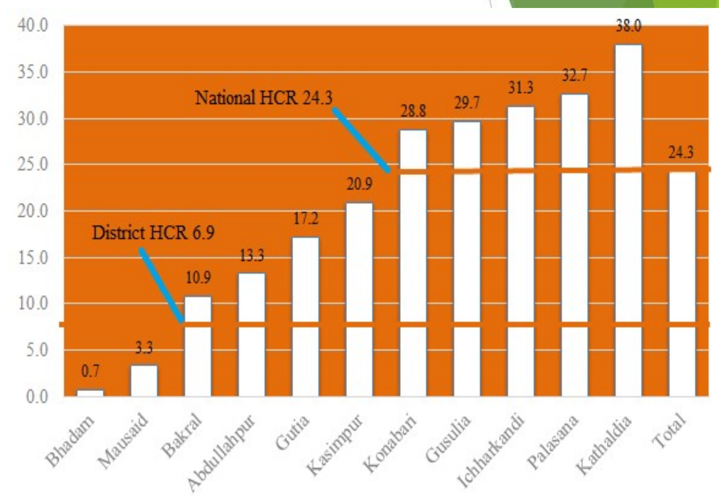
Characteristics of Households

- The average monthly expenditure of the household is BDT 17763 while the per capita monthly expenditure is BDT 4887.
- The standard deviation in expenditure is relatively highly suggesting inequality in expenditure pattern.
- One-fourth of the households has monthly expenditure below BDT 11400 and the one-fourth of the households has monthly expenditure over BDT 21500.

Gender of HH Head		Total Monthly Expenditure	Per Capita Monthly Expenditure	Share of expenditure on water
Female	Average	16211	5134	0.0063
	SD	11932	2966	0.0142
	Q1	9200	3075	0.0000
	Q2	13744	4650	0.0000
	Q3	19098	6163	0.0089
Male	Average	17910	4864	0.0062
	SD	9580	2733	0.0235
	Q1	11625	3110	0.0000
	Q2	16050	4250	0.0000
	Q3	21700	5900	0.0051
Total	Average	17763	4887	0.0062
	SD	9813	2754	0.0229
	Q1	11400	3108	0.0000
	Q2	15899	4267	0.0000
	Q3	21500	5925	0.0054

Characteristics of Households

- Under the UPL, the HCR is estimated at 24.3 percent which is equal to the national HCR of poverty but the incidence of poverty is high in the survey areas compared to the district level HCR.
- The national poverty lines of Household Income and Expenditure survey of 2016 are used as the base poverty lines. The poverty lines for 2017 are updated by changes in consumer price index.



Characteristics of Households

- Under the LPL, the HCR is estimated at 7.2 percent.
- Some of survey areas like Bhadam, Mausaid, Kasimpur, and Bakral are close to zeroing extreme poverty.

Characteristics of Households

Category of Poverty	Gender of Household Head		Overall
	Male	Female	
Chronic Poor	10.1	20.0	10.3
Movers	38.5	45.0	37.6
Fallers	11.1	38.0	12.2
Unchanged (Same)			
Better off (never in bad condition)	34.1	40.0	33.3
Struggling	6.2	17.0	6.6

- Around 10 percent households are chronically poor and the welfare of 12 percent households has declined.
- Around 6.6 percent households are struggling for better of life ever but the situation is not changing.
- The poverty status has been improved of around 37.6 percent households.

Characteristics of Household Head

- Around 91.3 percent households are led by male and 8.67 percent led by female.
- The average age of the household head is 42.5 years: average age of male household head is 44.5 years while the female household is 42.3 years on average.
- 25% of the household heads are below 33 years old while 25% of the household heads are over 55 years old.

Category of age	Gender of HH Head		Total
	Female	Male	
Below 20	1.27	1.32	1.31
21-25	5.7	6.83	6.74
26-30	8.23	13.37	12.92
31-35	15.82	15.11	15.17
36-40	13.29	16.49	16.21
41-45	15.82	12.11	12.43
46-50	12.66	11.09	11.23
51-55	7.59	8.21	8.16
56-60	9.49	8.33	8.43
Above 60	10.13	7.13	7.39

Statistics	Gender of HH Head		Total
	Female	Male	
Mean	44.51	42.34	42.53
SD	12.65	12.57	12.59
p25	35	33	33
p50	45	40	40
p75	55	50	50

Characteristics of Household Head

- Around 44.2 percent household heads are illiterate: the illiteracy rate is high among female household head (69%) and illiteracy rate is low among male household head (42%).
- Among literate household heads, most of them have years of schooling up to PSC.
- Not over 3.5 percent of the household heads have education level over HSC and higher education is high among the male household head compared to female household head.
- Average schooling is 4.24 while among literate group it is 7.61.

Category of years of schooling	Gender of HH Head		Total
	Female	Male	
Illiterate	68.99	41.87	44.22
1-5	21.52	21.90	21.86
6-8	3.80	13.20	12.38
9-10	2.53	13.98	12.99
11-12	1.90	5.40	5.10
Higher education	1.27	3.66	3.45

Statistics (Years of schooling)	Gender of HH Head		Total
	Female	Male	
Mean	1.84	4.47	4.24
SD	3.33	4.63	4.59
p50	0	4	4
p75	3	8	8

Statistics (Among literate)	Gender of HH Head		Total
	Female	Male	
Mean	5.92	7.69	7.61
SD	3.42	3.48	3.5
p25	4	5	5
p50	5	8	7
p75	7	10	10

Characteristics of Household Head

- Around 15.3 percent household heads are employed in RMG sector: Around 15 percent of the male household head is working in RMG sector and 15 percent female household is also working in this sector.
- Around 10 percent of female household heads is the domestic worker.
- Around 22 percent male household heads is engaged in business, 11.33 percent in farming, and 3.72 percent as day labor.
- Unemployment (voluntary or involuntary) is high among female household heads.

Occupation of HH Head	Gender of HH Head		Total
	Female	Male	
Agri. Worker	1.9	3.72	3.56
RMG Worker	15.19	15.35	15.33
Other Factory Worker	5.7	5.46	5.48
Casual Worker	3.16	7.19	6.85
Skilled Worker	0.63	6.89	6.35
Construction Worker	1.9	2.94	2.85
Domestic Worker	10.13	0	0.88
Boatman/fisherman	0	4.56	4.16
Farmer/Landlord	5.06	11.33	10.79
Govt. Service	0.63	0.84	0.82
Non-govt. Service	1.9	2.94	2.85
Rickshaw/van puller	0	3.24	2.96
Business	5.7	21.88	20.48
Others	7.59	8.39	8.32
Unemployed	40.51	5.28	8.32

Sources of Drinking Water

less_5	69.82
5_10	18.51
10_15	7.72
15_30	3.34
more_30	0.6

area	piped_dwelling	piped_yard	public_tap	tubewell_deep	tubewell_shallow	tubewell_motor	rainwater	vended_truck	vended_cart	vended_bottle	river_canal	lake	pond	other
Abdullahpur	2.73	24.09	12.73	1.82	1.36	55.91	0.45	1.36	0.00	0.45	0.91	0.00	0.00	0.91
Bakral	4.71	3.53	0.00	1.18	0.00	90.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bhadam	0.00	0.50	0.00	0.00	0.00	98.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01
Gusulia	0.00	52.31	1.54	0.00	0.00	46.15	1.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gutia	0.93	0.93	0.00	0.93	0.00	94.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.80
Ichharkandi	0.00	0.00	0.00	3.05	0.00	96.34	0.00	0.00	0.00	0.00	7.93	1.22	6.10	0.61
Kasimpur	15.69	21.57	0.49	2.94	2.45	56.37	0.00	0.00	0.49	0.00	0.49	0.00	0.00	0.00
Kathaldia	15.77	43.69	0.00	0.00	0.00	40.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Konabari	0.41	3.72	3.31	6.61	1.24	87.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.24
Mausaid	0.71	0.00	0.00	2.86	0.00	96.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Palasana	0.00	0.00	0.00	0.00	0.00	99.09	3.64	0.00	0.00	0.00	3.64	0.00	11.82	0.91
Rausadia	4.41	92.65	0.00	0.00	0.00	4.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	4.55	16.70	2.08	2.03	0.60	73.82	0.33	0.16	0.05	0.05	1.10	0.11	1.26	0.66

- The three major source of drinking water are: motorized tubewell (73.82%), piped yard connection (16.7%), and piped connection in the dwelling (4.55%).
- Piped yard connection is the key drinking water source in Rausadia, Kathaldia, Gusulia, Kasimpur and Abdullahpur.
- Around 96 percent households can collect water for drinking purpose within 15 minutes.

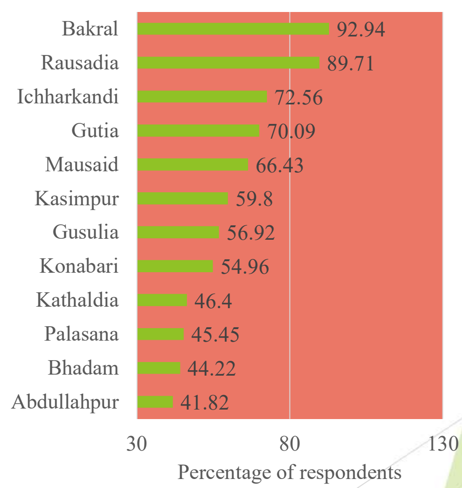
Is drinking water safe? Why?

- Around 93 percent respondents reported that they drink safe water.
- The residents of Abdullahpur, Bakral, Mausaid and Rausadia are concerned about the quality and safety of drinking water.
- The respondents think that albeit there is arsenic problem, but the presence of iron in the water (53 respondents), perceived presence of germ (24 respondents), and different taste (18 respondents) make them consider the drinking water unsafe. (Around 5% of the respondents stated that)

Area	Is drinking water safe? Don't know	No	Yes
Abdullahpur	9.09	11.82	79.09
Bakral	0	10.59	89.41
Bhadam	0	0.5	99.5
Gusulia	0	1.54	98.46
Gutia	0	0	100
Ichharkandi	0	1.22	98.78
Kasimpur	0	4.9	95.1
Kathaldia	0.45	0	99.55
Konabari	10.74	3.31	85.95
Mausaid	5	8.57	86.43
Palasana	0	1.82	98.18
Rausadia	0	8.82	91.18
Total	2.96	4.22	92.83

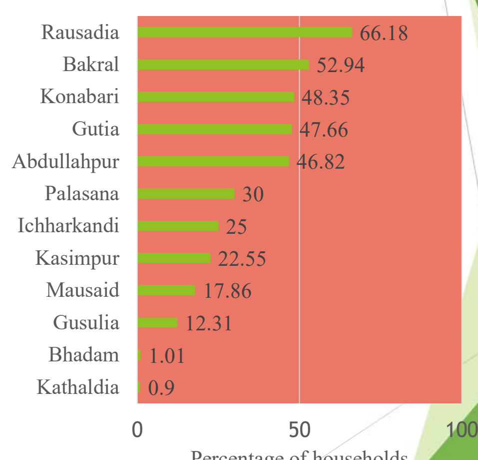
Major Environmental Concern

- Around 58 percent respondents reported dirty river water as the key environmental issues in the survey areas.
- Dirty river water is the extreme concern in Bakral and Rausadia (Over 90 percent of the respondent raised the issue).
- The dirty river water is least concern in Abdullahpur, Bhadam, and Palasana.



Incidence of Exposed to River/Lake/Pond Water

- Around 28 percent households are exposed to unsafe water for various purposes within a year: during monsoon and dry seasons.
- Over 50 percent of the households in Bakral and Rausadia exposed to unsafe water.
- The exposure to unsafe water is below 1 percent in Bhadam and Kathaldia.



Incidence of Exposed to Unsafe Water

- Households do contact with unsafe water mostly due to washing clothes, taking bath, and cleaning cooking utensils.
- The incidence of exposing to unsafe water is high during dry session compared to monsoon.
- The residents of Abdullahpur, Bakral, Gutia, Konabari, and Rausadia are highly exposed to river/lake/pond water for cleaning cooking untensils, washing clothes and bathing.

	Monsoon			Dry Session		
Area	Cooking and food preparation	Washing clothes and dishes	Bathing	Cooking and food preparation	Washing clothes and dishes	Bathing
Abdullahpur	1.36	15	19.09	5	39.09	45
Bakral	1.18	4.71	10.59	1.18	47.06	51.76
Bhadam	0	0	0	0	0.5	1.01
Gusulia	3.08	10.77	9.23	3.08	9.23	7.69
Gutia	0	31.78	32.71	3.74	42.99	46.73
Ichharkandi	0	15.24	16.46	0.61	20.73	21.95
Kasimpur	3.92	8.33	8.33	6.86	14.71	21.08
Kathaldia	0.45	0	0	0	0.45	0
Konabari	1.24	24.38	28.93	1.65	43.8	47.52
Mausaid	0	0.71	0	0.71	10.71	17.14
Palasana	0	26.36	29.09	0.91	28.18	30
Rausadia	0	4.41	7.35	0	57.35	63.24
Total	0.99	11.61	13.31	2.14	23.82	27.05

Causes of exposed to Unsafe Water

- Water scarcity during dry season.
- The poverty is inducing them to expose to unsafe water. The incidence of exposing to unsafe water is high among extreme poor.
- The female led households are more exposed to unsafe water compared to their counterfactual but the difference is not statistically significant.

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf.	Interval]
Upper Poverty Line						
Non-poor	1,489	27.40094	1.156237	44.61636	25.13291	29.66897
Poor	337	32.64095	2.558054	46.95963	27.60913	37.67277
Combined	1,826	28.36802	1.055204	45.0907	26.29848	30.43755
Diff		-5.24001	2.718016		-10.5708	0.090742
t-statistics						t = -1.9279
Lower Poverty Line						
Non-poor	1,721	27.83266	1.080646	44.83053	25.71314	29.95217
Poor	105	37.14286	4.738035	48.55042	27.74716	46.53856
Combined	1,826	28.36802	1.055204	45.0907	26.29848	30.43755
Diff		-9.3102	4.528649		-18.1921	-0.42832
t-statistics						t=-2.0558
Gender of HH Head						
Female	158	29.74684	3.648409	45.85979	22.54054	36.95313
Male	1,668	28.23741	1.102538	45.02894	26.0749	30.39992
Combined	1,826	28.36802	1.055204	45.0907	26.29848	30.43755
Diff		1.509425	3.754141		-5.85344	8.872291
t-statistics						t = 0.4021

Causes of exposed to Unsafe Water

Duration of residence	Percent
less_1yr	12.75
1_2yr	18.52
3_4yr	25.76
5_10yr	24.47
more_10 yr	32.57
Total	28.37

Long-term poverty status	Percent
Always struggling	39.6
Movers	18.49
Fallers	39.55
Alway better	30.27
Total	28.55

Duration of residence	Always struggling	Movers	Fallers	Always better	Total
less_1yr	19.05	5.08	26.09	15	13.29
1_2yr	15.38	12.7	25	25	18.18
3_4yr	40	9.09	47.06	32.43	25.58
5_10yr	26.67	20	30.77	27.63	25
more_10yr	46.08	22.22	44.2	32.59	32.64
Total	39.6	18.49	39.55	30.27	28.55

- The incidence of exposing to unsafe water is high among the households who are struggling for better life every time and have fallen down below the poverty line.

Consequences of Exposing to Unsafe Water: Incidence of Illness

Number of Ill members	Exposed to unsafe water		
	No	Yes	Total
0	44.27	27.22	39.43
1	28.75	33.59	30.12
2	17.13	23.17	18.84
3	6.65	9.65	7.5
4	2.52	5.41	3.34
5	0.46	0.97	0.6
6	0.08	0	0.05
7	0.15	0	0.11
Average	0.97	1.35	1.08
Difference		0.38	
Test statistics (t-stat)		6.5	

- The households exposing to unsafe water has more ill members (1.35 member on average) compared to their counterfactual group (0.97 member on average). The gap is found statistically significant.
- Around 73 percent of the households exposing to unsafe water has at least one ill member.

Consequences of Exposing to Unsafe Water: Types of Diseases Incurred

Number of Ill members	Exposed to unsafe water			Exposed to unsafe water		
	No	Yes	Total	No	Yes	Total
	Percent (At least one member has ..)			Average		
Dysentery/diarrhea	7.8	16.22	10.19	0.1	0.23	0.13
Cholera	0.76	0.58	0.71	0.01	0.01	0.01
Typhoid	5.66	7.34	6.13	0.06	0.08	0.06
Jaundice	7.49	12.36	8.87	0.08	0.15	0.1
Skin diseases	8.18	18.34	11.06	0.09	0.24	0.13
Gastric/ulcers	25.08	35.91	28.15	0.35	0.5	0.39
Mosquito borne	6.8	10.42	7.83	0.1	0.17	0.12
Respiratory disease	4.13	7.72	5.15	0.05	0.09	0.06
Other	24.39	27.22	25.19	0.32	0.34	0.32

- The households exposing to unsafe water has more ill members irrespective of disease types compared to their counterfactual group. Particularly, the incidence as well as the average number of member affected by the specific disease like dysentery/ diarrhea, jaundice, skin diseases, gastric/ulcers and mosquito borne diseases is high among the households exposing to unsafe water.

Consequences of Exposing to Unsafe Water: Out of Pocket Health Expenditure

Exposed to river/canal/lake water	n	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
No	1,308	261.12	48.8143	1765.432	165.36	356.90
Yes	518	582.083	129.3676	2944.358	327.93	836.23
Combined	1,826	352.1709	50.78216	2170.009	252.57	451.77
Difference		-320.963	112.4331		-541.47	-100.45
Test-statistics	t = -2.8547					

- The average monthly health expenditure among the households exposing to unsafe water is Tk. 582 ($7.1) whereas the counterfactual group has an average monthly health expenditure of Tk. 261 ($3.2).
- The households exposing to unsafe water has to spend Tk. 321 ($3.9) more as treatment cost compared to their counterfactual group.
- Annually they have to spend additional 3852 BDT to take care of the health of the household members

Association between Exposing to Unsafe Water and illness/health expenditure: The Pairwise Correlation Analysis

Pairwise correlation	Correlation Coefficient	P-value	Remarks
Contact with unsafe water and treatment expenditure	0.0667	0.0044	Significant
Contact with unsafe water and number of ill people	0.1505	0.0000	Significant
Treatment expenditure and number of ill people	0.1186	0.0000	Significant
Controlling the extreme values (treatment cost has been considered to be below at 99th percentile value			
Contact with unsafe water and treatment expenditure	0.1080	0.0000	Significant
Contact with unsafe water and number of ill people	0.1471	0.0000	Significant
Treatment expenditure and number of ill people	0.1347	0.0000	Significant

- The pairwise correlation values are positive suggesting there is a positive association between contacting unsafe water and number of ill people, contacting unsafe water and treatment expenditure. The associations are statistically significant even at 1 percent level of significance.

Exposing to Unsafe Water: The Regression Analysis (Logit Model)

Variable	Marginal Effect	Std. Err.	z	P>z
Affordability (expenditure on water is below 120, the median expenditure)	0.122	0.031	3.900	0.000
Gender of HH head (Male = 1)	0.029	0.035	0.810	0.417
Age of HH head	-0.002	0.001	-1.960	0.050
Years of schooling of HH head	-0.018	0.003	-6.960	0.000

- The lack of affordability is increasing the chance of exposing to unsafe water significantly. Education and age of household head negatively influences the decision of exposing to unsafe water significantly.
- The gender effect is not found statistically significant.

Exposing to Unsafe Water and Treatment Cost: The Regression Analysis (Tobit Model)

Share of treatment expenditure	Coef.	Std. Err.	t-stat	P>t	[95% Conf.	Interval]
Gender of HH head (Male = 1)	-0.0191	0.0071	-2.6900	0.0070	-0.03312	-0.00516
Age of HH head	0.0007	0.0002	4.0800	0.0000	0.000342	0.000976
Years of schooling of HH head	-0.0005	0.0004	-1.0600	0.2900	-0.00135	0.000404
Total number of ill members	0.0129	0.0017	7.4600	0.0000	0.00949	0.016258
Constant	0.0426	0.0101	4.2300	0.0000	0.022858	0.062406

- The role of gender is found significant in analyzing the effect of gender of HH head on out of pocket health expenditure of the household. Order household head has to spend more on health.
- One additional ill member will increase the out of pocket expenditure by 1.3 percent holding the effects of other variable constants..

Exposing to Unsafe Water and Loss in Working Days (Productivity Loss)

Exposed to unsafe water		1-2 days	3-7 days	1-2 weeks	Over 4 weeks
No	Average member	0.034	0.102	0.074	0.096
	SD	0.189	0.324	0.271	0.319
	Max	2	2	2	3
Yes	Average member	0.015	0.178	0.129	0.162
	SD	0.123	0.430	0.364	0.445
	Max	1	3	2	3
Total	Average member	0.028	0.123	0.090	0.114
	SD	0.173	0.359	0.301	0.360
	Max	2	3	2	3

- The number of ill member is high among the households exposing to unsafe water.
- The number of ill-days is high among the households exposing to unsafe water compared to their counterfactual.
- In total at least 7727 working days were lost due to illness.

Summary

- Urban riparian residents identified the dirty river water as the key environmental challenges.
- Out of 3 households, on average, one household exposed to unsafe water.
- The poor and marginalized people are exposing to unsafe water due to lack of affordability and scarcity of water during dry season.
- The chronically poor and vulnerable poor have also more chance to expose to unsafe water compared to others.
- The exposure to unsafe water is increasing the number of ill members in the household and thereby, is increasing the share of treatment cost to the total household expenditure.
- The households exposing to unsafe water has to spend Tk. 321 ($3.9) more as treatment cost compared to their counterfactual group. The extra expenditure on treatment is making the people vulnerable to poverty.
- The working days lost due to illness is high among the households exposing to unsafe water compared to their counterfactual.

Thank You Very Much

Questions !!!

Dynamics of Household Water Insecurity and Poverty – Drivers and Implications: Experiences from Dhaka Urban Riparian Areas

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Outline

Background
Motivation, Research Objectives, and Research Questions
Conceptual Framework
Research Methodology
Findings
Discussion and conclusion.

Background

- Water, the most indispensable natural resource for human (Solomon, 2010: 3; Koehler, 2008; Ashton, 2002) and in fact indispensable for all forms of lives (Bates et.al, 2008, Young et.al, 2004).
- Water is abundant but fresh water is a finite resource (Kahrl, 1979; Al-Jayyousi, 2003). Globally, less than three percent water is fresh and 2.5 per cent out of 3 per cent is frozen and locked up in Antarctica, the Arctic and glaciers, and only 0.5 per cent water is available for drinking purpose (UNESCO, 2003).
- Globally, 8 per cent of the fresh water is used for domestic purpose and the remaining 92 per cent is used for industrial (22%) and agricultural (70%) purposes.
- WHO and UNICEF (2017) reported that in 2015, 29 percent of the global population (2.1 billion people) do not have access to a safely managed drinking water services.

Background

- The urban centric industrialization process has accelerated the sector specific and overall economic growth and increased the contribution of urban people in various economic indicators like GDP, national savings, employment, and so on.
- The process has lifted many people out of poverty but putting significant stress on environment to supply fresh air, water and hence forced to absorb pollution.
- The greater Dhaka is bounded by the rivers like Buriganga, Meghna, Dhaleshwari, Sitalakhya, and Turag. The urban based especially Dhaka based, strong export oriented garment industries flourished in 20^{th} century. The recent statistics show that the garments of Dhaka contributed over 19 billion USD in the export volume.
- One industry already engaging in this work is the Ready Made Garment (RMG) sector. With plans to double annual revenue to USD 50 billion by 2021 the sector relies heavily on protecting the river systems as do many of the families of the four million workers who live by and interact with these river systems.

Background

- The industry contributes over 80 per cent of Bangladesh's foreign export earnings and has already helped lift millions of families out of poverty with future growth likely to provide employment for another two million workers by 2021, the year Bangladesh celebrates its 50th anniversary of independence. At the same time, they are the major source of pollution.
- Water security will influence progress to this ambitious target in terms of (1) the reliability of water resources for industry, (2) the returning effluent impacts on the aquatic environment, and (3) the implications for neighboring communities sharing the same water resources, particularly for drinking water, cooking water, and bathing water.
- The continued rapid urban growth and expansion of Dhaka neighborhoods also raises questions about long-term water security for new communities with increased exposure and dependence to the river systems.
- The capacity of the 4 rivers to safely absorb increasing point sources of pollution have raised questions on the need for improved monitoring and smarter policy to support industrial growth but not at the cost of environmental damage and public health impacts, particularly for the poor relying on rivers for drinking, washing, bathing or cooking water.

Background

- How Dhaka's dynamic and complex river systems respond to changing flow regimes, bulk abstraction and contamination from untreated sewerage, industrial effluents or upstream impacts is poorly understood. In turn, how river quality affects neighboring communities' health and productivity is an increasingly important question for government and the enterprises which rely on healthy workers to be productive and competitive in highly competitive markets.
- Specially, water bodies near to industrial area have been extremely affected from disposal of waste which can alter the physical, chemical and biological nature of the receiving water body.
- So, industrial waste is the most common source of water pollution in the present day and it increases yearly due to the fact that industries are increasing because most countries are getting industrialized. Industrial waste-water originates from the wet nature of industries which require large quantities of water for processing and disposal of wastes.

Background

Sources of Drinking Water in Bangladesh

		Supply	Tube well	Others
2016	National	12.01	85.18	2.81
	Rural	2.14	94.94	2.92
	Urban	37.28	60.18	2.54
2010	National	10.62	85.37	4.01
	Rural	1.47	94.97	3.56
	Urban	35.57	59.18	5.25

Source: HIES 2016

In 2010, around 5.25 percent of the households were exposed to unsafe water and in 2016, that declined to 2.54 percent. People are facing the threat of water-borne diseases like Dengue, Diarrhea, Malaria, Cholera, etc.

Background

- Data on sources of cooking water, bathing water, and washing are not available. Surely, sources of drinking water are crucial but sources of water for household purposes (cooking, bathing and washing). Using unsafe water for any purpose could be deleterious for health and hence, may affect the welfare of the households.
- Within 2030 by implementing SDG goal 6, the government aims to “Ensure availability and sustainable management of water and sanitation for all” with specific targets addressing all aspects of the freshwater cycle and more specifically, improving the standard of WASH services (6.1 and 6.2); increasing treatment, recycling and reuse of wastewater (6.3); improving efficiency and ensuring sustainable withdrawals (6.4); and protecting water-related ecosystems (6.6) as part of an integrated approach to water resources management (6.5).

Motivation, Objectives, and Research Question

- The key motivation of this research is to understand the linkage between the water insecurity and likely impacts on household welfare.
- First, to know the urban water use behavior, we are trying to know the key sources of water of urban riparian residents and if the urban riparian residents are exposed to open source water, which factors are causing such exposure: marginality, affordability, accessibility, and household/local level factors.
- Second, to understand the impact open source water contact on household welfare, we are trying answer the following questions:
  - Is there any differential effect of being exposed to unsafe water on illness, health expenditure and poverty?
  - Is there any differential effect on being exposed to unsafe water on productivity?

Relevance

The study primarily deals with industry, households, and environmental issues. Therefore, the study has policy relevance for those organizations or institutions governing households, industry, and environment.

The DoE and MoEF will directly be the policy stakeholders of this study. The findings of this study will directly contribute in formulating environmental policy especially the policies related to water management.

Literature Review

- Sufficient clean water is the most significant resource for reducing poverty and disease and improving the lives of the poor (Reid and Vogel, 2006; UN, 2006).
- Poor access to water could also be due to political or economic policies. People who do not have access to water are mostly geographically, economically, institutionally and socially marginalized (Mukheibir, 2010).
- The pollution in urban natural water bodies is increasing day by day causing wastewater irrigation in developing countries (Drechsel, 2009; Jiménez & Asano 2008; Scott et.al., 2004). Wastewater irrigation is posing risks to health through various routes as it contain excreta-related pathogens (viruses, bacteria, protozoan and multicellular parasites), skin irritants and toxic chemicals (WHO, 2006)
- Certain occupational groups, like farmers (Bayrau et.al., 2009) and fishermen, directly affected by contact to polluted water bodies (Blumenthal and Peasey, 2002; WHO, 2006) and thereby, more likely to be affected by water-related diseases, for example, high prevalence of hookworm infection (over 80 percent) in Haroonabad, Pakistan (Ensink et.al., 2002).

Literature Review: River Health (Turag)

Parameters	2006	2010	DoE Standard
pH	7.1	7.5	6.5-8.5
EC (electrical conductivity)	98	1800	-
Chloride	2	34	-
Turbidity	6.5	12.5	5
TS (total solids)	380	896	-
TDS (total dissolved solids)	342	812	2100
DO (Dissolved Oxygen)	6	0	>4.5-8.0
BOD (biochemical oxygen demand)	2.8	22	50
COD (chemical oxygen demand)	58	102	200

Source: Banu et.al. (2013)

Note: The unit is mg/L.

Literature Review: River Health (Turag)

Parameters	DOE Standard	Turag		Buriganga		Shitalakkhya	
		Wet	Dry	Wet	Dry	Wet	Dry
Al	200.0	92.7	294.4	79.6	152.3	113.2	116.6
Mn	5000	9.77	6.4	6.12	77.3	3.27	258.99
Fe	2000	12.67	380.8	9.82	358.68	11.19	341.21
Cu	500	2.52	7.4	4.13	6.75	1.97	15.83
Zn	5000	2.59	ND	2.49	23.12	1.89	ND
Cd	500	5.46	ND	5.47	ND	5.45	ND
Pb	100	4.75	ND	4.87	ND	4.72	ND

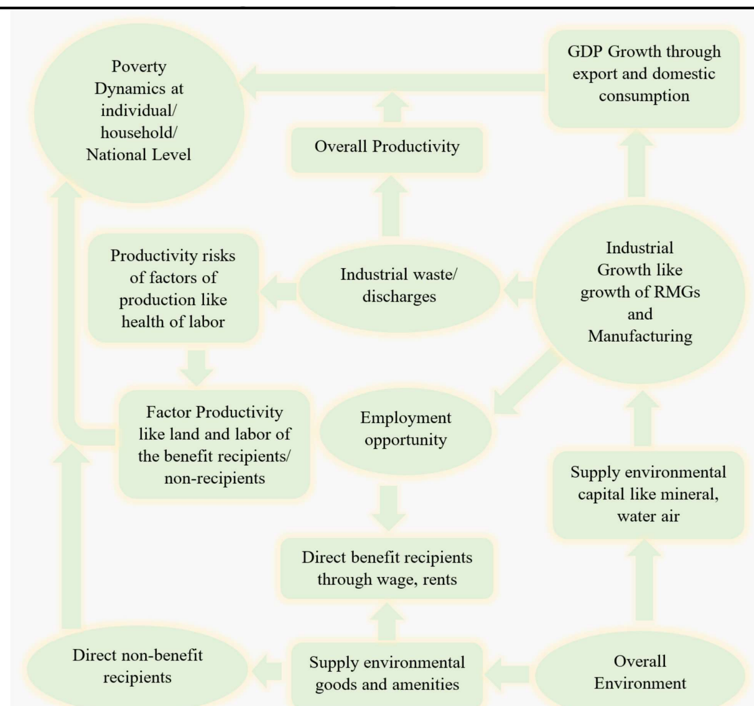
Source: Banu et.al. (2013)
Note: The unit is mg/L.

Conceptual Framework

Employment opportunity is created by economic sectors (industry, agri.)

Both benefit recipients and non-recipients may be affected due to environment unfriendly production.

Households or economy can be affected through health risks/productivity loss ….



Analytical Approach

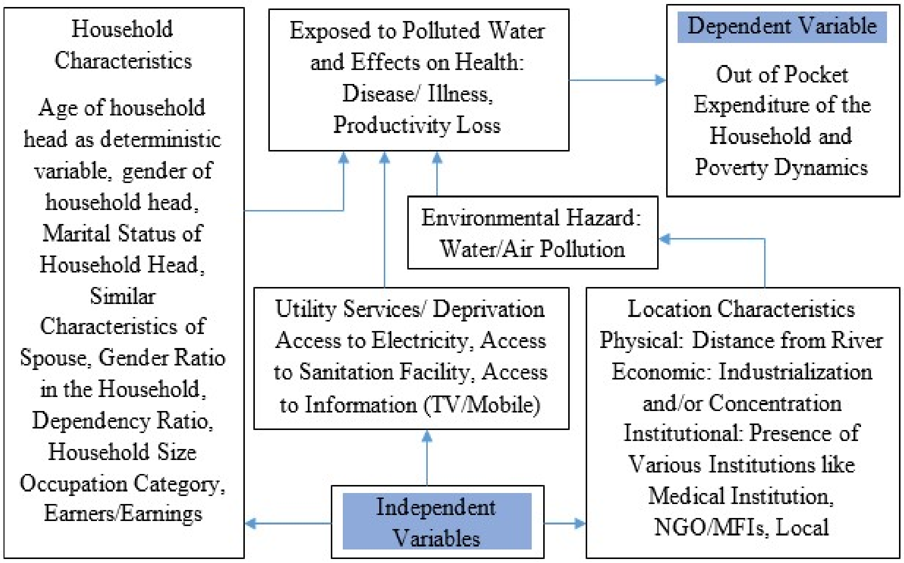


Figure: Analytical Conceptual Framework

Research Methodology

Approach: The study is mostly quantitative in nature. Some qualitative techniques have also been used to compliment the quantitative analysis.

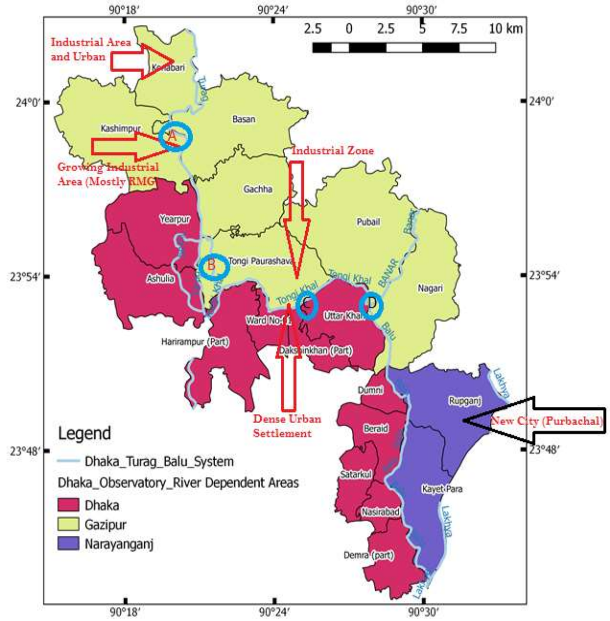
Sources of Data: The data has been collected from both primary (household level interviews) and secondary sources (various publications of BBS, WHO, and World Bank).

Sampling Method: Selection of Primary and Secondary Sampling Units – PSUs and SSUs.

Sampling Design: The study follows the systematic probability sampling technique in drawing the sample household, the unit of analysis. The samples are selected following the strategy of systematic random sampling.

Population: The study population will cover the households living near the banks or canals of Turag River. It will cover the samples from the newly growing industrial zones, the upstream of the Turag River, as well as from the downstream areas.

Research Methodology



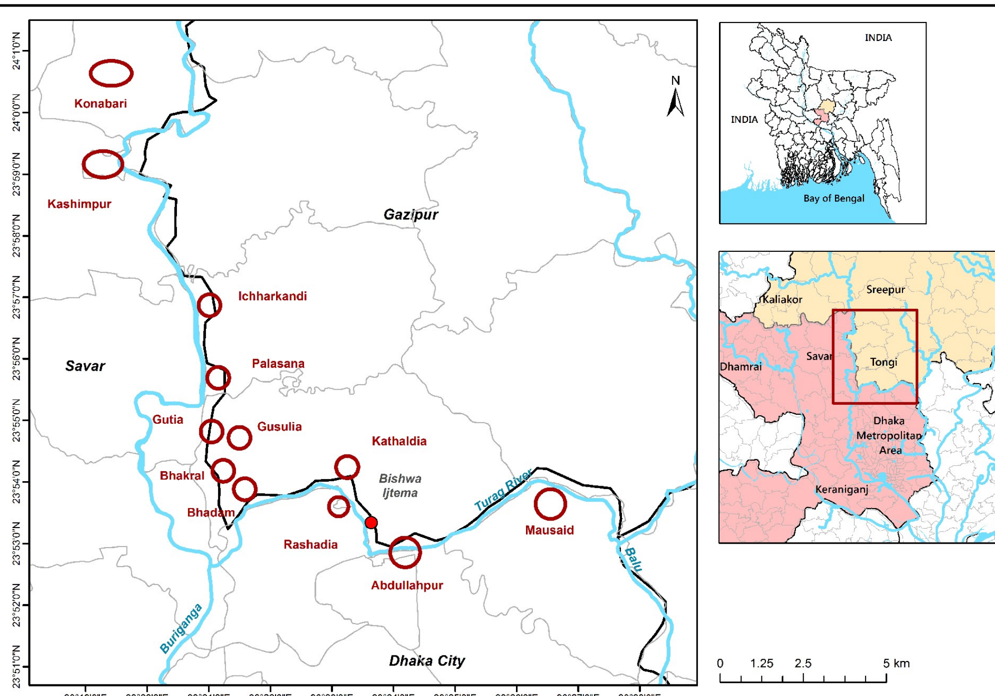
The water quality survey points of BUET covers the areas between the end point of Bongshai river and the connection points of Turag and Balu river, a distance is of around 49 kilometers by road (Joydevpur-Tangail Highway to Dhaka-Sylhet Highway to Tarabo to Rupganj).

The areas in between those points have some distinct characteristics: at the Bongshai- Turag points, mostly in the part of Konabari and Kashimpur areas, there are industrial settlements on one side and on the other side, there is low land mostly undergo during monsoon, and dwellers lived mostly in scatter form but mostly attached with the river.

Survey Areas

In total 1826 households are interviewed in 12 survey areas.

The survey has been completed within December 2017-February, 2018

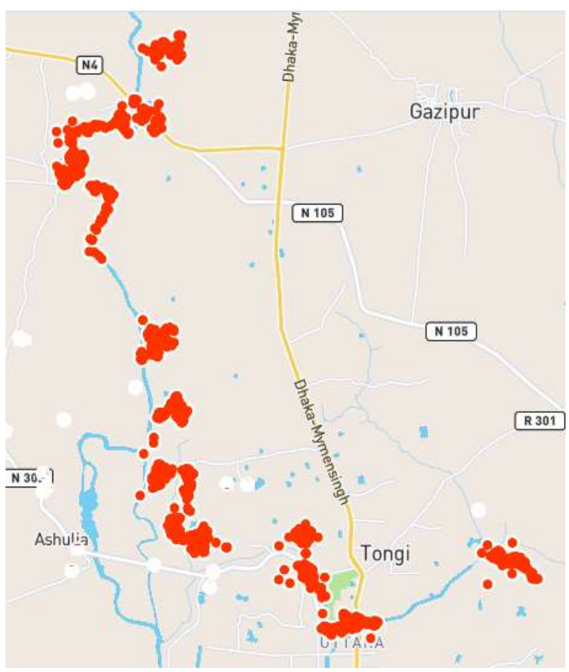


Distribution of Samples

In total 1826 samples were drawn from 12 survey areas.

Areas	Households	Pop	Water source other than tap and tube-well	Samples	Percent
1. Rasadia	193	705	12.1	68	3.72
2. Mausaid	466	2332	4.9	140	7.67
3. Bhadam	863	2850	0.6	199	10.90
4. Bakral	239	1068	11.5	85	4.65
5. Kasimpur	4065	13957	1.2	204	11.17
6. Konabari	7976	30176	0.2	242	13.25
7. Ichharkandi	423	1845	14.2	164	8.98
8. Gusulia	172	789	15.7	65	3.56
9. Palasana	471	2038	0	110	6.02
10. Kathadia	613	2640	14.6	222	12.16
11. Gutia	372	1818	5.4	107	5.86
12. Abdullahpur	1860	8289	0	220	12.05
Total	17713	68507	-	1826	100.00

Samples' location



Reconnaissance, Scoping Visit and Primary Scenarios






Survey Instruments

Survey Instruments: Structured closed-end questionnaire has been used to collect the household data.

The questionnaire contains several modules: the household demographics, domestic water use and sanitation, household expenditure, productivity and illness, poverty, and priority concern.

Both Bangla and English version of questionnaire is used but the data is preserved in English format only.

Data has been collected by 15 enumerators. The enumerators collected data from the households through Tab. The ONA software were used to collect and store the data.

Survey Monitoring: Three layers survey monitoring system has been followed. The enumerators collected the data, the supervisors (research associate/ Mphil Candidate) supervise the overall data collection, and the top management monitor the overall activity.

Ethical Consideration:

- Respect for all participants: The consents of the participants were taken before starting the survey.
- Respect for all enumerators
- Non-judgement

Findings

Characteristics of Households

Around 63 percent of the households are living over 10 years in their areas. Less than 9 percent of households are newcomers.

Most of houses have tin/iron-roof (92.44%) and few have brick/cement made roofs.

The walls are mostly covered by tin/iron (57.83%) and brick/cement (37.35%). Few walls of the houses are covered by earth/mud (3.4%).

Brick/cement and earth/mud are the key floor materials.

Variable	Description	Value
Years of residence (%)	Less than 1 year	8.63
	1-4 years	15.24
	5-10 years	12.79
	More than 10 years	63.34
Wall materials (%)	Brick/cement	37.35
	Tin/iron	57.83
Roof materials (%)	Brick/cement	6.52
	Tin/iron	92.44
Floor materials (%)	Brick/cement	60.19
	Earth/mud	35.49
	Wood/bamboo	3.56

Characteristics of Households

Around 93.7 percent of the households have grid supply electricity connection.

Most of houses use wood/fuel sticks as cooking fuel (75.6%) and around 44.4 per cent households have gas connection.

Households use multiple sources of fuel for lighting and cooking.

Around 31 percent of the households have at least one RMG worker.

Among male led households, a little over 31 percent has at least one RMG worker while among 28 percent female led households has at least one RMG worker.

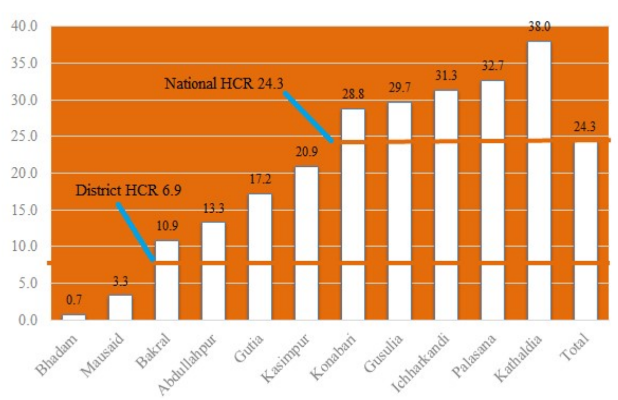
Lighting fuel	Percent
Grid supply electricity	93.65
Solar panel	0.77
Kerosene	3.56
Other (specify)	11.61

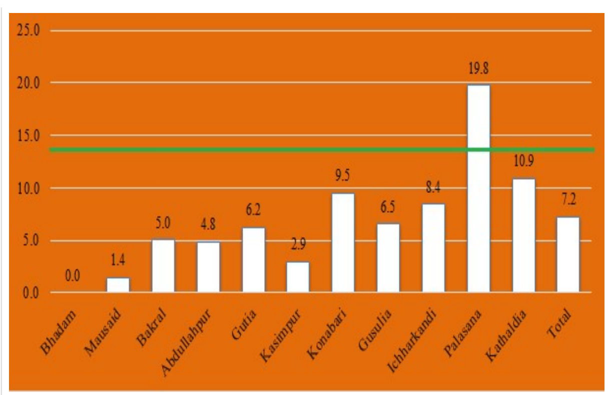
Any member is employed in RMG	Gender of HH Head		Total
	Female	Male	
No	72.15	68.76	69.06
Yes	27.85	31.24	30.94

Number of RMG workers	Gender of HH Head		Total
	Female	Male	
None	72.15	68.76	69.06
One	20.89	22	21.91
Two	5.7	7.67	7.5
Above two	1.27	1.56	1.53

Cooking fuel	Percent
Electricity	0.33
Natural gas (piped supply/ cylinder)	44.41
Animal dung	5.53
Kerosene	0.71
Wood/fuel sticks	75.63
Straw/shrubs/grass	34.78
Other (specify)	0.55

Characteristics of Households





Around 24.3 % people live under UPL and 7.2 % people live below LPL.

Characteristics of Households

Category of Poverty	Gender of Household Head		Overall
	Male	Female	
Chronic Poor	10.1	10.6	10.3
Movers	38.5	39.2	37.6
Fallers	11.1	13.2	12.2
Unchanged (Same)			
Better off (never in bad condition)	34.1	30.0	33.3
Struggling	6.2	7.0	6.6

Around 10 percent households are chronically poor and the welfare of 12 percent households has declined.

Around 6.6 percent households are struggling for better of life but the situation is not changing.

The poverty status has been improved of around 37.6 percent households.

Characteristics of Household Head

Around 91.3 percent households are led by male and 8.67 percent led by female.

The average age of the household head is 42.5 years: average age of male household head is 44.5 years while the female household is 42.3 years on average.

The average schooling of male household head is 4.47 and that is 1.84 for female household head.

Variable	Description	Value
Characteristics of Household head	Gender: male	91.4
	Average age: male head	42.3
	Average age: female head	44.5
	Average age	42.5
	Average education: male head	4.47
	Average education: female head	1.84
	Average education (years of schooling)	4.24
	Literate: male (%)	58.1
	Literate: female (%)	31.0
	Literate (%)	55.8

Characteristics of Household Head

Around 15.3 percent household heads are employed in RMG sector: Around 15 percent of the male household head is working in RMG sector and 15 percent female household is also working in this sector.

Around 10 percent of female household heads is the domestic worker.

Around 22 percent male household heads is engaged in business, 11.33 percent in farming, and 3.72 percent as day labor.

Unemployment (voluntary or involuntary) is high among female household heads.

Occupation of HH Head	Gender of HH Head		Total
	Female	Male	
Agri. Worker	1.9	3.72	3.56
RMG Worker	15.19	15.35	15.33
Other Factory Worker	5.7	5.46	5.48
Casual Worker	3.16	7.19	6.85
Skilled Worker	0.63	6.89	6.35
Construction Worker	1.9	2.94	2.85
Domestic Worker	10.13	0	0.88
Boatman/fisherman	0	4.56	4.16
Farmer/Landlord	5.06	11.33	10.79
Govt. Service	0.63	0.84	0.82
Non-govt. Service	1.9	2.94	2.85
Rickshaw/van puller	0	3.24	2.96
Business	5.7	21.88	20.48
Others	7.59	8.39	8.32
Unemployed	40.51	5.28	8.32

Sources of Drinking Water

Purpose of water use	Source	Value
Drinking (%)	Piped at dwelling/yard	21.25
	Public tap/ Deep tube-wells	4.11
	Motorized tube-wells	73.82
	Open source (river/canal/Lake/pond)	2.47
	Others	1.25
Source distance (%)	Within 5 minutes	69.82
	Within 10 minutes	83.00

The three major source of drinking water are: motorized tube-well (73.82%), piped yard connection (21.25%), and public tap/ deep tube-wells (4.11%).

Around 96 percent households can collect water for drinking purpose within 15 minutes.

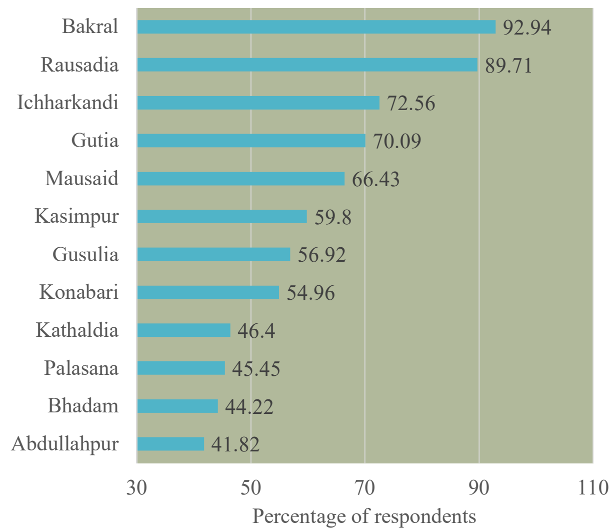
Around 93 percent respondents reported that they drink safe water.

Major Environmental Concern

Around 58 percent respondents reported dirty river water as the key environmental issues in the survey areas.

Dirty river water is the extreme concern in Bakral and Rausadia (Over 90 percent of the respondent raised the issue).

The dirty river water is least concern in Abdullahpur, Bhadam, and Palasana.

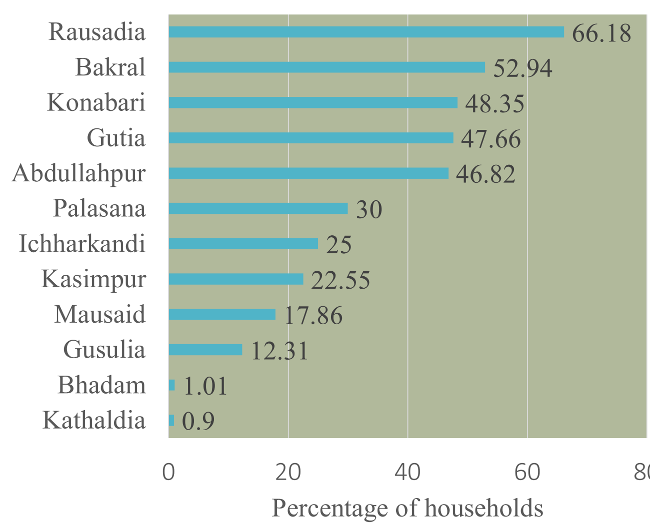


Incidence of Open Source Water Contact

Around 28 percent households are exposed to unsafe water for various purposes within a year: during monsoon and dry seasons.

Over 50 percent of the households in Bakral and Rausadia exposed to unsafe water.

The exposure to unsafe water is below 1 percent in Bhadam and Kathaldia.



Purposes of OSWC by Seasons

Cooking	Washing	Bathing	Seasons
• 2.14%	• 23.8%	• 27.1%	Dry
• 0.99%	• 11.6%	• 13.3%	Monsoon

Households do contact with unsafe water mostly due to washing clothes, taking bath, and cleaning cooking utensils. The incidence of exposing to unsafe water is high during dry session compared to monsoon.

Causes of OSWC

	Non-poor		Poor
UPL	27.4%	Gap: 5.2% t-stat: 1.93	32.6%
LPL	27.8%	Gap: 9.3% t-stat: 2.06	37.1%

Causes of OSWC

	Mean (%)	SD/Z-score
Always struggling	39.6	48.99
Movers	18.49	38.85
Fallers	39.55	49.01
Alway better	30.27	45.98
Compared to always better group	Gap	z-score
Always struggling	9.33	2.67
Movers	-11.78	-5.15
Fallers	9.28	2.37

The incidence of exposing to unsafe water is high among the households who are struggling for better life every time and have fallen down below the poverty line.

Causes of OSWC

Purposes	Average incidence		Difference	
	%	SD	Gap	Z-value
Agri. Worker	36.92	48.64	4.03	0.64
RMG Worker	16.79	37.44	-16.1	-4.57
Other Factory Worker	10	30.15	-22.89	-4.23
Casual Worker	46.4	50.07	13.51	2.7
Skilled Worker	32.76	47.14	-0.13	-0.03
Construction Worker	26.92	44.79	-5.97	-0.86
Domestic Worker	18.75	40.31	-14.14	-1.16
Boatman/fisherman	46.05	50.18	13.16	2.18
Farmer/Landlord	34.52	47.66	1.63	0.39
Non-govt. Service	15.38	36.43	-17.51	-2.48
Rickshaw/van puller	33.33	47.58	0.44	0.07
Business	32.89	47.04	Base	
Others	26.97	44.53	-5.92	-1.33
Unemployed	20.39	40.43	-12.5	-2.83

Causes of OSWC

Purposes	Average incidence		Difference	
	%	SD	Gap	Z-value
Illiterate	34.08	47.43	26.14	3.79
I-V	30.08	45.92	22.14	3.36
VI-VIII	24.34	43.01	16.4	2.68
IX-X	21.1	40.89	13.16	2.3
XI-XII	13.98	34.86	6.04	1.14
Higher education	7.94	27.25	Base	

	Obs.	Mean (%)	SE
Affordability			
Water cost below 120	1,543	26.38	1.12
Water cost above 120	283	39.22	2.91
Diff		-12.85	2.90
t-statistics	t = - 4.43		

Causes of OSWC: Logit Model

$$ln\left(\frac{Pr\left(osw_i = 1\right)}{1 - Pr\left(osw_i = 1\right)}\right) = \beta_1 + \beta_2 WC_i + \beta_3 AF_i + \beta_4 POV + \beta_5 HHC + u_i$$

Here, the dependent variable as defined earlier is binary in nature. The explanatory 'WC' refers to the required time to collect water from the water point, 'AF' means affordability which refers to the capacity of the households to pay the water cost, poverty is defined as the lack of income to meet the required basic needs along with the allowances for non-food items, and 'HHC' refers to household characteristics which includes the characteristics of the household head and household characteristics.

The term u_i is the stochastic disturbance term. Since poverty is basically a multidimensional form of deprivation, affordability and poverty status could be interlinked and the models are estimated separately to understand the effect of poverty on contacting with open source of water.

Causes of OSWC: Logit Model

Model	Explanatory variable	Coefficeint	Z-value
Model 1	Water colletion time	0.096	9.081
Model 2	Water colletion time	0.096	8.963
	Monthly water cost over 120	0.575	4.128
Model 3	Water colletion time	0.09	8.352
	Monthly water cost over 120	0.549	3.902
	Gender of HH head (Male =1)	0.23	1.17
	Age of HH head (years)	-0.006	-1.319
	Schooling years	-0.078	-5.809
	Household size	0.066	1.65
Model 4	Extreme poor	0.427	2.041

Note: β= raw coefficient, Z=Z-score for the test of $\beta = 0$

Causes of OSWC: Logit Model

Model	Explanatory variable	e^{β}	$e^{\beta StdX}$	Marginal Effect
Model 1	Water colletion time	1.101	1.599	0.019
Model 2	Water colletion time	1.101	1.598	0.019
	Monthly water cost over 120	1.778	1.232	0.115
Model 3	Water colletion time	1.094	1.553	0.018
	Monthly water cost over 120	1.732	1.22	0.108
	Gender of HH head (Male =1)	1.259	1.067	0.045
	Age of HH head (years)	0.994	0.927	-0.001
	Schooling years	0.925	0.697	-0.016
	Household size	1.068	1.097	0.013
Model 4	Extreme poor	1.532	1.105	0.087

Note: e^{β}= factor change in odds for unit increase in X, $e^{\beta StdX}$=change in odds for SD increase in X. The coefficients are estimated using Logit model.

Modeling the Effects of OSWC on Selective Variables

$$illmem_i = \lambda_0 + \lambda_1 osw_i + \lambda_k HHC_{ki} + u_i$$

$$numdisease_{i_i} = \gamma_0 + \gamma_1 osw_i + \gamma_k HHC_{ki} + u_i$$

$$log\left(treatcost\right)_i = \mu_0 + \mu_1 osw_i + \mu_2 illmem_i + \mu_k HHC_{ki} + u_i$$

Association of OSWC with Selective Variables

Pairwise correlation	Correlation Coefficient	P-value	Remarks
Open source water contact and treatment expenditure	0.0667	0.0044	Significant
Open source water contact and number of ill people	0.1505	0.0000	Significant
Treatment expenditure and number of ill people	0.1186	0.0000	Significant
Controlling the extreme values (treatment cost has been considered to be below at 99th percentile value			
Open source water contact and treatment expenditure	0.1080	0.0000	Significant
Open source water contact and number of ill people	0.1471	0.0000	Significant
Treatment expenditure and number of ill people	0.1347	0.0000	Significant

The pairwise correlation values are positive suggesting there is a positive association between contacting unsafe water and number of ill people, contacting unsafe water and treatment expenditure. The associations are statistically significant even at 1 percent level of significance.

Effects of OSWC on Diseases Incurred

Number of Ill members	Exposed to unsafe water			Exposed to unsafe water		
	No	Yes	Total	No	Yes	Total
	Percent (At least one member has			Average		
Dysentery/diarrhea	7.8	16.22	10.19	0.1	0.23	0.13
Cholera	0.76	0.58	0.71	0.01	0.01	0.01
Typhoid	5.66	7.34	6.13	0.06	0.08	0.06
Jaundice	7.49	12.36	8.87	0.08	0.15	0.1
Skin diseases	8.18	18.34	11.06	0.09	0.24	0.13
Gastric/ulcers	25.08	35.91	28.15	0.35	0.5	0.39
Mosquito borne	6.8	10.42	7.83	0.1	0.17	0.12
Respiratory disease	4.13	7.72	5.15	0.05	0.09	0.06
Other	24.39	27.22	25.19	0.32	0.34	0.32

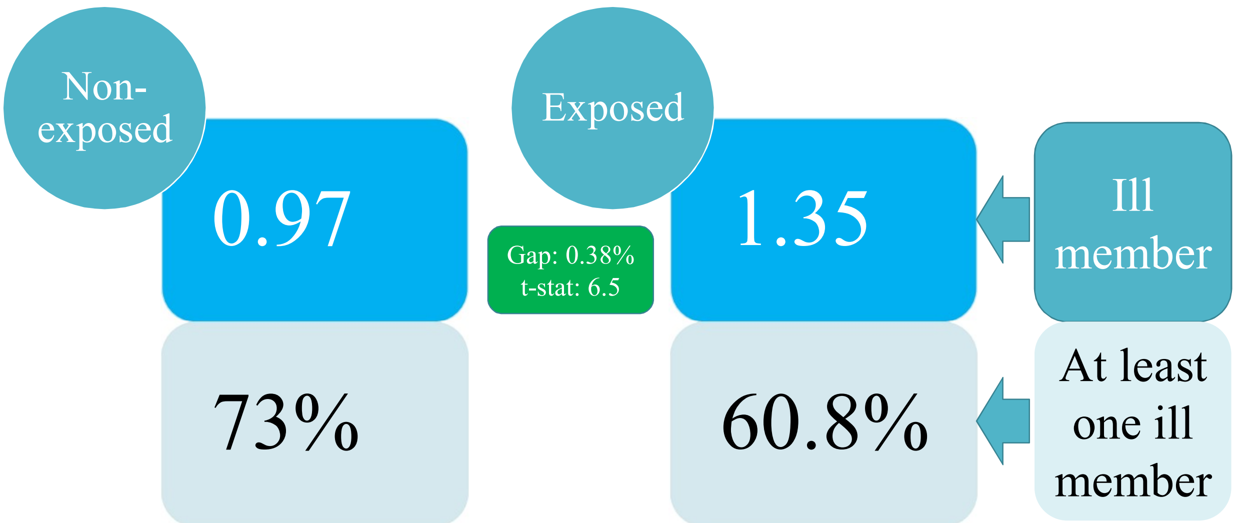
The households exposing to unsafe water has more ill members irrespective of disease types compared to their counterfactual group. Particularly, the incidence as well as the average number of member affected by the specific disease like dysentery/ diarrhea, jaundice, skin diseases, gastric/ulcers and mosquito borne diseases is high among the households exposing to unsafe water.

Effects of OSWC on Diseases Incurred

Explanatory variable	OLS	TOBIT
Contact with open source water (yes=1)	0.448***	0.703***
	(0.058)	(0.092)
Gender of household head	-0.138	-0.168
	(0.095)	(0.15)
Age of household head	0.004*	0.008**
	(0.002)	(0.003)
Education of household head	0.001	-0.003
	(0.006)	(0.01)
Household size	0.104***	0.152***
	(0.019)	(0.031)
Constant	0.448***	-0.380*
	(0.14)	(0.226)
Sigma		1.658***
		(0.039)
Number of observations	1,825	1,825
F	20.832	

Note: The figures in parentheses show standard errors.
Data Source: Household Survey (2018)

Effects of OSWC on Illness

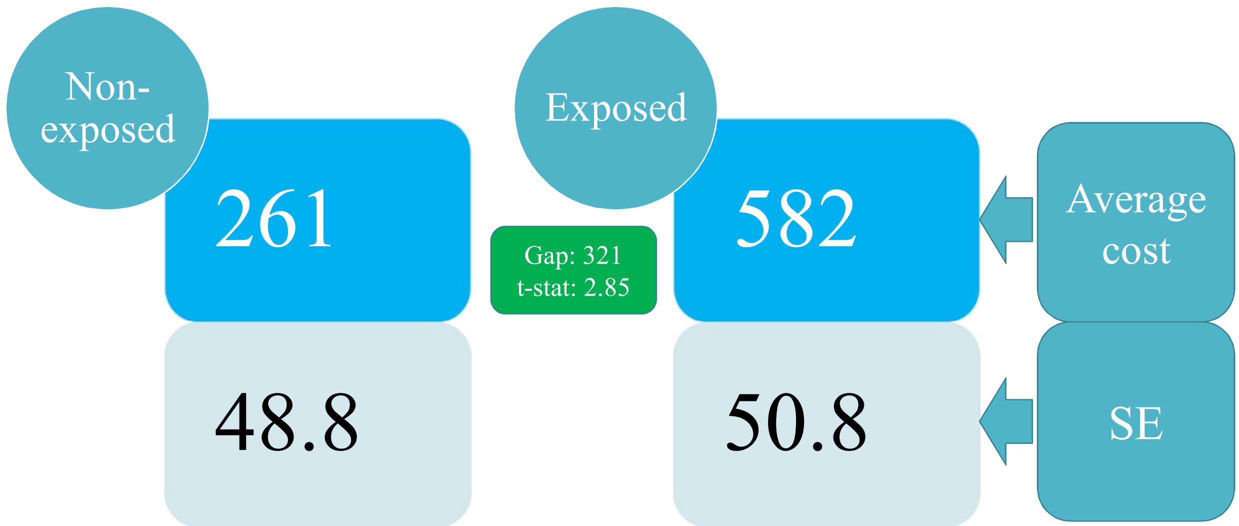


Effects of OSWC on Illness

Explanatory variable	OLS	TOBIT
Contact with open source water (yes=1)	0.361***	0.610***
	(0.059)	(0.093)
Gender of household head	-0.057	-0.076
	(0.095)	(0.152)
Age of household head	0.004*	0.008**
	(0.002)	(0.003)
Education of household head	-0.004	-0.009
	(0.006)	(0.01)
Household size	0.153***	0.207***
	(0.019)	(0.031)
Constant	0.272*	-0.589***
	(0.141)	(0.228)
Sigma		1.675***
		(0.039)
Number of observations	1,825	1,825
F	24.832	

Note: The figures in parentheses show standard errors.
Data Source: Household Survey (2018)

Effects of OSWC on Treatment Cost



Effects on Treatment Cost

Explanatory variable	OLS	TOBIT
Contact with open source water (yes=1)	0.771***	4.667***
	(0.127)	(0.817)
Gender of household head	-0.078	-0.275
	(0.203)	(1.335)
Age of household head	-0.003	-0.014
	(0.005)	(0.031)
Education of household head	-0.011	-0.064
	(0.013)	(0.088)
Household size	-0.026	-0.346
	(0.042)	(0.291)
Number of ill members	0.377***	2.189***
	(0.05)	(0.33)
Constant	0.722**	-12.570***
	(0.301)	(2.157)
Sigma		10.522***
		(0.569)
Number of observations	1,825	1,825
F	19.194	

Note: The figures in parentheses show standard errors.
Data Source: Household Survey (2018)

Effects on Productivity

Characteristics of workers

Occupation	Female worker (22.6%)	Male worker (72.6%)	Total (47.6%)
Agricultural labour	0.78	3.56	2.9
Boatman	0	0.15	0.11
Business	6.44	24.6	20.25
Construction labour	2.04	3.22	2.94
Domestic maid	11.15	0.05	2.71
Farmer	1.1	9.41	7.41
Fisherman	0.16	4.16	3.2
Garment factory	54.47	20.79	28.87
Govt. service	0.78	0.89	0.87
Landlord	1.73	0.89	1.09
Non govt. service	3.45	4.16	3.99
Other casual labour	4.08	9.16	7.94
Other factory	10.05	6.78	7.56
Rickshaw puller	0	3.71	2.82
Skilled labour	3.77	8.47	7.34

Data Source: Household Survey (2018)

Effects on Productivity

Productivity loss	Female worker (22.6%)	Male worker (72.6%)	Total (47.6%)
Lost working days (% of workers)	21.04	16.68	17.73
Average days in last two weeks (days)	4.3	4.5	4.5
Average treatment cost (BDT)	2132	2145	2142
Average salary/wage (LFS, 2016-17)	13321	17106	15912

Data Source: Household Survey (2018)

Summary

Urban riparian residents identified the dirty river water as the key environmental challenges. Out of 3 households, on average, one household exposed to unsafe water.

The poor and marginalized people are exposing to unsafe water due to lack of affordability and scarcity of water.

The chronically poor and vulnerable poor have also more chance to expose to unsafe water compared to others.

The OSWC is increasing the number of ill members in the household.

The exposure to OSW is increasing the share of treatment cost to the total household expenditure which is making the people vulnerable to poverty.

Moreover, the exposure is increasing the number of lost day due to illness and which is exacerbating labour productivity.

Thank You Very Much

Questions !!!

Household survey questionnaire – Dhaka Observatory, Bangladesh

QUESTIONS	CHOICES	INSTRUCTIONS FOR ENUMERATORS
Section 1. Introduction and Identifiers		
1.1 Identification number of enumerator	**SELECT ONE** 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10 -	
1.2 Consent and confidentiality agreement	I am working with the University of Dhaka as part of a research programme. I want to carry out a short survey, where I will be asking questions about you and your household members. The survey is expected to take approximately 30 minutes to complete. If you agree to participate, the information you provide will be used for research purposes only. Your responses to these questions will remain strictly confidential and your name will not appear in any data that is made publicly available. You may withdraw from the study at any time and if there are questions that you would prefer not to answer then we respect your right not to answer them. We would like to write down your contact information in case some issues in the questionnaire are unclear and we need to follow up with you for more information or clarification. Do you consent to participate in and provide information for this study?	
1.3 Is the respondent happy to continue with the survey?	**SELECT ONE** Yes No	If no, thank the respondent for their time and move on to the next survey
1.4 Collect the GPS coordinates of this household	**PRESS GET COORDINATES** Stand directly in front of the household main entrance. Accuracy level should be at least 5m.	Coordinates will be captured automatically once it gets below an accuracy threshold of 5m.

1.5 Please select the site where this interview is occurring	**SELECT ONE** Rasadia Mausaid Bhadam Bakral Kasimpur Konabari Ichharkandi Gusulia Palasana Kathadia	
1.6 How long have you been living in this area?	**SELECT ONE** Less than 1 year 1 - 2 years 2 - 5 years 5 - 10 years More than 10 years	
Section 2. Household demographics [2.2 – 2.9 to be repeated for each household member]		
2.1. How many people live in this household?	**INSERT INTEGER**	
2.2 Name of household member X	**INSERT TEXT**	
2.3 What is X's relationship to the household head?	**SELECT ONE** Head Spouse Son or daughter Son-in-law or daughter-in-law Father or mother Father-in-law or mother-in-law Grandchild Brother or sister Adopted/foster child /step child Other relative Not related Others	One of the members must be identified as the Head If 'Others' is selected, no need to specify further
2.4 Sex of X	**SELECT ONE** Male Female	
2.5 Age of X	**INSERT INTEGER**	
2.6 What is the highest grade X completed? *Relevant if age>5*	**SELECT ONE** No education Pre-school/ kindergarten Class 1 Class 2 Class 3 Class 4 Class 5 (PSC)	

	Class 6 Class 7 Class 8 (JSC) Class 9 Class 10 (SSC) Class 11 Class 12 (HSC) Bachelors/diploma or higher Don't know	
2.7 Occupation of X *Relevant if age>5*	**SELECT ONE** 1. Garment factory worker 2. Skilled labour/professional (e.g. accountant, electrician, plumber, mechanic, tailor, etc) 3. Factory (non-garment industry – cement, tannery, etc) 4. Government (police, teacher, nurse) 5. Agricultural labor 6. Construction worker 7. Fishing 8. Rickshaw/van puller 9. Domestic maid 10. Boatman 11. Business (shop owner, vendor etc) 12. Farmer (agriculture, aquaculture in own/ leased in land) 13. Service (e.g. private job) 14. Landlord/ Income from property rent 15. Unemployed/ housewife 16. Student 17. Casual labour (construction, farm, other) 18. Others (Specify)	
2.7.1 If (1) a garment factory worker: Which of the following are you involved in?	1. Sewing, cutting (dry production) 2. Dying, washing, other (wet production) 3. Management 4. Multiple roles 5. None of the above - other	
2.8 Does X have a personal mobile phone? Relevant if age>13	**SELECT ONE** Yes No	
Only applicable for individuals working in the garment industry, government, professional, or factory (categories 1-4 above)		
For how long have you been working in this job/factory?	**SELECT ONE** Less than 1 year 1 - 2 years 2 - 5 years	

	5 - 10 years More than 10 years	
What are the terms for the work you do? (unprompted, select ONE)	**SELECT ONE** 1=Paid by hour 2=Paid by output(??)/piece rate 3=Rolling daily contract 4= Project contract (to fulfil order?) 5= Weekly or Monthly contract 6= Annual contract or longer 7=Don't know	
Based on above, are the terms in:	1=Writing 2= Verbal 3=Other, specify 4=Don't know	
Section 3. Health and productivity [to be repeated for each household member]		
3.1 Is there any water facility for drinking purpose in your workplace?	1=Yes 2=No 3=Don''t know 4=No response	
3.1.1 If yes, is the water:	1=safe to drink 2=near to your work place 3=always available when needed 4=Don't know	
3.2 Is there any toilet facility for you/worker in your workplace?	1=Yes 2=No	
3.3 Is there any washroom facility **with soap** for you in your workplace?	1=Yes 2=No	
3.4 Were you absent in your office or workplace in the past two weeks?	1=Yes 2=No	

3.5	If yes, how many days?	[Number]	
3.6	What were the reasons of your absence in your job? [Can choose more than one]	1= Illness 2= Depression 3= Injuries 4= Job hunting 5= Workload/stress 6= To care for family members 7= For social purpose 8= Others	
3.7	[if 1=illness] If you were absent in your office or workplace due to illness, how many days in the last two weeks? [insert integer – or range scale]	[insert integer – or range scale]	
3.8	In the past two weeks, how many hours in a day (on average) could you not work at full capacity at work due to illness?		
3.9	Can you remember how much you spent for treatment purposes for the past two weeks?	1=< 100 Taka 2=100-500 Taka 3=500-1000 Taka 4=>1000 Taka 5=Don't Know 6=No Response	
3.10	In the past, **six months** did X suffer from any major illness?	**SELECT MULTIPLE** Dysentry (diarrhoea with blood) Cholera Typhoid Jaundice Skin diseases Gastric ulcers Chikungunya/ dengue/ malaria Tuberculosis/ Pneumonia Don't know Others (specify)	
3.11	Does X suffer from any other chronic	**SELECT MULTIPLE** Body pain	

	(long term) illness/ disability that affect their ability to work properly?	Fatigue Headache/ Migraine Hypertension Diabetes Mental health problems Physical disability	
3.12	Have you faced any issues in your job due to absence from illness? (Code)	1= Yes 2= No	
3.13	(If yes) What kind of issues at work have you faced? (Code)	1= Dismissed from the job 2= Less salary has been paid 3= Extra work/ had to work without pay 4= No payment has been made 5=Verbal warning 6=Reduced productivity 7= Others	
3.14	On average, how many days per month are you absent from work because of this (chronic) illness?	[integer]	Record approximate number of days, or '999' if not known
3.15	Does any person work under your supervision?	1=Yes 2= No	
3.16	How many people work under your supervision? [integer]		
3.17	Does your absence due to your illness affect the activity of the people who work under your supervision?	1=Yes 2=No	
3.18	Do you face any issues in your	1=Yes 2=No	

	household due to your or a family member’s illness?		
3.19	What kind of issues have you faced as a result of your own illness or for taking care of others? (select multiple)	1=Had to take leave from job/activity to take care 2=Regular income had reduced 3=Had to meet unanticipated treatment cost 4=Had to reduce consumption level 5= Reduce savings 6=Had to increase financial liability/taking loan 7=Impact remittance amount able to send 8=Others	
3.20	What kind of issues have your **family members** faced as a result of their own illness or for taking care of others?	1=Had to take leave from job/activity to take care 2=Regular income had reduced 3=Had to meet unanticipated treatment cost 4=Had to reduce consumption level 5=Had to stop saving 6=Had to increase financial liability/taking loan 7=Impact remittance amount able to send 8=Others	
3.21	Did you seek any advice, treatment or medicine for X's illness from any source?	**SELECT ONE** Yes No Don’t know	
3.22	If yes, where did you seek advice or treatment?	**SELECT MULTIPLE** Government Medical College/Specialized Hospital Upazilla Hospital Private clinic Mother and Child Welfare Centre (MCWC) UHC (Union health centre) Union Health and Family Welfare Centre (UH & FWC) Satellite clinic/EPI outreach site Community clinic Family welfare/health centre NGO static clinic NGO satellite clinic NGO field worker Qualified doctor Unqualified doctor Pharmacy Homeopathy Ayurvedic Self-treatment	

		Other (Specify)	
3.23	If you did not seek treatment, why not?	1=Cost is too high 2=Not know where a treatment facility is 3= No time to go 4 = self treatment 5 =illness not severe enough 6=Other	
5.1	For the most recent major family illness, how did you manage the health treatment cost (related costs like fees, medicine, and others)? (code)	1= Regular income 2= Savings 3= Borrowing 4= Asset sale 5= Consumption rationing 6=remittance 7= Others	
5.2	How do you typically meet regular expense demands /remit when regular income is interrupted due to illness?	1= Do nothing 2= Withdrawal of savings and remit 3= Borrowing from neighbour/colleagues 4=purchase items on credit and remit 5= Asset sale 6= remit 7= Consumption rationing and remit 8= Others	

Section 4. Water and sanitation		
4.1 Drinking water - Source, affordability and reliability		
4.1.1 Name ALL the sources of DRINKING water used by your household in the past 12 months	**SELECT MULTIPLE** Public Piped into dwelling Public Piped into yard Public tap/ stand pipe Deep tubewell (with handpump only) Shallow tubewell (with handpump only) Electric tubewell (with motor only OR both motor and handpump) Rainwater Tanker truck Cart with small tank/ containers Bottled water River/canal Lake Pond Others (specify)	
4.1.2 Who owns this tubewell? *Relevant if 'Deep tubewell', 'Shallow tubewell' or 'Electric tubewell' is selected*	**SELECT ONE** Own immediate family/ Extended family (cousin, brother, etc.)	

	Another unrelated family (neighbor OR landlord) Group of families (collective) Community/ government (Public) Others	
Main source of drinking water		
4.1.3 Of the sources mentioned above, which one is your MAIN drinking water source?	**SELECT ONE** Public Piped into dwelling Public Piped into yard Public tap/ stand pipe Deep tubewell (with handpump only) Shallow tubewell (with handpump only) Electric tubewell (with motor only OR both motor and handpump) Rainwater Tanker truck Cart with small tank/ containers Bottled water River/Canal Lake Pond Others (specify)	ONA programming: Only the options selected in 4.1.1 will appear for this one MAIN source is defined as the one which is used 'usually' or for the majority of the year
4.1.4 Do you share this water source with other households?	**SELECT ONE** Yes No	
4.1.5 How many households share this water source?	**SELECT ONE** Less than 5 Between 5 and 10 More than 10	
4.1.6 How much time does it usually take to go to the source, get water, and come back?	**SELECT ONE** Less than 5 minutes 5-10 minutes 10-15 minutes 15 - 30 minutes More than 30 minutes Don't know	
4.1.7 Who usually goes to this water source to fetch the water for your household?	**SELECT MULTIPLE** Adult male(s) Adult female(s) Male children Female children	For this question, children are defined as any individual less than 12 years of age
4.1.8 Has this person(s) ever faced any challenges while fetching water?	**SELECT MULTIPLE** Quarrels/ conflicts with neighbours Felt uncomfortable in using someone else's source Felt unsafe	If required, read out the choices as prompts

	Eve teasing Physical/ sexual harassment Physical burden associated with carrying heavy water containers Other (Specify)	
4.1.9 Do you or someone in your household pay for this water?	**SELECT ONE** Yes No	This refers to payments for water only
4.1.10 To whom are payments for water made?	**SELECT ONE** At the Water Utility office/bank/ to the tariff collector Included in house rent/ to landlord At the place where water is fetched from/ delivered to Other (Specify)	
4.1.11 How often do you pay?	**SELECT ONE** Monthly (Fixed amount) Seasonally/lump sum (Fixed amount paid for certain times of the year) Per container Per cubic meter (Volumetric payment applies for metered connections only)	
4.1.12 How much do you pay? Record in Taka	**INSERT INTEGER**	
Secondary source of drinking water [If Number of sources>1]		
4.1.13 Of the sources mentioned above, which one is your SECONDARY drinking water source?	**SELECT ONE** Public Piped into dwelling Public Piped into yard Public tap/ stand pipe Deep tubewell (with handpump only) Shallow tubewell (with handpump only) Electric tubewell (with motor only OR both motor and handpump) Rainwater Tanker truck Cart with small tank/ containers Bottled water River/Canal Lake Pond Others (specify)	SECONDARY source is the one the household uses when the MAIN source is unavailable, or when alternative sources are used temporarily for issues related to availability, accessibility, reliability, and affordability ONA programming: Only the options selected in 4.1.1 and not selected in 4.1.3 will

		appear for this question
4.1.14 Why did you use this SECONDARY source instead of your main source?	**SELECT ONE** Infrastructure not working New infrastructure installed Unreliable supply (for piped connections only) Not enough water Alternative source has better quality Alternative source is cheaper Alternative source has better taste/smell/colour Easier access Other (Specify)	
4.1.15 For how long did you have to use this secondary source?	**SELECT ONE** Less than 5 days Between 5 and 30 days Between 1 month and 2 months More than 2 months Don't know	
[Repeat questions 4.1.4 – 4.1.12 for SECONDARY source]		
4.1.16 Did you face any additional challenges as a result of switching from your MAIN source to this SECONDARY source?	**SELECT ONE** No challenges Women spent more time/ effort in collecting water Girls (<12yrs) spent more time/ effort in collecting water Women felt unsafe collecting water Girls (<12yrs) felt unsafe collecting water Felt uncomfortable in using someone else's source Higher costs Poor water quality Other (Specify)	
4.2 Drinking water investment and interventions		
4.2.1 In the past 12 months, did anyone conduct any maintenance or repairs to the water source?	**SELECT ONE** Yes No Don't know	This involves replacing screws, rods, washers, buckets, pipes, handles, base platform, or electric parts of pump motor
4.2.2 How much did it cost in total?	**INSERT INTEGER**	Record in Taka. Write '999' if

Relevant if 'Yes' is selected in 4.2.1		amount not known.
4.2.3 Has your household contributed any money to this repair/ maintenance work? If yes, how much? *Relevant if 'Yes' is selected in 4.2.1*	**INSERT INTEGER**	Record in Taka. Write '999' if amount not known.
4.2.4 In the past 5 years, has there been any development intervention that has improved your drinking water situation?	**SELECT ONE** Yes No Don't know	
4.2.5 If YES, what type of intervention has been implemented?	**SELECT MULTIPLE** Installation of deep/shallow tube-well (Handpump only) Installation of deep/shallow tube-well (motorised) Water vending (new/ expansion) Rain water harvesting system Public Pond excavation Other (specify)	This refers to community level interventions by the government, private sector, institutions or CBOs, NOT by households for their private use.
4.2.6 In the past 5 years, did your household install any new water related infrastructure?	**SELECT ONE** Yes No Don't know	This refers to installation of new tube-well or motor/pipes, not repair or maintenance work
4.2.7 If YES, what did you install?	**SELECT MULTIPLE** New shallow tube-well (hand-pump only) New deep tube-well (hand-pump only) Electric/diesel motor (to existing or new tube-well) Storage tank/pipes Rain water harvesting system Other (Specify)	
4.2.8 How much money did your household spend/contribute to this installation?	**INSERT INTEGER**	Record in Taka. Write '999' if amount not known.
4.3 Drinking water - Quality and storage		
4.3.1 Do you think that the water you drink is safe?	**SELECT ONE** Yes	

	No Don't know/ No response	
4.3.2 If not, why?	**SELECT MULTIPLE** Water has Arsenic Water has Iron Water has germs Water doesn't taste/smell/ look good Other (specify)	
4.3.3 Is there anything you usually do before drinking from this water source?	**SELECT ONE** Yes No	
4.3.4 (if yes) What do you usually do before drinking this water?	**SELECT MULTIPLE** Boil Add bleach/chlorine Add alum Add halotab Strain through a cloth Water filter (Bio sand/composite/ceramic filter) Solar disinfection Let it stand and settle Other (specify)	
4.3.5 Does your household store water on the premises?	**SELECT ONE** Yes No	This refers to storing large quantities of water for at least a few hours due to difficulties in fetching water as and when needed
4.3.6 Please show me where you store water. Take picture of the storage container(s)		
4.3.7 How long is the water stored for?	**SELECT ONE** 6 hours or less 6 - 12 hours 12 - 24 hours 1 - 2 days More than 2 days	
4.3.8 Where do you store the water?	**SELECT MULTIPLE** Pitcher (kolshi) Jug Bucket Container/ Jerrycan Bottle	
4.3.9 Is the storage container covered with a lid?	**SELECT ONE** Yes	Observation only

	No	
4.3.10 Do you clean the container(s) before water collection?	**SELECT ONE** Always Sometimes Never	
4.3.11 Where do you wash the storage container?	**SELECT ONE** At home/pond At the water source Others (Specify)	
4.3.12 What materials do you use to wash the container?	**SELECT MULTIPLE** Only water Ash Soap Others (Specify)	If the container is mostly washed with water only, and sometimes with soap/ash, select both options
4.4 Water for domestic uses		
4.4.1 What is your household's main source of water for the following purposes? Bathing (personal hygiene) Washing (utensils, laundry) Cooking and food preparation	**Dry season** **Wet season** **SELECT MULTIPLE** Public Piped into dwelling Public Piped into yard Public tap/ stand pipe Deep tubewell (with handpump only) Shallow tubewell (with handpump only) Electric tubewell (with motor only OR both motor and handpump) Rainwater Tanker truck Cart with small tank/ containers Bottled water River/Canal Lake Pond Others (specify)	
4.4.2 (if river water is selected) You mentioned using river water for some of the domestic purposes. Who usually performs these activities?	**SELECT MULTIPLE** Adult male(s) Adult female(s) Male children Female children	
4.5 Sanitation and hygiene		

4.5.1 What kind of toilet facility do ADULTS of your household use?	**SELECT ONE** Flush to septic tank Pour flush to pit latrine Ventilated improved pit latrine Pit latrine with slab Pit latrine without slab/open pit Hanging toilet/waste discharged directly into waterbodies No facility/bush/field	
4.5.2 Where do you dispose of your child's waste? *Relevant if a child (under 5) uses a potty/re-usable cloth*	**SELECT ONE** Not applicable (no child under 5) In the toilet On dry open ground/ bush Into waterbodies (pond/ river) Other (specify)	
4.5.3 Do you share this toilet facility with other households?	**SELECT ONE** Yes No	
4.5.4 How many households usually share this toilet facility?	**SELECT ONE** Less than 5 Between 5 and 10 More than 10	This refers to sharing on a regular basis
4.5.5 Please show me your toilet and handwashing facilities. Take photo of toilet, if permitted		
4.5.11 What do you wash your hands with?	**SELECT ONE** Only water Soap Detergent Ash Mud Sand Other (specify)	
4.6 Water-related risks		
4.6.1 In the past ONE year, has your household been affected by river flooding?	**SELECT ONE** Yes No	
4.6.2 How did this event affect your household?	**SELECT MULTIPLE** Water came inside the house damaging belongings Unaesthetic living conditions (foul smell, rubbish, insects etc.) Difficulty in commuting to work Affect income Difficulty in performing household chores Difficulty in accessing toilets Difficulty in fetching water Affect crops production Individual(s) became ill	

	Other (specify)	
4.6.3 How many days did this event affect your household?	**SELECT ONE** Less than 5 days Between 5 and 30 days Between 1 month and 2 months More than 2 months Don't know	This is the cumulative number of days in the whole year
4.6.4 In the past ONE year, has your household been affected by waterlogging/ drainage congestion after heavy rain?	**SELECT ONE** Yes No	
4.6.5 How did this event affect your household?	**SELECT MULTIPLE** Water came inside the house damaging belongings Unaesthetic living conditions (foul smell, rubbish, insects etc.) Difficulty in commuting to work Reduced income Difficulty in performing household chores Difficulty in accessing toilets Difficulty in fetching water Damage to crops Individual(s) became ill Other (specify)	
4.6.6 How many days did this event affect your household?	**SELECT ONE** Less than 5 days Between 5 and 30 days Between 1 month and 2 months More than 2 months Don't know	This is the cumulative number of days in the whole year
Section 5. Poverty		
5.1 Assets		
5.1.1 What is your current occupancy status?	**SELECT ONE** Owner Tenant Free accommodation (public land/embankment) Other (specify)	
5.1.2 What is the monthly rent for the house you are living in? *Relevant if 'tenant' is selected in 5.1.1*	**INSERT INTEGER** >	Record in Taka; or '999' if not known
5.1.3 Does your household have any of the following assets?	SELECT YES/NO for each Television	

	Radio/CD player Computer/ laptop Bicycle Motorcycle Autobike/tempo/CNG Car/truck/microbus Rickshaw/van/animal cart An almirah/wardrobe/showcase Refrigerator An electric fan Power tiller/tractor Electric/ diesel pump IPS/Generator	
5.2 Land and livestock		
5.2.0 Do you own any land?	**SELECT ONE** Yes No Don't know/ No response	
5.2.1 If yes, what kind of land do you own?	1= Own agriculture land (self-cultivated) 2= Own non-agriculture land 3= Leased out agriculture land 4= Leased in agriculture land 5= Leased out non-agriculture land 6= Leased in non-agriculture land 7=Homestead land 8= None	This refers to land from which the household derives any sort of income (cash/in kind)
5.2.2 If (1) or (7), how much land do you own?	**INSERT INTEGER**	Record in decimals. If respondent mentions other units like bigha/kani/acre, convert to decimals
5.2.2 If (1): is your agricultural land affected by river water pollution?	1= Yes 2= No	
5.2.2.1 [if yes] What areas are affected by the river pollution? (decimal)		
5.2.2.2 Do you think the river water pollution reduces your agricultural revenue?	1=yes 2=no	

5.2.2.3 [if yes] How much revenue is lost per year in agriculture due to water pollution? (BDT)		
5.2.3 Does your household own any livestock?	**SELECT ONE** Yes No	
5.2.4 No. of Cow/buffalo	**INSERT INTEGER**	
5.2.4 No. of Goat/sheep	**INSERT INTEGER**	
5.2.6 What is the source of drinking water for livestock?	**SELECT MULTIPLE** Public Piped into dwelling Public Piped into yard Public tap/ stand pipe Deep tubewell (with handpump only) Shallow tubewell (with handpump only) Electric tubewell (with motor only OR both motor and handpump) Rainwater Tanker truck Cart with small tank/ containers Bottled water River/Canal Lake Pond Others (specify)	
Please give a rough estimate on the following expenditure heading:		

Items	Monthly expenditure	Does Illness affect it?

		(1=Yes, 2=No)
1. Food expenditure		
2. Clothes and footwear		
3. Fuel and lighting		
4. Education		
5. Treatment Cost (Doctors fees, medicine cost, hospital fees)		
6. House rent		
7. Miscellaneous		

5.3 Power sources and housing material		
5.3.1 What is the power source for lighting and electronics?	**SELECT MULTIPLE** Grid supply electricity Generator Solar panel Kerosene Other (specify)	
5.3.2 What type of fuel does your household mainly use for cooking?	**SELECT MULTIPLE** Electricity Natural gas (piped supply/ cylinder) Animal dung Kerosene Wood/fuel sticks Straw/shrubs/grass Other (specify)	
5.3.3 Do you have a separate room which is used as a kitchen?	**SELECT ONE** Yes No	
5.3.4 With how many households do you share your kitchen?	**SELECT ONE** Not shared with any other household Shared with 1-2 other households Shared with more than 2 households	
5.3.5 Main material of the floor of house	**SELECT ONE** Earth/mud Wood/ bamboo Brick or Cement Tiles/ Mosaic Other (specify)	
5.3.6 Main material of the roof of house	**SELECT ONE** Leaves/straw/ plastic Wood/bamboo Tin/corrugated iron Brick/ Cement Other (specify)	
5.3.7 Main material of the exterior walls of house	**SELECT ONE** Leaves/ straw/ cardboard/ plastic	

	Earth/mud Wood/ bamboo Tin/ corrugated iron Painted Brick/Cement Others (specify)	
5.3.8 How many rooms do members of this household usually use for sleeping?	**INSERT INTEGER**	
5.3.9 Take a picture of the house so that the roof, wall and floor materials are clearly visible.		
5.3.10 How would you describe the current welfare situation of your household?	**SELECT ONE** Doing well Doing just OK Struggling Unable to meet household needs Don't know/ No response	
5.3.11 How would you describe the welfare situation of your household about FIVE year ago?	**SELECT ONE** Better than present situation Same as present situation Worse than present situation Don't know/ No response	
Section 6. Priority concerns		
6.1 General concerns		
6.1.1 Now I am going to go through a list of CONCERNS that some families in this area have expressed. Suppose that the government could help your area with just THREE of these issues, which would YOUR FAMILY choose? *Read out all concerns and rank in order of importance*	Concern #1 Concern #2 Concern #3 **SELECT ONE for each** Healthcare Transportation and roads Sanitation Drinking water services Water for agriculture (Irrigation services) Clean environment Security and crime Employment Education Electricity Gas supply Financial services Agricultural support No concerns Others (Specify) Don't know/ No response	If the respondent cannot name any concerns, mention a few from the list as examples. However, do not mention anything related to water. ONA programming: Option selected for 'Concern #1' cannot be selected for 'Concern#2' and so on. If 'No concerns' is selected for 'Concern #1', for example, questions for

		'Concern #2' and 'Concern #3' will not appear.
6.2 Concerns regarding water		
6.2.1 Now, I would like to know which are your major concerns with regards to water. Do you have any concerns regarding the WATER you drink and use for domestic purposes?	**SELECT ONE** Yes No	
6.2.2 What are your three main concerns? *Relevant if 'yes' is selected in 6.2.1*	Concern #1 Concern #2 Concern #3 **SELECT ONE for each** Water is unsafe to drink Water supply is too costly Water source is too far Water for domestic use is dirty Water supply is unpredictable Not enough No concerns/ Don't know Other (Specify)	ONA programming: Option selected for 'Concern #1' cannot be selected for 'Concern#2' and so on. If 'No concerns' is selected for 'Concern #2', questions for 'Concern #3' will not appear.
6.2.3 In your opinion, what types of initiatives should be taken to address these concerns? *Relevant if 'yes' is selected in 6.2.1*	**SELECT MULTIPLE** Install new/ extend piped water system Install deep tube-well in the vicinity Increase coverage of vended water Excavate/manage existing ponds Install community rainwater harvesting system Other (Specify)	
6.3 Concerns regarding the natural environment		
6.3.1 Do you have any concerns regarding your NATURAL ENVIRONMENT?	**SELECT ONE** Yes No	
6.3.2 What are your three main concerns? *Relevant if 'yes' is selected in 6.3.1*	Concern #1 Concern #2 Concern #3 **SELECT ONE for each** Rivers/canals are dirty or polluted No/ inadequate rubbish collection or cleaning People commonly defecate in public spaces Riverine flooding in wet season	ONA programming: Option selected for 'Concern #1' cannot be selected for 'Concern#2' and so on. If 'No concerns' is selected for

	Waterlogging after heavy rain Decline of fisheries population No concerns/ Don't know Other (Specify)	'Concern #2', questions for 'Concern #3' will not appear.
Section 7. Enumerator Closing Questions		
7.1 Did the respondent understand the majority of the questions?	**SELECT MULTIPLE** Understood all the questions well Understood most of the questions, but not all Understood some of the questions (roughly half) Did not understand many questions (less than half) Understood very few questions	
7.2 How would you rate the accuracy of the respondent's answers?	**SELECT MULTIPLE** Accurate Satisfactory Average Poor	
7.3 Contact phone number 1	**INSERT TEXT**	*Enter '999' if the phone number is not given*
7.4 Name of individual using this phone		
7.5 Contact phone number 2	**INSERT TEXT**	*Enter '999' if the phone number is not given*
7.6 Name of individual using this phone		