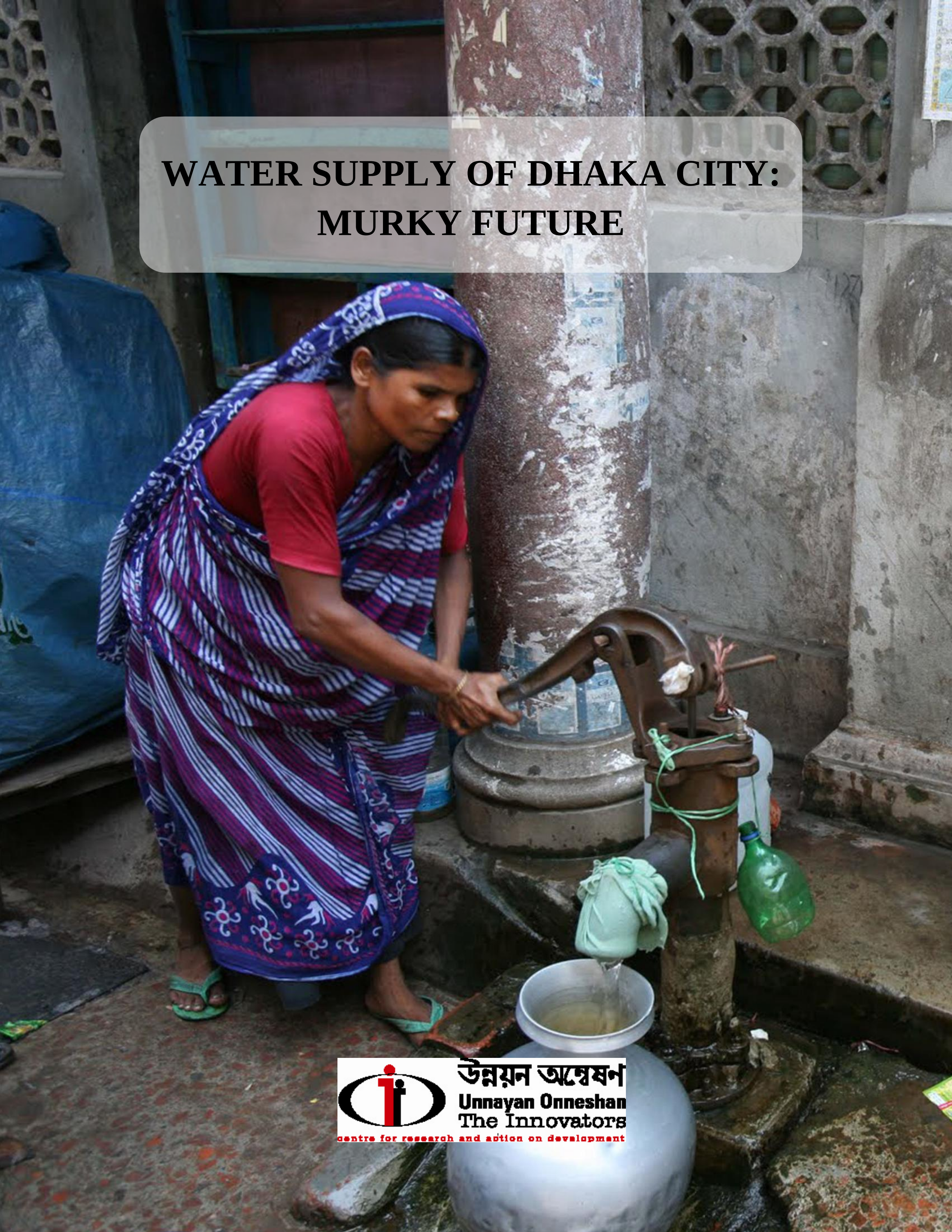
WATER SUPPLY OF DHAKA CITY: MURKY FUTURE



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WATER SUPPLY OF DHAKA CITY: MURKY FUTURE
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EXECUTIVE SUMMARY

Access to water is a basic human right and it is a crosscutting issue for sustainable development. Water resources have unlimited importance including human survival, socio-economic stability and environmental sustainability. 'Water is right or economic good' has been a matter of discourse since industrial revolution in the Eighteenth century. Dhaka city dwellers, following an unsystematic urban sprawl, are deprived of basic urban amenities where water supply has appeared as the most critical issue. The theoretical propagation on 'access to water' has received momentum with the accelerated pace of water pollution and resultant freshwater scarcity. Being a crosscutting resource, water experiences socio-ecological mismatch in resource management where the scale at which decisions are made for water management, does not match the scale at which it functions. To address the existing problems of water demand and supply, and to draw future scenarios, the current study has employed both qualitative and quantitative research techniques. Particular attention has been given to elucidate access and inequality in getting an adequate amount of water in Dhaka Metropolitan Area (DMA).

Water supply of Dhaka city is heavily dependent on groundwater extraction where more than 87 percent of the supplied water is being extracted from this source. Such extensive dependency enhances a very high depletion rate of groundwater table. Dhaka city has been experiencing a sharp declination in groundwater table with more than 20 meters lower down during the last seven years at a rate of 2.81 meter per year (m/y). Considering the existing depletion rate, the study predicts that the groundwater table will go down to 120 meters by 2050. The study shows that the potential groundwater recharge of Dhaka city is only 1.33 m/y in contrast to 2.81 m/y of groundwater depletion rate. Such finding implies that despite sufficient amount of rainfall, Dhaka city is experiencing 1.48 m/y groundwater recharge deficit every year. Moreover, increased rate of urbanization, illegal occupation, and encroachment reduce the amount and volume of surface water bodies around the city that deteriorate the present situation.

The study has attempted to draw three scenarios considering existing water supply situation, future roadmap, unaccounted for water (UFW), downtime loss, or production loss (Cs) to project water demand and supply up to 2050. All of the three scenarios showed a mismatch in water demand and supply. The first scenario, which has taken into account the current production as status-quo, projects that the gap would be 2451 Million Litre per Day (MLD) by 2050 against the demand of 4539 MLD. The second scenario considered future roadmap of DWASA and current trend of system loss or UFW that ended up with a gap of 1012.4 MLD. This scenario also suggested that unless reducing the UFW from current 31.68 percent to less than 15 percent, DWASA would not be able to fulfill the future demand. The final and highly ambitious scenario considered both 10 percent UFW and 10 percent production loss arising from regular maintenance, power shortage and other technical problems that also project a gap of 704.3 MLD. Such evidences give a murky future for the water supply of Dhaka city.

DWASA has projected water demand as 150 litres per person per day (l/p/d). Empirical evidence shows that one-third of the city dwellers receive only 40 l/p/d and they have to manage their daily activities with this little amount of water. Only 5.1 percent of total population of Dhaka city receives more than 60 l/p/d. On an average, 42.8 percent of the respondents can receive basic requirement of 50 l/p/d and the rest (57.8 percent) are suffering from water scarcity despite piped connection.

Poor people, mostly living in the slum areas, are being neglected both at demand and supply side and are more deprived of having acceess to potable water. The study reveals that 31.43 percent households in Dhaka city do not have access to piped connection and they have to rely on NGO or other sources (standpipe). Despite little consumption, they have to pay more than middle-income or high- income group people. The study finds that a poor household (whose total household income is less than 10000 BDT) has to spend 500 BDT per month for 30 l/p/d while a middle-income or high-income group family (whose total household income is more than 10000 BDT) has to pay 400 BDT/month for water supply of 45-50 l/p/d or more. Poor people have to buy additional water to maintain their daily activities. This extra spending of water hinders to improve the livelihood status of them.

Despite dominance of uncontaminated groundwater in DWASA water supply system, the user-end water quality exceeds World Health Organization's (WHO) prescribed drinking water permissible limit due to poor maintenance. The current study found that about 22.86 percent city dwellers could not use the DWASA supply for drinking purpose due to bad smell and have to rely on bottled or jar water that is of dubious quality. On the other hand, 66 percent of the consumers boil DWASA supplied water for drinking purpose and they have to boil the water at least for half an hour to make it potable. Among them, at least 50 percent also use water filter to ensure maximum safety.

The study found that two-thirds of the Dhaka city dwellers believe that current water supply management system could not fulfill their demand. In addition, irregular monitoring and inadequate supply make people rely on privately owned water supply that eventually leads to huge deadweight loss.

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1. INTRODUCTION

Water constitutes two-thirds of the surface of the earth and is a crosscutting resource. It is an essential component of all organisms and usually a good solvent for a large variety of substances. Moreover, its being necessary for most biological processes makes it one of the major components of socio-economic development and poverty alleviation. The Third World Water Forum 2003 has entitled water as a 'driving force for sustainable development' and a strategic tool to fight against poverty. Water resources have unlimited importance in human survival, socio-economic stability and environmental sustainability.

Water covers 71 percent of the earth's surface but only three percent is freshwater out of which 69 percent is "trapped" as ice, mainly in the two polar regions. The remaining freshwater occurs in rivers, lakes and aquifers which human being, plants and other animal species can use. The distribution must be carefully managed to avoid irreversible depletion of the resource (WHO/UNICEF JMP, 2010).

Water scarcity has been causing conflict since the beginning of civilizations. Kjellén and McGranahan (1997) predicted that two-thirds of the world's population will experience water stress condition by 2025 and some countries would experience high water stress condition where water withdrawal against available resources exceeds 40 percent. The alarming news is that in South Asia, the withdrawal rate against available resources is 48 percent (Ariyabandu, 1999). Bangladesh, as being a riverine country, has been facing dual challenges from water: firstly, unlimited flood water during wet season and secondly, increasing scarcity during dry season. However, one in eight people does not have access to safe drinking water and two of five people do not have adequate sanitation worldwide (Water Aid, 2010). Life cannot sustain beyond a few days without water. Moreover, lack of access to adequate safe water leads to the spreading of diseases. Children and women bear the greatest health burden associated with poor water and sanitation. World Health Organization (2002) estimated that 1.73 million deaths occur each year due to diarrheal diseases attributed from poor water supply, sanitation and hygiene.

Dhaka city has been increasing with an annual rate of 3.5 percent following an unsystematic approach (Islam *et al.,* 2009) to accommodate huge population influx of more than seven million (BBS, 2009) people. Such urban sprawl exerts immense pressure on the infrastructures of the city. The city inhabitants, therefore, are deprived of basic amenities of urban life where water supply has appeared as the most critical issue. At present, water demand has surpassed the water supply where 25 percent of the total population of Dhaka city has no direct access to potable water (Nishat, *et al.*, 2008). Dhaka Statistical Metropolitan Area (DSMA) covers an area of 1353 KM^2, out of which Dhaka Metropolitan Area (DMA) constitutes 27 percent (360 KM^2). Until 1989, Dhaka Water Supply and Sewerage Authority (DWASA) operation was limited to DMA butin 1990; it extended operating area to adjacent Narayangonj metropolitan as well. Even though this paper will focus on DMA but it will also consider the total demand and supply of DWASA as a whole.

Being a crosscutting resource, water experiences socio-ecological mismatch in resource management where the scale at which decisions are made for water management, does not match the scale at which it functions. Scale is a term used to describe the spatial, temporal, organizational 'level' at which some being exist, or process occur. (Cash *et al.*, 2006 *cited in* Rathwell, 2009). The urban water management involves complicated and systematic process that includes planning, research, design, engineering, regulation, and administration. Under the circumstances, the current study has attempted to understand the trend and extent of water demand and supply both at spatial and temporal scale through analyzing status of surface and groundwater, and proposing management options based upon future demand and supply projection. Particular attention has been given to elucidate access and inequality in getting an adequate amount of water in Dhaka Metropolitan Area (DMA).

1.1. Water is Right or Economic Good: A Discourse Beyond Scale

"Water is right or economic good" has been a matter of discourse since industrial revaluation in the Eighteenth century. The theoretical propagation on 'access to water' has received momentum with the accelerated pace of water pollution and the resultant freshwater scarcity.

Drawing examples from *tragedy of commons*, a group of people, industries, farmers and governments have warned that unregulated 'free access to water' would lead to serious depletion of this essential life sustaining resource (Hardin, 1968). These proponents consider water as an economic good, not a "free" limitless resource by arguing that adequate supply of safe water involves a complex mixture of social, economic and environmental issues where there should have a range of quality and level of water delivery depending on 'freedom of choice' and people's 'willingness to pay'. Water, as a socially vital economic good requires careful management for sustainable development and for reducing poverty. Being an apparently abundant but critical natural resource, water demands much attention in allocation and distribution, equity, conservation, pricing, regulation, participation, and sustainable use. Thus, water is considered neither social nor a public good, but 'a socially vital economic good'.

On the other hand, the 'rights' discourse on water argues that water is not a commodity, which can be sold for profit in the market place to the highest bidder rather it is a 'right' that underpins life on earth. Water has been recognized not only universally but also religiously as an invaluable resource and every living being has right to access it. United Nations (UN) has also acknowledged "Right to Water" as fundamental to development. Accordingly, UN Human Rights Declaration (2002) states,

> *"The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible, and affordable water for personal and domestic uses. An adequate amount of safe water is necessary to prevent death from dehydration, reduce the risk of water-related disease, and provide for consumption, cooking, personal, and domestic hygienic requirements".*

Inspired by 'right based approach' the current study has considered 'access to water' as a basic human right through extending the recognition from narrow economic consideration to broader social and cultural perspective.

1.2. Right to Water: Bangladesh Prespective

Water right, inherently linked to other fundamental human rights is not merely a right issue rather it is a highly political and policy issue. The constitution of Bangladesh reserves the rights of its citizen and acknowledges country's obligation to provide the basic necessities of life such as food, clothing, shelter, education and medical care. It seems that the water right is considered under food, but no article or clause deduces the water right issue conspicuously.

'It shall be fundamental responsibility of the State to attain, through planned economic growth, a constant increase of productive forces and a steady improvement in the material and cultural standard of living of the people, with a view to securing its citizens through the provision of the basic necessities of life, including food, clothing, shelter, education and medical care'. [Bangladesh Constitution, Article 15, clause (a)]

In Bangladesh, the National Policy for Safe Water Supply and Sanitation (1998) declares state ownership to water. Even though the policy acknowledges that access to safe water is essential for socio-economic development of the country but no special provision has been made to ensure citizen's right to water. Rather, the policy in the article 4.3 (paragraph f) addresses water as an 'economic good' by keeping provision of conferring water right to private or community bodies to provide secure, defensible and enforceable ownership/usufructuary rights for attracting private investment. Moreover, the proposed Water Act 2010 in its preamble defines 'right to water' as acquired access and use rights. In addition, the act does not acknowledge 'citizen right to water' and state's obligation to supply safe water; rather it encourages privatization of water through a general authorization or license. These provisions conflict with the spirit of constitution's deceleration on rights to the basic necessities. The Government of Bangladesh (GoB) has also planned to develop and manage water resources efficiently in Poverty Reduction Strategic Paper (PRSP), but 'right to water' issue remained overlooked there as well. Under the umbrella of PRSP and sectoral development policies, many projects have already been implemented or some are at the implementing stage, but 'right to water' has remained an under treated issue.

2. AIMS AND OBJECTIVES

The present study aims to know the prevailing scenario of urban water supply and the demand of Dhaka city. In addition, some other specific objectives are as follows:

- To project future water demands and supply scenario of Dhaka city up to 2050
- To project the groundwater depletion rate up to 2050 and to know the potential groundwater recharge rate for Dhaka city
- To explore access and equality in water supply of Dhaka city
- To elucidate possible remedies for water governance

3. METHODOLOGY

The current study has employed a two-track methodology. In the first track, secondary data have been collected from books, journal articles, and reports of different government and non-government organizations. On the other hand, the second track intended to gather empirical data through a mixture of research techniques such as Key Informant Interview (KII), In-depth Interview using semi-structure questionnaire and Case Study. To make projection for water demand and supply and to calculate the potential groundwater recharge, both 'Growth Rate' and 'Simple Hydrological Balance Equation' have been used respectively.

3.1. Key Informant Interview

Key informant interviews are qualitative in-depth interviews with resource person including community leaders, professionals, or residents who have first-hand knowledge about the concerned issue. The purpose of key informant interviews is to collect information on particular issue and to understand the nature of problems and to recommend for solutions as well. To understand present trend of water supply and possible future scenario, three experts from DWASA, BUET and Dhaka University were being interviewed respectively. Both face-to-face interview and telephone calls have been arranged to gather key informants' views and knowledge regarding water demand, supply and management options in Dhaka city.

3.2. In-depth Interview

To understand the status and extent of water supply and demand problems faced by Dhaka city dwellers, 80 in-depth interviews were conducted through semi-structured questionnaire in two phases. In the first phase, 60 households were being interviewed based upon locality and income group. Employing a *purposive-random sampling technique*, interviews were carried out in Azimpur, Bashabo, Dhanmondi, Farmgate, Kamalapur, Mirpur, Mohammadpur, and Uttara depending on higher, middle and lower income group peoples' dominance. On the other hand, 20 shops (hotel, restaurant, and café who use jar and bottled water) have been surveyed and interviewed to attain a clear picture of drinking water consumption pattern of the people. For shop selection, Farmgate, Gabtoli bus terminal, Mirpur, and Sayedabad bus terminal areas were considered depending on peoples' gathering regardless of age, profession and income but using the same sampling technique as applied for the household.

3.3. Projection

To make projection for demand and supply, 'Growth Rate Equation' has been used. The formula was **Growth Rate (r) = 1/t[(C-B)/C]*100**, where, t= time period, C= Current year, B=Base year, and the projection was estimated by manual calculation.

On the other hand, to estimate the potential groundwater recharge, simple hydrological balance equation (**$R_e = P - P_e - U$**) has been used where R_e= Potential Recharge, P= Rainfall, P_e= Potential Evapotranspiration, and U= Surface Run-off. During calculation of the ground water recharge, potential evapotranspiration has been calculated by 'Blaney-Criddle' formula [**$P_e = p(0.46T+8)$**], where, Pe= Potential Evapotranspiration, P= Mean Daily Percentage of Annual Daytime Hours, and T= Mean Daily Temperature.

Limitation of the study

This study aimed at exploring the demand and supply scenario, and access and inequality in water consumption. However, shortage of information related to groundwater reserve, ignorance of people regarding their right to water, difficultly in accessing service provider organisation forced to rely on projection and information from secondary literature. To address the limitation, the study made three projections for three different scenarios in the case of water demand and supply.

4. WATER SUPPLY: A SITUATION ANALYSIS

Water supply including adequate sewerage system is the single most important determinant of public health. Destruction of water supply after major calamities (e.g. earthquakes, floods, war, etc.) poses the immediate threat of severe epidemics of waterborne diseases. In 2010, about 84 percent of the global population (6.74 billion people) had access to piped water supply including standpipes, protected springs, and wells (UNICEF, 2010). Safe water includes treated surface water, as well as untreated but uncontaminated water from sources such as natural springs and sanitary wells. Despite being renewable resources, water scarcity has stricken many parts of the world due to unregulated depletion, surface and groundwater pollution and insufficient water infrastructures. The United Nations Medium Population Projection (1998) predicted that more than 2.8 billion people in 48 countries would face water stress (less than 1700 m^3 per person per year) or scarcity (less than 1000 m^3 per person per year) by 2025. The number of countries facing such water stress or scarcity would rise to 54 by 2050. (UNFPA, 1997 *cited in* Mahbub *et.al.*, 2007).

Bangladesh, as in the lower riparian, has limited control over upstream rivers that reduce water availability during dry seasons which largely influences flood and drought accompanied with the inflow of low quality of water (National Water Policy, 1999). The progressive rate of urbanization and industrialization make the situation worse. The net result is that per capita supply of renewable water is declining throughout the basins that Bangladesh shares with India. In such a condition, reduced water availability in the Ganges-dependent areas of Bangladesh are being affected in a number of ways, including salinity intrusion, changes of river morphology, and increased environmental hazards. Rivers and watersheds are being polluted by dumping of waste and garbage into them and thus safe water supply is reducing. People are using water faster than nature can replenish. Abundance of rainfall in this delta influences people to make wastage of water as they never have considered the costs to treat the water after it is used.

Without safe water, people cannot lead healthy and productive lives. More than million people worldwide suffer from water-related diseases, such as diarrhoea, bilharzias, cholera, elephantiasis, and hookworm (World Bank, 2001). Most of these people live in low and middle-income group countries, and children and elderly people are at the greatest risk among them. Due to the lack of hygienic water supply, a considerable number of people are experiencing stunting from diarrhoea-caused malnutrition that reduces life expectancy. Ill health, lack of available sanitation and extra time incurred from water collection are contributing to increase dropout rate, particularly in rural areas. Furthermore, the increased cost of safe drinking water exerts additional burden to the poor people, vulnerable already.

Getting water is more difficult and often more expensive for the poorest people. In developing countries, women and children of both rural and urban settings spend hours in extreme cases up to six to eight hours each day to collect water from different sources. In such cases, the poor do not have the access to the piped water in their property rather they have to buy or take water from other sources. People who buy water from other sources may have to pay three to ten times more than the usual price of piped water.

In Bangladesh, the water supply coverage has been increasing both in the urban and rural areas since the 80's. However, almost 88 percent of water is withdrawn for irrigation, livestock while only 10 percent, and two percent use it for household and industry respectively (FAO, 2010). Nearly 97 percent of the rural population is using over 10 million hand tube wells to fulfill their drinking water demands. However, arsenic contamination of groundwater, above the permissible limit of 50 μg/L (micrograms per liter), has affected an estimated of 25 percent of the shallow tube wells that has reduced safe water coverage in rural areas to around 76 percent. To attain the supply coverage levels at 100 percent by 2010, many programs have been initiating which deal with the massive task of rehabilitation, improvement and extension of the city's water supply systems (National Water Management Plan, 2001).

At present, more than 15 million people are living in Dhaka city while 35 percent of them are living in slums/squatter settlements. In the slums of Dhaka city, the average user to water-point ratio is 1,000:1 and only 20 percent people have some form of sanitary latrine (Ahmed, 2006). Lack of sanitation, long queuing times for water collection and unhygienic surroundings are the most important environmental concerns in the slums of Dhaka city. Other than these squatters, permanent residents of Dhaka city are also experiencing a year-round water scarcity more acutely in dry season. In response to water scarcity, many affluent residents and water-vendors have established illegal private deep tube wells and pump groundwater that contribute to the downward groundwater table. Another major concern of Dhaka water supply system is its quality. Even though DWASA claims of maintaining the quality, according to WHO requirements the consumers are doubtful regarding the quality and seldom drink untreated piped water. The city dwellers usually boil supplied water to kill dangerous bacteria to make it potable. For this purpose, they use gas and in some cases (slum and squatting households) wood or charcoal. The fuel they burn may cause severe indoor air pollution. Moreover, in the case of wood or charcoal usage, destruction of forests will take place that will be causing additional environmental problems including erosion and loss of top soil. This also has a severe negative impact on human health.

Over the years, surface water sources have been considered as unreliable for drinking water that requires more capital input to serve the population demand and hence emphasis is given to groundwater extraction. Through enormous authorized and unauthorized deep tube wells, the groundwater table is going below the extraction level. Moreover, recharge rate is decreasing and surface run-off is increasing which make the situation more vulnerable due to rapid urbanization.

4.1. Surface Water Resources of Bangladesh

Being the world's largest delta, Bangladesh is located within the flood plains of three great rivers: the Ganges, Brahmaputra and Meghna (GBM) and their tributaries. The combined discharge of these rivers is the highest in the world that they drain into the Bay of Bengal through Bangladesh as:

- The River Ganges flows (discharge rate 75000 m^3/s) east-southeast for 212 km from the Indian border to its confluence with the Brahmaputra, then as the River Padma for about a further 100 km to its confluence with the River Meghna at Chandpur;
- The River Brahmaputra enters into Bangladesh from the north and flows to south for 270 km to join the River Ganges at Aricha, about 70 km west of Dhaka in central Bangladesh and discharge at a rate of 100000 m^3/s;
- The River Meghna flows to the southwest draining eastern Bangladesh and the hills of Assam, Tripura, and Meghalay of India to join the River Padma at Chandpur. The Meghna then flows to the south for 160 km and discharges at the rate of 160000 m^3/s to the Bay of Bengal.

Total length of the river courses in Bangladesh is approximately 24000 km and the total catchment area of the GBM is about 1.75 million km^2, out of which only seven percent lies within Bangladesh. Among the large network of 230 rivers, there are 57 trans-boundary rivers, 54 of which are shared with India and the rest one with Myanmar. On an average 1106 km^3 of water crosses the borders of Bangladesh annually, of which 85 percent takes place between June and October. Around 54 percent (599 km^3) is contributed by the Brahmaputra, 31 percent (344 km^3) by the Ganges and nearly 15 percent (163 km^3) by the tributaries of the Meghna and other minor rivers. (Banglapedia, 2006).

Endowed with numerous rivers and sufficient rainfall, Bangladesh has an excess of surface water in the summer (July to October). However, dry winter months experience relative scarcity of water. Most of the surface water in Bangladesh which is contributed through inflowing trans-boundary rivers,where they provide 1,100 km^3 watercourse annually. The internal renewable water resources are about 105 km^3 per year. Moreover, Bangladesh receives sufficient amount of rainfall that contributes to enrich country's internal surface water reservoirs. Bangladesh's average annual precipitation rate is 2320 mm which varies from 1110 mm (north-west) to 5690 mm (north-east) (FAO, 2010).

About 10-15 percent of Dhaka city's land areas are comprised of surface water area including a number of rivers, canals, lakes (Islam *et. al.,* 2010). Major surface water bodies of Dhaka city are the Buriganga, Turag, Balu, Tongi *Khal*, Dhanmondi Lake, Ramna Lake, Gulshan Lake and Cresent Lake. There were more than 35 canals within Dhaka city area (Khan, 2001) even though most of them are now fully encroached or polluted to a level that cannot be used even for washing purposes.

4.2. Groundwater Resources of Bangladesh

Groundwater resources are determined by properties of groundwater storage reservoir and volume of annual recharge. Mainly rainfall, flooding and stream flow in rivers penetrate earth surface and recharge groundwater reservoirs. Although Bangladesh has been considered rich in groundwater resources, the total groundwater storage data is absent. National Water Plan Phase-II estimated average groundwater as 21 Km^3 in 1991 (FAO, 2010). However, with the increased trend of urbanization and irregular rainfall behavior, surface run-off has increased in recent times, which reduces groundwater recharge considerably.

Groundwater storage reservoirs are composed of three aquifers[1] in Bangladesh:

1. Upper aquifer or composite aquifer
2. Main aquifer (it is at depths six meters in north-west and to 83 m in the South) and
3. Deep aquifer

An upper clay and silt unit underlie the composite aquifer composed of very fine-to-fine sand. The main aquifer and the overlying composite aquifer are hydraulically interconnected. Clay layers of varied thickness distinguish the main aquifer from the deep aquifer. The thickness of this part ranges from a few meters in the northwest to as much as 60 m in the south of the country. Beneath the composite aquifer, medium and coarse-grained sandy sediments are found commonly. These sediments are form the main aquifer and occur up to depths of about 140 m below the ground surface. In Bangladesh, it occurs at depths ranging from less than 5m in the northwest to more than 75m in the south. The transmission property of the main aquifer is good to excellent over most of the country but it is deteriorating towards the south and the east. Underlying the main aquifer, there is a deeper water-bearing unit separated by one or more clay layers of varied thickness referred as the deep aquifer that has been exploited by tube wells in Dhaka and in the coastal areas where water table is descending due to over extraction or salinity contamination of upper or main aquifer. (Banglapedia, 2006)

[1] Geological formations containing useable groundwater resources

5. WATER PRODUCTION SYSTEM AND GROUNDWATER TABLE OF DHAKA CITY

5.1. Current Water Demand and Production

Water supply in Bangladesh relies mainly on groundwater. In rural areas, more than 97 percent of the population extracts groundwater to fulfill drinking water demands. Whereas, 87.72 percent of the Dhaka city's water supply is dependent on groundwater resources. Even though Dhaka city is surrounded by the four rivers namely Buriganga, Balu, Turag and Tongi *Khal* but only 12.28 percent of supplied water is obtained from these rivers. Dhaka city faces two major problems in supplying water to its residents: i) gradual decrease of raw water sources and ii) discharge of large quantities of polluted water (Serajuddin, 1993). Surface water sources from surrounding rivers and lakes have already exceeded the standard limits of many water quality parameters because of the discharge of huge amount of untreated and municipal waste materials. Treatment of this water has become so expensive that water supply agencies have to depend on groundwater aquifer for drinking water production (Biswas, *et. al*., 2010). Other than these four over-polluted rivers, the nearest water body is the river Padma and the Meghna that have acceptable water quality and ability to fulfill the demand. However, those rivers are located within a distance of 17 km and 50 km respectively from Dhaka.

Box-One: Basic Water Requirement

Water requirement (e.g. drinking, removing or diluting waste materials, producing manufactured goods, growing food, producing and using energy) varies with weather, lifestyle, culture, tradition, diet, technology, and wealth. The type of access to water is an important determinant in gross water use where use of water is the commutation of withdrawal (intake), recirculation, and reuse (Gleick and IWRA, 1996).

Minimum Drinking Water Requirement

The National Research Council of the National Academy of Sciences in the USA estimated the minimum human water requirements by correlating them with energy intake in food. They recommend a minimum water intake of between one and one-and-a-half milliliters of water per calorie of food (1-1.5 ml/kcal). With recommended daily diets ranging from 2000 to 3000 kcals, an adult person has to drink minimum 2 to 4.5 liters per day (National Research Council, 1989 cited *in* Gleick and IWRA, 1996).

Basic Requirements for Sanitation

There is a direct link between the provision of clean water, adequate sanitation services and improved health. Gleick and IWRA (1996) recommend a minimum of 20 liters per person per day for the maximum benefits of combining waste disposal and related hygiene, and to permit for cultural and societal preferences.

Basic Water Requirements for Bathing

In industrialized nations, water use for bathing ranges from 45 to 100 l/p/d with an average of 70 l/p/d, while in developing countries the requirement is ranging from 5 to 25 l/p/d with and without showering. A recommended basic level of water supply for bathing is 15 l/p/d.

Basic Requirement for Food Preparation

For food preparation, 10 to 50 liters per person per day water are used in developed countries with a mean of 30 l/p/d. On an average, 10 l/p/d will satisfy the basic needs of food preparation in most of the regions (Brooks and Perters *cited in* Gleick and IWRA, 1996).

Using a minimum level of 15 l/p/d for bathing and 10 l/p/d for cooking, the international organisations and water providers recommended adopting an overall Basic Water Requirement (BWR) of 50 liters per person per day for meeting domestic basic needs, irrespective of climate, technology, and culture (Gleick and IWRA, 1996).

DWASA projects total water demand considering per person per day water demand as 150 liter and accordingly supplies water to the city dwellers. Total water demand in Dhaka city varies from 2100 to 2300 MLD with seasonal variation. However, total production capacity of DWASA is 2247.47 Million Liter per Day (MLD) (both groundwater and surface water). Apparently, DWASA is able to fulfill current water demand through their capacity. However, DWASA has never reached its production target and actual production for groundwater and surface water is 1831.20 MLD and 256.30 MLD respectively (Table 1) with a demand-supply gap of 160 MLD. Moreover, if we account 31.68 percent Unaccounted for Water (UFW) or system loss between production and end-user level then real supply would be 1426.18 MLD. The statistics imply that almost half of the population in Dhaka city are deprived of getting DWASA projected standard water requirement (150 l/p/d). To supply water in Dhaka city, DWASA runs 560 deep tube wells (DTWs) and four surface water treatment plants (SWTPs). The total length of the water line across the Dhaka city is 2533.73 km (Table 2) including 286911 household connections and 1643 standpipes. Moreover, there are also 1330 and 1500 DTWs that are under operation by private agencies and other unrecognized sources respectively.

Table 1: Water production scenario of DWASA

Source	**Production Capacity**	**Actual Production**		**Source wise % of production**	**No. of DTWs and SWTP in operation**
		MLD	% of capacity		
Groundwater	1948.30	1831.20	93.99	87.72	560
Surface water	299.17	256.30	85.67	12.28	4
Total	**2247.47**	**2087.50**	**92.88**	**100.00**	

Source: DWASA, 2010

Table 2: Water Production System of DWASA

Water Line	2533.73 Km
Water connection	286911 no.
Daily water production	2087.50 MLD
DTW in operation	560 no.
DTW of other agencies	1330 no.
Overhead tank in operation	38 no.
Water treatment plant	4 no.
Public stand pipe	1643 no.
Strom water drainage	185 Km
Strom water pumping station	3 no.
Religious institutions	1898 no.

Source: MIS Report, DWASA, 2011

5.2. Groundwater Table of Dhaka City

In Bangladesh, the depth of water tables varies from less than a meter to more than 30m. The shallowest water table occurs in the coastal region whereas the deepest water table occurs in the Barind Tract and Dhaka City (more than 30m from the ground surface) (Banglapedia, 2006). The depth to the water table moves seasonally with annual recharge and discharge conditions. The amount of seasonal fluctuation varies from less than a meter to more than 10m depending on the local hydrogeological conditions, amount of groundwater abstraction and natural discharge of groundwater. In recent years, there is a declining trend in the water table due to larger amount of groundwater withdrawal.

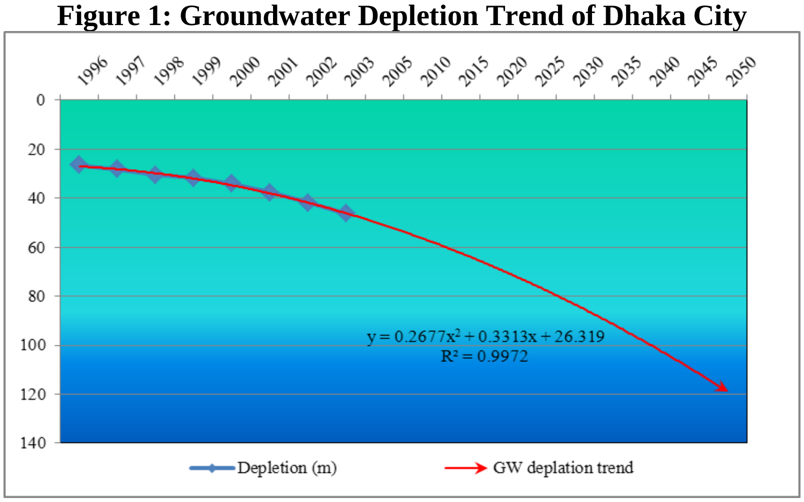
Geologically, Dhaka city is under the category of the Pleistocene terraces mostly composed of the Madhupur clay deposits. There is little variation in the surface elevation of the city. The thickness of the Madhupur clay ranges from eight m to about 45 m with an average thickness of 10 m in this city. The underlying layer is known as 'Dupi Tila' composed of sand particles that are considered as the main aquifer of Dhaka city. The impermeable clay layer of variable thickness overlies the sandy layer that makes the groundwater aquifer mostly confined in nature. The total thickness of the Dupi Tila aquifer varies from 100 m to about 200 m with an average thickness of 140 m. Some scientific studies on the groundwater of the city revealed that the aquifer piezometric level which is the natural water level of a confined aquifer of the city main aquifer, has gone down significantly in last few years due to over-withdrawal of groundwater (Akther, Ahmed and Rasheed, 2009).

5.3. Groundwater Depletion of Dhaka City

In Dhaka city, groundwater extraction started from a depth of 100 meters and in some extreme condition the well goes up to 300 meters to reach the main aquifer. The depletion rate varies from area to area as in Mirpur the groundwater level dropped 53.75 meters between 1991 and 2008 at a rate of 3.2 meter per year. While the decline was 1.1 m/y in Mohammadpur, 2.2 m/y in Sabujbagh, 0.5 m/y in Sutrapur, and 0.8 m/y in Dhaka Cantonment during the same period (The Daily Star, 2010). The city's groundwater level has dropped about 20 meters over the last seven years at a rate of 2.81 meter per year, and from the year 2000, the rate is increasingly high.

Taking into account the current groundwater depletion trend at 2.81 m/y, a projection has been made for 2050 and it predicts that the groundwater table will be lowering down to 120 meters by 2050 from the existing water table (Figure 1). This depletion will hamper the constant water supply as many of the operating deep wells may shut down due to water unavailability. The production cost may rise at the highest peak.

Figure 1: Groundwater Depletion Trend of Dhaka City



Source: Authors' calculation based on Dhaka City State of Environment 2005, 2011

Box-Two: Causes and Consequences of Groundwater Depletion

Causes of Groundwater Depletion

There are various reasons that are responsible for gradual declination of groundwater level in Dhaka city of which high groundwater withdrawal from the aquifer is the most crucial. In addition, rapid urbanization including construction of roads, buildings, other engineering structures, flood protection dams, and embankments are continuously hindering the natural groundwater recharges from rainfall and perennial water sources existing in and around the city (Rahman and Alam, 2005). A network of 22 lakes, canals, and small rivers facilitate the natural drainage for the floodwaters and groundwater recharge in this city. Illegal encroachment and disappearances of them also depreciated groundwater recharge over the last four decades.

Consequences of Groundwater Depletion

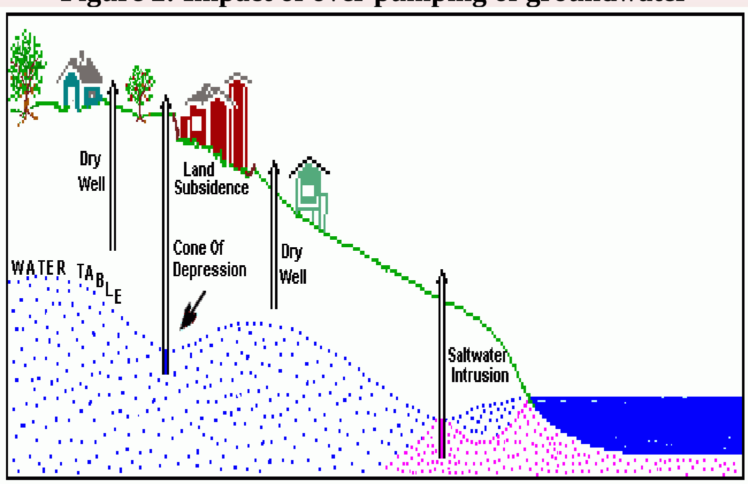
a) Lowering of the Water Table

The most severe consequence of excessive groundwater pumping is lowering down the groundwater table. If groundwater levels decline too far, then the well owner might have to deepen the well, drill a new well, or at least attempt to lower the pump. In addition, as water levels decline, the rate of water yield may decline.

b) Increased Costs

Water production cost increases with decreasing groundwater level. Water must be lifted higher to reach the land surface than before if the water level go down. If pumps are used to lift the water, more energy will be required to drive the pump that would eventually increase the expense of the users.

Figure 2: Impact of over pumping of groundwater



Source: USGS, 2003

c) Reduction of Water Flow in Streams and Lakes

A great deal of the water flowing in rivers comes from seepage of groundwater into the streambed. However, groundwater pumping can alter water circulation between an aquifer and a stream, lake, or wetland by either intercepting groundwater flow that is discharged into the surface-water body under natural conditions or by increasing the rate of water movement from the surface-water body into an aquifer. A related effect of groundwater pumping is the lowering of groundwater levels below the depth which is required by the streamside or wetland vegetation to survive. The overall effect is a loss of riparian vegetation and wildlife habitat.

d) Land subsidence

The basic cause of land subsidence is the loss of support below ground. Indiscriminate groundwater extraction from main aquifer may contribute to land subsidence.

e) Deterioration of water quality

Under natural conditions, the boundary between the freshwater and saltwater tends to be relatively stable. Over pumping can cause saltwater to migrate inland and upward, resulting in saltwater contamination of the water supply.

5.4. Potential Groundwater Recharge in Dhaka City

Assessment of future groundwater development potential is a prerequisite for the proper and sustainable use of the resource. Terribly polluted surface water resources and increased urbanization exacerbate the depletion rate of groundwater in Dhaka city. Initiatives have already been taken by DWASA to recharge groundwater artificially as a pilot basis (DWASA, 2009). However, it is important to know the natural recharge rate to prepare a sustainable development plan in this regard.

Groundwater availability for pumping in terms of potential recharge estimated by simple hydrological balance as follows:

$$\mathbf{R_e = P - P_e - U} \quad \text{……………………………………} \quad \mathbf{(i)}$$

Where,
R_e= Potential Recharge
P= Rainfall
P_e= Potential Evapotranspiration
U= Surface Run-off

Potential recharge is the excess of rainfall over run-off and potential evapotranspiration. To make the estimation more comprehensive, monthly basis is preferred over seasonal basis. Surface run-off estimated as a percentage of rainfall (20-50 percent) depending on the amount and intensity of rainfall, topography or land use pattern, and geo-hydrological condition. As an urbanized area with much paved structures, the surface run-off for Dhaka city has been estimated as 50 percent.

Evaporation is the primary process of water transfer in the hydrological cycle. The evaporation including transpiration form vegetated surface is known as potential evapotranspiration. To calculate the potential recharge rate, potential evapotranspiration (P_e) should be taken into consideration. To calculate $P_{e,}$ the 'Blaney-Criddle' formula has been used in the current study:

$$\mathbf{P_e = p\,(0.46T+8)} \text{……………………………………………} \mathbf{(ii)}$$

Where,
P_e= Potential evapotranspiration
p= Mean daily percentage of annual daytime hours
T= Mean daily temperature

The mean temperature for Dhaka city has been estimated through averaging monthly maximum and minimum temperature and the mean temperature was 26.06˚C. To determine the value of p (Mean daily percentage of daytime), the value of latitude is necessary. Considering Dhaka city's latitude 23^0 N, p has been estimated as 0.27.

Now, from equation (ii),

P_e= p(0.46T+8)
= 0.27(0.46×26.06+8)
= 5.40
≈ 5.40 mm/day

Where, p= 0.27%
T= 26.06˚C

Putting the value of P_e into the equation (i),

R_e= P-P_e-U
= 2666-5.40-1333
= 1327.6 mm
= 1.327 m/year
≈ 1.33 m/year

Where, P= 2666 mm/year
Pe= 5.40 mm/day
U= 1333 mm/year

The finding shows that potential groundwater recharge for Dhaka city is 1.33 m/y while the groundwater depletion rate is 2.81 meter per year. Therefore, despite sufficient amount of rainfall Dhaka city experiences 1.48 m/y groundwater recharge deficit every year. Increasing rate of urbanization and decreasing surface water bodies will worsen the situation.

6. FUTURE WATER DEMAND AND SUPPLY OF DHAKA CITY

Social well-being, economic development and environmental quality are dependent on water resources and a meager change can largely affect the development process. Besides management efficiencies, water supply in developing countries is also suffering from climate change through disrupting hydrological cycle in the form of increased flood in wet season and drought in dry season. Climate change has two-fold impacts: supply-side and demand-side pressure. The supply-side pressures include reducing or increasing the amount of water associated with environmental degradation. On the other hand, demand-side pressures include urbanization leading to increased water demand for domestic, industrial, agricultural (irrigation), and environmental demands (Arnell, 1999).

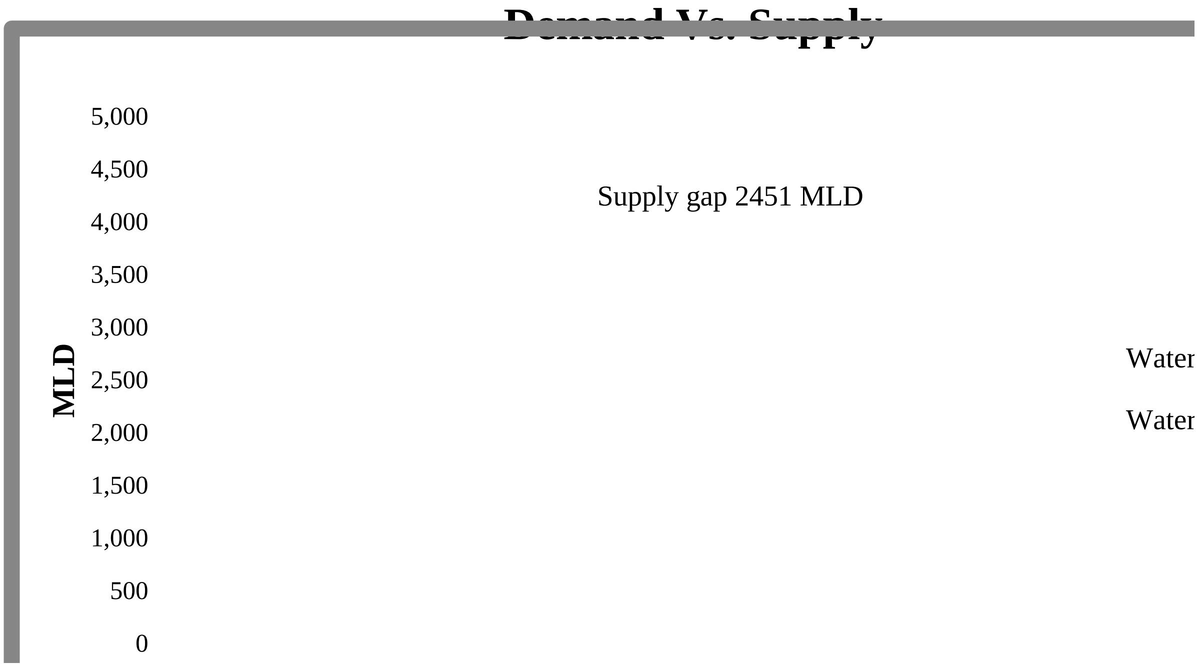
With rapid urbanization, the paved area of Dhaka city is increasing without following any regulated and structured trend, affecting the percolation of run-off into the subsurface water. In addition, paved area increases the total run-off, which also affects the drainage system. In many parts of the city, the condition of the main aquifer has changed from confined to an unconfined condition. Such change in the hydrodynamic condition can make the aquifer vulnerable to possible groundwater contamination. Moreover, groundwater reserve will decrease that results into production loss and contribute to the increasing gap between demand and supply.

To understand future water demand and supply status in Dhaka city, the study has attempted to draw three scenarios based on existing situation and future roadmap. The second and third scenario also considered Unaccounted for Water (UFW) and Downtime Loss or Machine Loss (Cs).

6.1. Scenario 1 *(Obscure)*

Based on empirical data on demand and supply, considering 2010 as status quo in water production, a projection (Figure 2) has been made which illustrates that by the year 2050 the supply gap would be 2451 MLD if current supply does not increase. The supply gap implies that 16 million people of Dhaka city will suffer from acute water crisis in 2050 unless the production increases comprehensively.

Figure 2: Demand and Supply Scenario Up To 2050 Considering Supply of 2010 as Maximum



Source: Authors' Calculation Based on DWASA, 2011

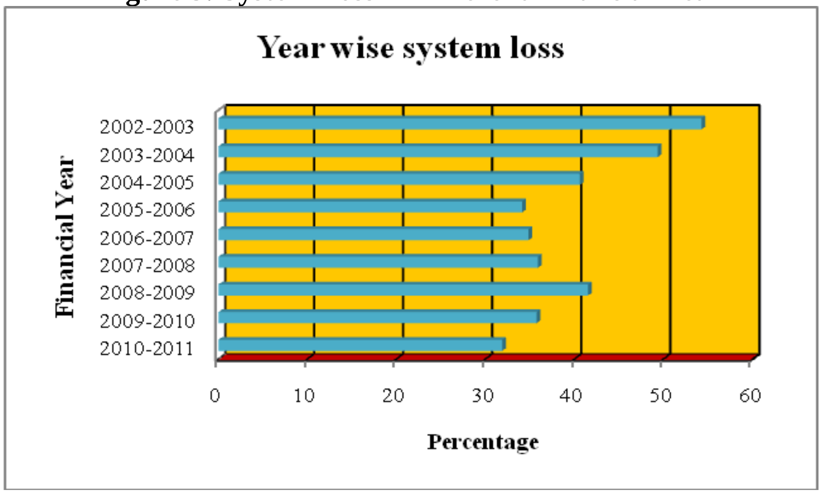
6.2. Scenario 2 *(Enigma)*

To address the increasing pace of present and future demand, DWASA has taken a number of initiatives. Even though many of those initiatives are still at the planning stage, the second phase of Saidabad Surface Water Treatment Plant will be completed by 2012 with supplying capacity of additional 225 MLD. Moreover, several other projects are under consideration to lessen the dependency on groundwater and enhance the surface water extraction. The current study has made another projection for 2050 based on DWASA future roadmap. Taking into account the Unaccounted for Water (UFW) or system loss as 30 percent from production to end-user level, the projection shows that in spite of huge investment plan in water production, DWASA will not be able to meet future demands without reducing UFW to 15 percent or less from the current percentage of 31.68.

Box- Three: System Loss or Unaccounted For Water (UFW)

System loss comprises of wastage and illegal connection for which the supply cannot attain the 100 percent. During field survey, it was observed that some landowners maintain duel connection illegally and sell water to the poorest people at a high rate. They collect water from the mainline without permission or in contract with the corrupted person of the supply authority. During the financial year 2002-2003, almost 52 percent system loss was accounted that indicates very poor management scenario. The situation has been fluctuating but never come to an admissible limit. Present Government has taken a few initiatives to lessen system loss in water supply. With this and by the increasing effort of the DWASA officials, the system loss is gradually decreasing.

Figure 3: System Loss in Different Financial Year



Source: MIS Finance Report, DWASA, 2011

During the FY 2009-2010, the system loss was accounted for 35.74 percent while in FY 2010-2011 the UFW goes down to 31.68 percent (Figure 3). It is an indication that if Government and authority show their willingness to improve management, the situation becomes well off. In addition, awareness campaign regarding misuse of water also contributes to the lowering down of the system loss.

Table 3: Water Production Road Map to Meet Future Demand

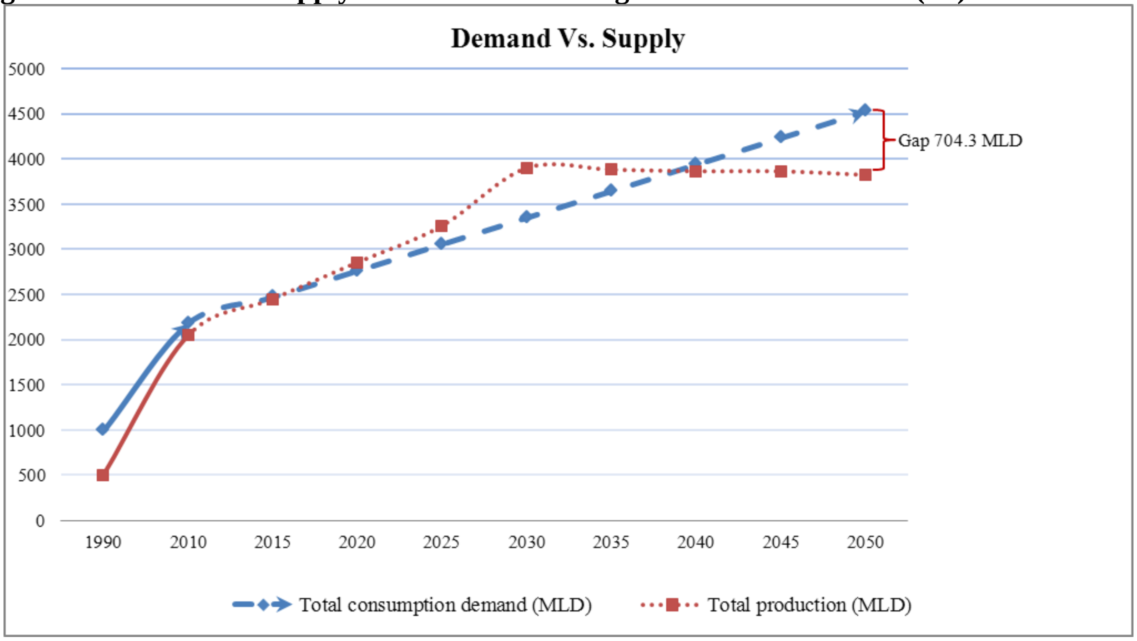
	Year								
Total water requirement	**2012**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Total user-end demand (MLD)	**2179**	**2474**	**2769**	**3064**	**3359**	**3654**	**3949**	**4244**	**4539**
UFW (%)	30%	30%	30%	30%	30%	30%	30%	30%	30%
GW (MLD)	2088	2088	2088	2088	2088	2088	2088	2088	2088
Sayedabad SWTP I (MLD)	225	225	225	225	225	225	225	225	225
Sayedabad SWTP II (MLD)	225	225	225	225	225	225	225	225	225
SWTP III (Khilkhet) (MLD)		500	500	500	500	500	500	500	500
SWTP IV (Padma) (MLD)			500	500	500	500	500	500	500
SWTP V (Sayedabad) (MLD)				500	500	500	500	500	500
SWTP VI (MLD)					500	500	500	500	500
SWTP VII (MLD)					500	500	500	500	500
Total production capacity (MLD)	**2538**	**3038**	**3538**	**4038**	**5038**	**5038**	**5038**	**5038**	**5038**
Total user-end gap (30% UFW) (Total production-30% UFW-Total user -end demand)	**-402.4**	**-347.4**	**-292.4**	**-237.4**	**+167.60**	**-127.4**	**-422.4**	**-717.4**	**-1012.4**

Source: Authors' calculation based on DWASA, 2011

6.3. Scenario 3 *(Utopia)*

The third scenario is a mixture of ambition and reality. This scenario is based upon DWASA's future production roadmap and perceives that DWASA has improved their management system so that they have been able to reduce UFW or system loss up to 10 percent from current 31.68 percent. However, due to power shortage, downing water table, pump-overhauling time, the pump cannot operate to its full capacity. The scenario, therefore, is considered 10 percent downtime or loss of production (Cs). The groundwater table is declining at a rate of 2.81 m /y, the upper Dupi Tila aquifer has reached its limit, and it is likely that 223 numbers of DTW will need to replace as the existing ones will go out of service by the year 2013 because of the falling of groundwater table. Under the scenario, it is assumed that DWASA will be able to fulfill Dhaka city's water demand by 2015 and by maintaining increased trend of production status and management system, DWASA supply will supersede the demand in 2022. However, unless new treatment plants are erected or come into operation in response to increased demand starting at 2040, DWASA will experience 704.3 MLD (Figure 4) supply deficit by 2050 even in this highly ambitious scenario.

Figure 4: Demand and Supply Scenario Considering 10% Production Loss (Cs) and 10% UFW



Source: Authors' calculation, 2011

7. CHALLENGES REGARDING ACCESS TO WATER

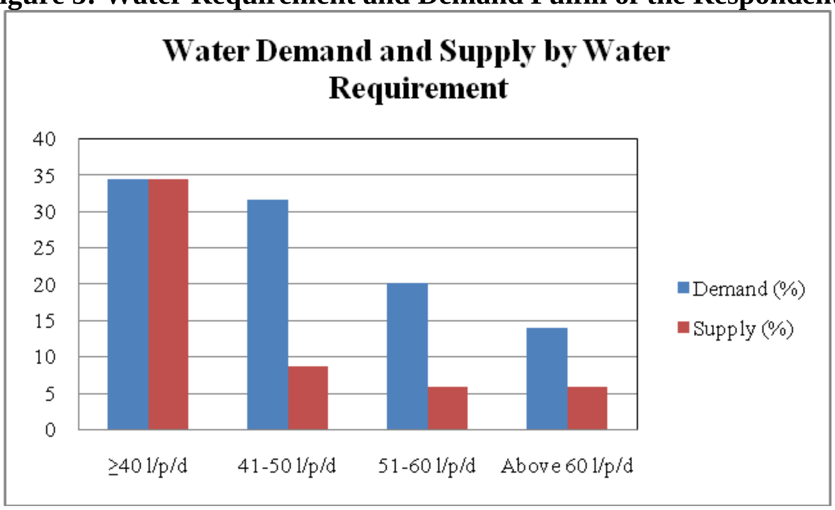
Challenges regarding water vary from area to area and with the changing socio-economic status. There is variation of water consumption rate in different regions. The DWASA demands projection taking into account the water consumption at a rate of 150 l/p/d whereas the internationally accpected standard is 110 l/p/d. DWASA produced few scenarios to fulfill future demands considering water demand as 140 l/p/d for residential consuemrs in 2010 with provision of reducing water demand to 110 l/p/d by 2025 through incresaing water use efficiency. On the other hand, for slum dwellers, current water demand has been protected as 35 l/p/d with the aim of increasing the amount to 50 l/p/d by 2050. Poor people, mostly living in slum areas, are neglected both at demand and supply side as well as more deprived of having access to potable water. In addition to existing inequality, unplanned rapid urbanization, climate change, and over extraction of groundwater make the inhabitants more vulnerable to access safe water.

To maintain daily life, a substantial amount of water is required. At least 50 l/p/d of water is considered as basic water requirement as suggested by Gleick and IWRA (1996). During field survey, questions were asked to the city dwellers regarding water availability based on basic water requirement. The study finds out that one third of the respondents receive less than 40 l/p/d and somehow they manage their daily activities with this minimum amount of water. On the other hand, 31.5 percent respondents adjusted their daily activities with minimum 40-50 l/p/d, but among them,only 8.6 percent receives the required amount. Those who desired to get water supply of more than 60 l/p/d, can get access to such amount by only 5.1 percent. On an average, 42.8 percent of the respondents can receive basic requirement of 50 l/p/d and the rest 57.2 percent respondents are suffering from water scarcity despite having piped connection.

Case-One

Halima Khatun, age 38, a middle-income homemaker lives as a tenant in Mirpur sector-6. She has been living in this area for the last 8 years with her husband and two sons. She explained her misery regarding water despite having access to the piped water connection. She faced no such problems even five years ago until last summer. Landowner controls water supply to accommodate the increasing demand with limited water and supplies water to the tenants two times in a day for an hour every time. This is terrible for her to manage the household works with limited water in a specific time binding. She receives water at a rate of 45 l/p/d while she needs at least 60 l/p/d to fulfill the daily requirement. She has to buy a two-liter water bottle daily to maintain her family's drinking water demand at a cost of 25 BDT (Bangladeshi Taka). She pays 400 BDT per month to the landowner for supplied water. Including bottled drinking water, her water costs nearly 1200 BDT, which is six percent of her total family income. Despite huge water-related cost, the quality has been far from satisfactory. Sometimes she is supplied with water of obnoxious quality. Mrs. Khatun argued that illegal connection, poor management and less production compared to demand are responsible for water crisis.

Figure 5: Water Requirement and Demand Fulfill of the Respondents



Source: Field Survey, 2011

Most of the poor people do not have direct piped connection since they are living in slums. Households with no water connection have to spend more time and money to collect water.

Table 4: Water Connection and Distance from House

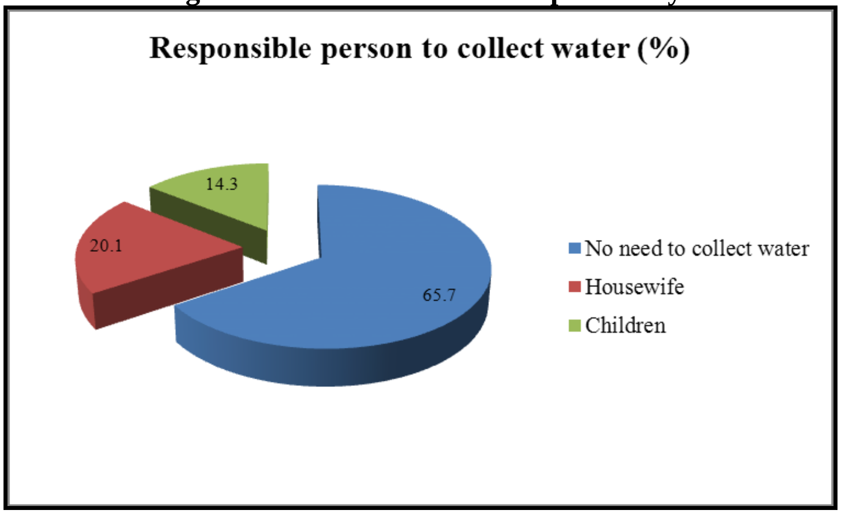
Connection type	% of connection	Distance from house		
		<20m	20-40m	>40m
Piped	68.57	0	0	0
Standpipe	31.43	14.3	8.6	11.5

Source: Field Survey, 2011

The study reveals that 31.43 percent households in Dhaka city do not have access to the piped connection and they have to rely on standpipe connection or other sources to fulfill their minimum water demand. People who collect water from standpipe, have to wait in long queue but most of the times they fail to collect the required amount of water. In case of water collection distance, 11.5 percent people were identified who have to travel 40 meters or more to collect drinking water (Table

4). Such water collection consumes one to three hours of a day that lessens the duration of other income generating activities. Moreover, inadequate amount of water does not allow them to accomplish household activities in a hygienic manner.

Figure 6: Water Collection Responsibility



Source: Field Survey, 2011

Nevertheless, homemakers (20.1 percent) and children (14.3 percent) those who do not have access to the piped water, are primarily responsible for collecting water for drinking and household purposes (Figure 6). During field survey, women and children were asked about their experience regarding water-collection time and they burst into anger while replying and said that this is an extra burden for them to collect water besides managing the family or school or play. They further added that waiting in a long queue under the hot weather condition is hazardous for them. Howard and Bartram (2003) found a strong correlation between health risk and water consumption pattern. They showed that very poor or no access to water possesses very high level of health risk both from collection and consumption point of view (Table 5).

Table 5: Correlation between Water Access and Health

Service level	**Access measure**	***Needs met***	**Level of health concern**
No access (quantity collected often below 5 l/c/d)	More than 1000m or 30 minutes total collection time	Consumption – cannot be assured Hygiene – not possible (unless practiced at source)	Very high
Basic access (average quantity unlikely to exceed 20 l/c/d)	Between 100 and 1000m or 5 to 30 minutes total collection time	Consumption – should be assured Hygiene – hand washing and basic food hygiene possible; laundry/ bathing difficult to assure unless carried out at source	High
Intermediate access (average quantity about 50 l/c/d)	Water delivered through one tap on plot (or within 100m or 5 minutes total collection time	Consumption – assured Hygiene – all basic personal and food hygiene assured; laundry and bathing should also be assured	Low
Optimal access (average quantity 100 l/c/d and above)	Water supplied through multiple taps continuously	Consumption – all needs met Hygiene – all needs should be met	Very low

Source: Howard and Bartram, 2003

7.1. Inequality in Access to Water

More than 35 percent of the population of Dhaka city lives in slum areas who are deprived of adequate water supply. Moreover, poor people have to pay more than that of middle-income or high-income group people in order to get access to potable water. The study finds out that a poor household (whose total household income is less than 10000 BDT) has to spend 500 BDT monthly for 30 l/p/d whereas a middle-income or high-income group family (whose total household income is more than 10000 BDT) has to pay 400 BDT/month for water supply of 45-50 l/p/d or more. This inequality in both expense and access to water, puts an extra pressure on the poor to impede spending money for children's education, to get access to health care facilities, to make household assets and to improve their socio-economic status as a whole.

Case-Two

Abdul Zobbar, age of 45, a daily laborer lives in slum in Bashabo. He has to go for work early in the morning and comes late at night. By the whole day's hard work, he is able to earn 4500 taka per month out of which he has to spend 1200 taka for house rent. He has two sons and three daughters. Two sons are engaged in income generating activities while one of his daughters, 13 years of age, is engaged as house cleaner. She wakes up before sunrise to collect water by waiting in a long queue for at least one and half an hour. She collects two jars (10 liter each at a rate of five taka) of water that she uses as drinking water. For bathing and washing, they used to go to the nearby highly polluted surface water bodies (pond) of industrial waste materials. Most often, Mr. Zobbar's younger daughter suffers from water borne diseases like diarrhoea and scabies. However, he had to rely on traditional healer (*Kobiraj*) due to his inability to bear the regular medical expenses. Mr. Zobbar blames his economic condition for such sufferings and regrets for a piped water connection.

7.2. Quality of Supplied Water by DWASA

Contamination of drinking water with human faecal organisms is a common phenomenon throughout the South Asia. Dumping of industrial and household waste materials to open sources is aggravating the situation. Moreover, microbiological contamination is deteriorating the surface water quality that eventually reduces the cognitive development of children, lessens educational achievement, declination in economic growth and increases the childhood deaths. In addition, contamination of groundwater through the exposure of high level of arsenic reduces child survival and cognitive impairment, increases cardiovascular diseases and cancer. Therefore, quality of supplied water is a matter of great concern.

DWASA relies on both ground and surface water for maintaining water supply in Dhaka city. Groundwater quality is generally examined during the installation of a new pump and on a monthly basis. Sometimes, however, emergency tests may be carried out in case of consumer's objection. DWASA claims that supplied groundwater is pure and does not contain heavy metal but due to illegal connection leakage, contamination cannot be cast out of probability. Moreover, the water quality may be deteriorated for storing water for a long time and from unclean overhead tanks.

Table 6: Quality of Water Served by DWASA

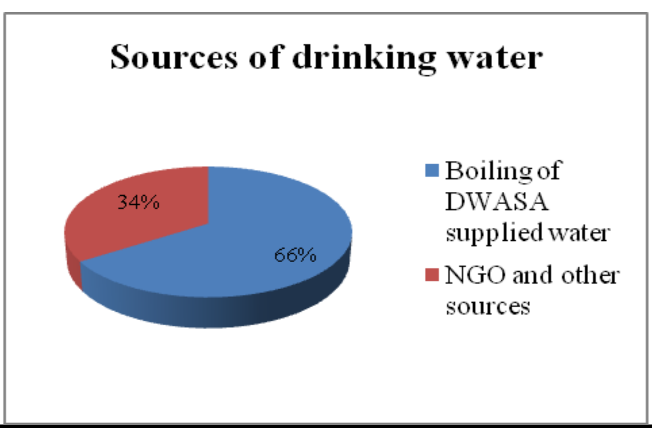
Parameters	Standard quality prescribed by WHO	Deep Tube Well	Water Reservoir at consumer level
Color (Pt./Co. Unit)	15	4	20
Turbidity (N.T.U)	5-10	1.17	8.28
p^H	6.5-8.5	6.7	7.06
TDS (mg/L)	1000	117	231
Conductivity (µS/cm)	-----------	233	461
Ammonia-N (mg/L)	0.5-1.5	0.001	7.615

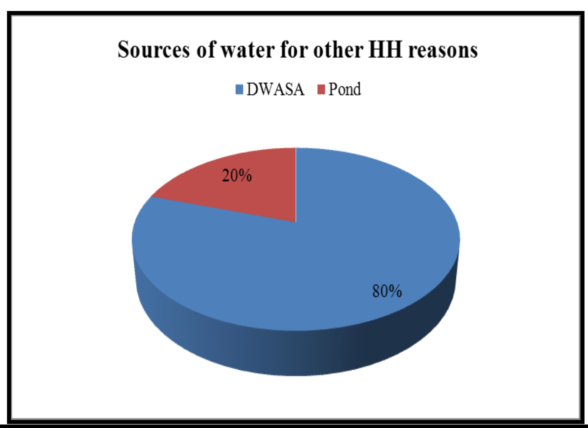
Source: Microbiology and Chemical Department of DWASA, 2011

Apparently, different parameters of DWASA supplied groundwater are under permissible limit. However, water quality in reservoir has been deteriorated due to irregular clearance or intrusion of waste in the pipelines (Table 6). On the other hand, four SWTPs are in operation to purify the river water in Dhaka city. Nevertheless, the rivers surrounding the city, are so polluted that three times chlorination and excess use of Aluminum Sulphet (Al_2SO_4) cannot purify them properly. Consumers alleged that the supply water smells bad due to excessive chlorination and presence of Ammonia. Even though presence of heavy metal in DWASA supplied water is still under admissible limit, the National Drinking Water Quality Survey 2009 showed that about 40 percent drinking water contains more than one milligram of iron per liter and 35 percent contain 0.4 milligrams manganese per liter which may affect both the human taste and health (BBS, MICS and UNICEF, 2011).

Despite dominance of uncontaminated groundwater in DWASA water supply system, the user-end water quality exceeds WHO drinking water admissible limit due to poor maintenance. The current study finds that 22.86 percent city dwellers could not use the DWASA supply for drinking due to bad smell and rely on dubious quality bottled or jar water. About two-thirds (66 percent) of the respondents rely on supplied water from DWASA (Figure 7). To remove micro-becteria and bad-smell they have to boil the water at least for half an hour. Among them, at least 50 percent use water filter as well to ensure maximum safety. Those who rely on NGOs or other sources (34 percent) for drinking water are mainly residents of slum and squatting households. They never boil or filter their drinking water. To have the minimum access to drinking water, they have to maintain a long queue for minimum an hour to maximum three hours.

Figure 7: Sources of Drinking Water and Other Household Reasons in Dhaka City





Source: Field Survey 2011

In the case of water for other household purposes, the scenario is almost identical. Four-fifths (80 percent) of the respondents directly rely on DWASA supply water system for other household activities. Rest of the respondents (20 percent) who have no such supply opportuntity, manintain their household activities by exploiting pond water or any other open water bodies as such even though those water bodies are not safeguarding their health condition properly (Figure 7).

7.3. Water Related Diseases

There are several transmission routes to spread out water related diseases. Firstly, **water-born** route where water brings the pathogens to become infected (e.g. diarrhoeas, dysenteries). Secondly, **water-washed** route spreads diseases because of the failure of carrying the pathogens away like skin diseases. Thirdly, **water-based** transmission where pathogens spend part of their life cycle in aquatic animals and finally, **water-related insect vectors** where diseases spread by insects that breed in or bite near water like mosquito (Kjellén and McGranahan, 1997). In Dhaka city, poor people are compelled to drink untreated supplied water. Consequently, they face immense health burden with the highest percentage of water borne diseases like vomiting and diarrhoea (30 percent), skin diseases (24.3 percent), weakness (24.3 percent) and Hepatitis B (21.4 percent). Middle or higher income group families seek medical facilities from private practitioners (65.7 percent) while poor people are used to go to the traditional healers (20 percent) due to insufficient money allocation and low literacy which make them more vulnerable to health hazards (Field Survey, 2011).

7.4. Public Pipe to Private Jar: The Growing Water Business

One of the most important and controversial trends in the global water arena is the accelerating transfer of the production, distribution and management of water services from public entities into private hands (Morison and Gleick, 2004). In many countries, private companies are inspired to take over the supply chain management of public water supply through policy provision. In addition, due to unreliable water supply and poor management by public entities, this trend is increasing at an alarming rate. Bangladesh draft water act 2010 encourages private sector to invest and control water resources through buying concession from government without confirming state's obligation to ensure equitable access to water. Interestingly, international development agencies also put emphasis on privatization or sometimes force government to privatize water sector by addressing government's inefficient management in water supply.

To fulfill the daily water requirement from reliable source, dependency on private sector is increasing day by day. Most of the people in Dhaka city buy filtered or bottled water though they are not well aware of the quality of this water. There is a common perception of city dweller regarding DWASA supplied water that it is full of micro-bacterial organisms and contaminated with different chemical and biological contaminant. Even though almost 87 percent of the supplied water of DWASA is retrieved from groundwater that is safe from microorganisms and heavy metal contamination, it is likely that the supplied water might be contaminated due to the leakage in pipelines and reservoirs. In reality, poor management, irregular monitoring, and inadequate supply make people rely on privately owned water supply. In addition to bottled and filtered water business, there is another business of water filtering. The study finds that a retailer sells on an average 20 water filter per day of worth 60000 to 70000 BDT.

During household survey, it was found that almost one-third (33 percent) of the respondents filter their boiled water for maximum safety. Moreover, electronic and print media show a tendency of highlighting the use of such filter and bottled water to lessen health risk. There are 40 authorized including many unauthorized water vendors who are supplying jar water to the city dwellers. It is highly unlikely to find any hotel, restaurant, café and office which uses DWASA water for drinking rather than depending on such private water vendors. To catch benefit stream of growing water business, DWASA also started marketing bottled water (Shanty) for consumers, even though they failed to ensure supplying quality water to its consumer. In such a condition, a question arises in the minds of people that if they can ensure the purification and safety of bottled water why can not they do it for the supplied water? The answers from respondents reflect the reality of privatization. Most of the cases, vendors who supply 'jar' water to tea stall or café never control the quality of supplied water. They filled up the 'jar' with WASA supply water and sell at BDT 100 for 60 liters.

7.5. Role of Donors

Many projects and initiatives have been taken so far to improve the living conditions of Dhaka city dwellers where water quality and access remain as critical issues. Deficiencies in water supply and sanitation services have resulted in higher costs for businesses, slower urban economic growth, and create social unrest. Being a least developed country, Bangladesh faces immense problems in implementing development plans and thus the major investments for different sectors are donor supported, where Dhaka water supply and sanitation is one of the major donor driven sectors.

Most of the donor financed projects are targeted towards improving supply system and management of DWASA for better service delivery through Technical Assistance (TA), Grants and Loans. Both bilateral and multilateral donors are involved in water sector development. The Danish International Development Assistance (Danida) and the Swedish International Development Agency (Sida) are considering the funding to increase the intake and doubling the capacity of the existing surface water treatment plant (SWTP) at Saidabad and minimizing system loss. The World Bank has initiated to assist DWASA in (i) wastewater management, (ii) storm water drainage, (iii) water supply and sanitation services to low-income communities, (iv) social and environmental safeguards and (v) DWASA performance improvement plan. Moreover, World Bank has been maintaining a close coordination with Asian Development Bank (ADB) to provide water supply and sanitation services to low-income group communities and to improve the performance of DWASA. The ADB mostly provides technical assistances for long-term solutions to augment water supplies through preparing a master plan to provide 24/7 supply to all zones of Dhaka, and to enhance public-private partnerships to ensure the sustainability of the planned interventions. In addition, the organization provided TA (2005) to the People's Republic of Bangladesh for preparing the Dhaka Water Supply Project that aimed to (i) the master planning of Dhaka water supply including the feasibility of new water sources; (ii) advance action on detailed designs for tube well rehabilitation and distribution improvement; and (iii) the institutional development of DWASA. Furthermore, ADB is providing loans and grants over the year to make the water supply scenario more accessible. The Department for International Development (DFID) has shown their interest to work with DWASA for slum improvements or institutional development. The Government of Japan is actively supporting Chittagong WASA and has expressed its willingness to assist DWASA, which depends on the water authority's satisfactory capacity building.

Besides bilateral institutional donors, some Non Governmental Organizations (NGOs) are also involved in water sector; however, their intervention mostly concentrated on supply end, particularly focusing poor people's accessibility to water. Water Aid, an international NGO, has established some water point in slum areas of Dhaka with their partner organization Dustha Shastha Kendra (DSK) to provide potable water for the slum dwellers.

However, institutional donors like World Bank and ADB's support in the water sector is highly criticized for their conditionality on privatization. In solution to current water crisis, they are continuously creating pressure on government to privatize the service sector that will significantly limit the potential technological choices and the room for user charges. Moreover, the tariff will go high which may create another artificial water stress condition for the poor.

Box-Four: Deadweight Loss

In economics, a deadweight loss (also known as excess burden or allocative inefficiency) is a loss of economic efficiency that can occur when equilibrium for a good or service is not 'Pareto Optimal'. In other words, either people who would have more marginal benefit than marginal cost are not buying the product or people who have more marginal cost than marginal benefit are buying the product. Deadweight loss can be beneficial when there is a negative externality where it can be considered a deadweight gain as it would help those who were being hurt by the negative externality.

To estimate the deadweight loss, there should have two different markets i.e., a perfect competitive and a monopoly market. DWASA does not act for maintaining the principle monopolistic market rather their fundamental assertion is to maximize social welfare. On the other hand, private vendors supply only drinking water at a high price. Providing the total water facilities to the city dwellers may not be possible for a private farm as the diseconomies of scale in the production process might accelerate the Average Total Cost (ATC) from state-owned industry like WASA. For that reason, to estimate the deadweight loss, this study has drawn two examples. The first example considered the supply deficit by DWASA and the second one considered an average 2.15 percent of total supply as drinking water. In addition, to make supplied WASA water potable, fuel cost and fixed costs also considered.

Table 7: Deadweight Loss in Drinking Water Supply

<table>
<tr><td colspan="2">Scenario-One:
Total supply deficit by DWASA is 212 MLD. Let us assume that this amount of water provided by private sector. In this circumstances, total revenue:</td></tr>
<tr><td>WASA</td><td>Private Sector</td></tr>
<tr><td>Price for 1000 liter= 23.565 BDT
So, price for 212 MLD= 4.9957 million BDT
≈5 million BDT</td><td>In case of Jar water:
Price for 20 liter= 60 BDT
Price or 212 M D= 636 million BDT</td></tr>
<tr><td colspan="2">If DWASA would be able to minimize the supply deficit, the city dwellers' water related cost would increase only 5 million BDT per day, but now they have to spend 636 million BDT each day to fulfill their water demand other than DWASA supply.</td></tr>
<tr><td colspan="2">Scenario-Two:
In Dhaka city, considering an average consumption pattern of 3 l/p/d for drinking purpose, water demand for this category requires 2.15 percent of supplied water i.e., 44.892 or 45 MLD. It is hardly possible to find a person in Dhaka city who drinks supplied water directly without boiling it and in most cases they use bottled or jar water collected from private water vendors at high price.</td></tr>
<tr><td>WASA</td><td>Private Sector</td></tr>
<tr><td>Price for 45 MLD considering fuel and fixed costs:
Price for 1000 liter= 23.565 BDT
So, price for 45 MLD= 1.06 million BDT

In addition,
Fuel cost to boil 40 liter of water= 20 BDT
So, fuel cost to boil 45 MLD of water= 22.50 million BDT

Furthermore,
Fixed cost (cost of filter and its maintenance) for 40 liter of water= 25 BDT
So, fixed costs for 45 MLD= 28.13 million BDT

Cumulatively,
Total cost= (1.06+22.50+28.13) million BDT =51.69 million BDT

In case of bottled water (Shanty)
Cost of 1 liter= 12 BDT
So, cost of 45 MLD= 540 million BDT</td><td>In case of Bottled water,
Price for 1 liter= 15 BDT
Price for 45 MLD= 15*45= 675 million BDT

In case of Jar water

Price for 20 liter= 60 BDT
Price for 45 MLD=135 million BDT</td></tr>
</table>

The second example implies that due to lack of quality drinking water supply, Dhaka city dwellers have to spend 675 million or 135 million BDT each day for bottled or jar water respectively to fulfill drinking water demand. On the other hand, to make the supplied water potable, they have to spend additional 50.63 million BDT for boiling and filtering other than DWASA revenue 1.06 million BDT. In case of DWASA supplied bottled water, city dwellers would have to spend 540 million BDT, even though DWASA has failed to maintain adequate supply of quality water. The whole scenario reflects a poor management and violation of peoples' inherent right to water.

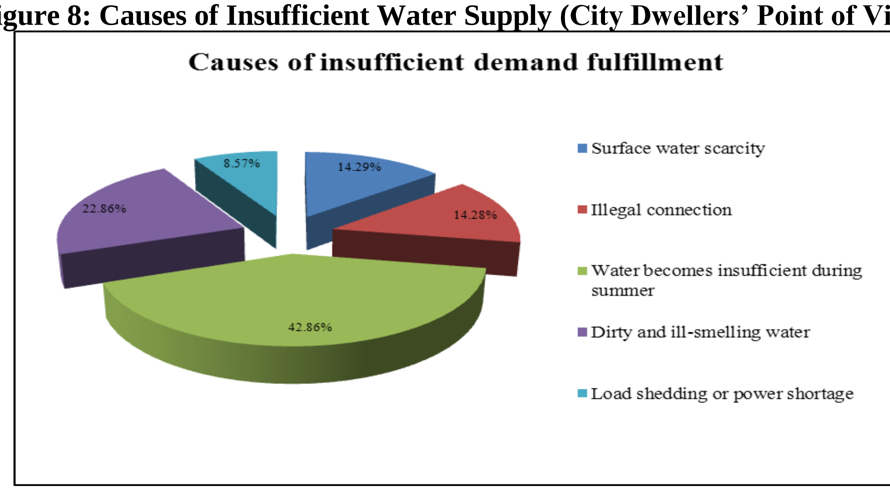
8. CONCLUSIONS AND RECOMMENDATIONS

Access to safe water is critical to economics as well as ecosystems and a scarcity of safe water can directly affect the long-term prospects for sustainable development. Without an adequate water supply, living organisms may die; factories depending on water may have to be closed down temporarily; crop yields may decline; workers may be unproductive; fisheries may be destroyed.

The present water supply in Dhaka city is heavily dependent on groundwater that signals a murky future with acute water crisis. Though the WASA has already started to shift its present groundwater based production system to surface water production, the shift demands huge investment and time. Moreover, the status of peripheral rivers of Dhaka city is highly degraded and a major portion is under illegal encroachment. That is why it is highly unlikely to fulfill the future demand just by relying on these sources. Considering the present crisis and future demand, it is high time to seek additional sources.

Majority of the Dhaka city dwellers (74.29 percent) believe that the current water supply management system will not be able to fulfill their demand. Water scarcity during summer season has been regarded as the matter of immense sufferings by 42.86 percent respondents. They argued that power shortage coupled with water scarcity aggravate their sufferings. On the other hand, 14.28 percent respondents identified the illegal connection as primary cause of inadequate water supply (Figure 8).

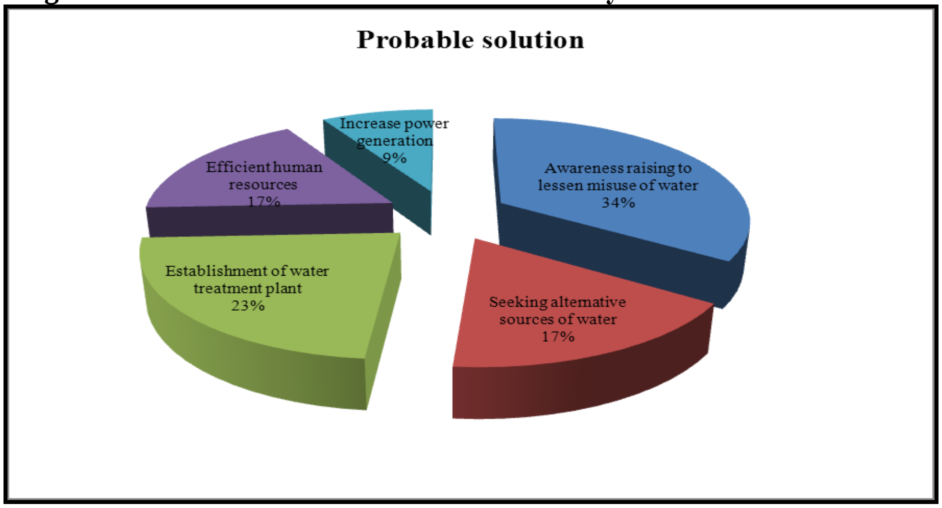
Figure 8: Causes of Insufficient Water Supply (City Dwellers' Point of View)



Source: Field Survey, 2011

What could be the solutions of this overwhelming water crisis? In response to the question, one-third (34 percent) of respondents emphasized on raising awareness among the common mass as well as DWASA personnel to reduce the misuse of water. To eliminate dirt and ill smelling, 23 percent respondents demand technologically improved water treatment plant. On the other hand, a significant proportion (17 percent) of the respondents opined that efficient human resources and seeking alternative sources of water might fulfill the demand (Figure 9).

Figure 9: Solution to the Water Crisis from City Dwellers' Point of View



Source: Field Survey, 2011

Furthermore, some other recommendations to improve the water supply system of Dhaka city may be listed as follows:

1. Implementation of right based approach in water production and supply.
2. Devise and implement pro-poor water policies by taking climate change, future urban growth, consumer's water demand and preference into consideration.
3. Creation of an effective regulatory body to ensure proper use of water, to consider customer's objections, and to penalize the illegal connection.
4. Prepaid billing system in order to lessen revenue loss and to increase the accessibility to the poor.
5. Regular maintenance of overhead and service tanks in order to supply clean potable water.
6. Surrounding rivers i.e. Buriganga, Shitalakkhya, Turag, Balu etc. and canals inside the Dhaka city should be kept free from pollution and illegal occupation.
7. Rainwater harvesting should be introduced at a massive scale to ensure supply of drinking water to the households who still have no piped connection.
8. Private investment should be regulated in such a way that would enhance the capacity building of government institutions and in such a manner that people should rely only on supplied water at an affordable cost.
9. Sense of ownership is crucial to manage water supply sustainably. Active participation of key stakeholders i.e. officials, representatives, individuals, community people etc. should be ensured at all levels of planning, implementation, regulation, monitoring, and evaluation of water supply scenario.
10. Sewerage treatment system should be more efficient so that effluents do not pollute their destination.
11. New technologies should be incorporated to improve the quality and efficiency of surface water treatment plants (SWTPs).
12. Proper awareness campaign through print and electronic media should be carried out to inform and to aware people regarding 'right to water' and the reduction of the misuse of water.

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