ACCESS TO SAFE DRINKING WATER IN RURAL BANGLADESH: WATER GOVERNANCE BY DPHE

A Dissertation

By

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ID No. 08272005

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Statement of the Candidate

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ABBREVIATIONS

ADP	Annual Development Program
BADC	Bangladesh Agriculture Development Corporation
BCM	Billion Cubic Meter
BGS	British Geological Survey
CCSLR	Climate Change and Sea Level Rise
CHT	Chittagong Hill Tract
CWP	Chulli Water Purification
DFID	Department of International Department
DGHS	Directorate General of Health Services
DPHE	Department of Public Health and Engineering
DSP	Deep Set Pump
DTW	Deep Tube-Well
GDP	Gross Domestic Product
GoB	Government of Bangladesh
HWT	High Water Table
IDWS	Improved Drinking Water Sources
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JAICA	Japan International Cooperation Agency
JMP	Joint Monitoring Program
LGD	Local Government Department
LGI	Local Government Institution
LWT	Low Water Table

MDG	Millennium Development Goals
NGO	Non-Governmental Organization
O & M	Operation and Maintenance
PMU	Project Management Unit
PPP	Public-Private Partnership
PSF	Pond Sand Filter
PWS	Piped Water Supply
R & H	Research and Development
RWHS	Rain Water Harvesting System
SDP	Sector Development Program
STW	Shallow Tube-Well
UNICEF	The United Nations Children's Fund
UP	Union Parishad
WASA	Water and Sewerage Authority
WHO	World Health Organization

ABSTRACT

For human existence the availability of safe drinking water is very important. In our country there is abundance of water, but for some reasons pure drinking water is becoming scarce. Groundwater is the most reliable source of drinking water in Bangladesh. In the early 1990s, almost 97 per cent of rural people had access to an improved source of drinking water. Currently, only 78 per cent of rural people have access to an improved source of water due to arsenic contamination and other causes. According to World Bank estimation, 18 million people in Bangladesh are poisoning themselves by drinking arsenic contaminated water and the health of 35 to 76.9 million people is at risk of arsenicosis. Arsenic, salinity intrusion, depletion of groundwater table, drought, flooding etc. make it difficult for rural people to get access to improved drinking water sources. According to the Coastal Zone Policy 2005, 76 upazilas of 19 coastal districts of the country are likely to be seriously affected by the anticipated sea level rise. About 15 million people forced to drink saline water and 30 million people deprived to collect drinking water from nearly available sources. Although groundwater is used for many purposes, but the groundwater table is declining due to gradual desertification process especially in the North-Western region of the country. It is predicted that every year the ground water table is declining by one meter (average) and 27 per cent of tube-wells are out of operation in the dry season. About 55 million people are denied the use of water from tube-wells due to the fall in ground water level during the dry season.

The Department of Public Health and Engineering (DPHE) with cooperation of Non-Governmental Organizations (NGOs) and Donor Agencies are involved in drinking water governance in Bangladesh. DPHE is the only government institution which directly involved in water governance to ensure safe water supply in rural Bangladesh. Statistics suggests that this effort is not enough to ensure peoples' access to safe drinking water. So, the institutional capacity of DPHE in terms of drinking water governance in rural Bangladesh is to be examined. In this study, attempt has been made to assess the effectiveness of water governance provided by DPHE and to find out the way to attain good and efficient governance capacity of this institution.

Key words: Arsenic contamination, sea level rise, salinity intrusion, groundwater level depletion, safe water supply, access, service delivery, water governance, sustainability.

1

CHAPTER

INTRODUCTION

1.1 PRELUDE

Water, water, everywhere, And all the boards did shrink; Water, water every where, nor any drop to drink" — this poem by prominent romantic English poet Samuel Taylor Coleridge successfully portrays a picture of the age-old and universal crisis of safe drinking water. These lines substantiate that abundance of water can not ensure access to safe drinking water. In a similar vein, two thousand years ago, Greek philosopher Pinder proclaimed "Water is the best of all things." In the same passion, legendary artist Leonardo da Vinci said, "Water is the driver of nature." There is a popular song by Lalon Fakir that "Lalon dies of thirst, while Meghna runs nearby" ("Lalon morlo jol pipashay, thakte nodi meghna"). Instead of the literal meanings of 'water' and 'thirst', those words have philosophical spirit in this particular song. Lalon meant that the Almighty is always around us, but if we could not satisfy Him then human life carried no value. This philosophical utterance induces people to think that availability of water does not carry any value if it not safe and not within the reach of the rural people. Besides, in the Holy Qur'an, Almighty Allah uttered the word 'water' seventy two times and in Surah Nahl, ayat no. 10, it is pronounced that, "He (Allah) sends down from the sky water for your drink, and to grow trees for your benefit." So, water is important for the ecological balance of the nature as well as for all life on Earth.

When it comes to drinking water[1], availability of water does not really matter if it is unsafe and can not quench the thirst of human beings. The exact amount of water a human needs to drink is highly individual, as it depends on the condition of the subject, the amount of physical exercise, and on the environmental temperature and humidity. But people use water not only for drinking but also for cooking, bathing and washing. Apart from these, there are many other uses of water in the life cycle of the earth. Per capita consumption of water varies according to the socio-economic condition of an individual. It

[1] DRINKING WATER is water of sufficiently high quality and free of contamination with any organic or inorganic substances that it can be consumed or used without risk of immediate or long term harm.

is not surprising that an individual of developed countries consume more than underdeveloped and developing countries. On average, a European and a North American respectively use 200 liters and 400 liters of water every day. In Australia, annual per capita consumption of water in 2006 was nearly 422 liter per day (Government of Australia: 2006). In contrast, the average person in the developing world uses only 10 liters of water every day for their drinking, washing and cooking (Amader Samoy: 2009). Loic Fauchon, head of the World Water Council said that, 'the era of easy water is over. We have to embark on policies for regulating demand.' He also added that, 'all of us, around the world, have to ask questions about our relationship with water and work to use less of it' (Daily Star: 2009). This is why each and every nation of this globe has to emphasize on the prudent use of water resources nowadays.

1.2 BACKGROUND OF THE STUDY

One may find it quite difficult to understand that a country like Bangladesh has a scarcity of drinking water. Bangladesh is widely known as 'a country of rivers' as hundreds of rivers travel throughout the country on their way down to the Bay of Bengal. But scarcity of safe drinking water is the reality in today's Bangladesh and nearly one-fourth of total population have no access to safe drinking water (WHO: 2008). It is measured by the number of people who have a reasonable means of getting an adequate amount of water that is safe for drinking, washing, and essential household activities. People mainly depend on groundwater for drinking. As the groundwater is located beneath the ground surface and typically it is considered as liquid water flowing throw shallow aquifers. There is natural process of groundwater recharge and it is recharged by surface water bodies and wetlands (Sophocleous 2002: 52-57). Contamination of some metalloids made groundwater unsafe and it causes severe health risks including skin cancer (Ali and Tarafder 2002: 182-183). Increasing demand for drinking water, coupled with water pollution (both ground and surface) make it difficult for people of rural area (large and isolated areas of the country with comparatively low population density) to get access to safe drinking water.

Rural people's access to safe drinking water sources is on the decline because both surface and groundwater are becoming unsafe to drink. It is very hard to find 'a drop of drinkable surface water' around the country because surface water sources are polluted in many ways and require treatment (Gupta et. al. 2005: 389). Arsenic[2] contamination in groundwater resources has been discovered in 1993 and is a major setback in water supply[3] to the people of rural Bangladesh. Estimates indicate that in

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[2] ARSENIC is a notoriously poisonous metalloid naturally found in groundwater and its contamination has led to a massive epidemic of arsenic poisoning in Bangladesh.

[3] WATER SUPPLY is the process of self-provision or provision by third parties to different users. In this process water is collected from different sources then purified to make it safe for use.

2008, up to 70 million people in the country are still exposed to drinking water contaminated with arsenic poison, which does not comply with WHO standards (WHO: 2008). In rural Bangladesh, people of more than 80,000 villages are at risk of excessive level of arsenic and water of more than 80 per cent tube-wells of those villages is poisoned with arsenic (Prothom Alo: 2009). Another emerging threat to the accessibility of rural people to improved drinking water sources (IDWSs) is heavy groundwater withdrawal for irrigation and industrial uses. Heavy groundwater withdrawal has lowered the water table[4] in many areas making groundwater out of reach to hand tube-wells.

Bangladesh has 710 long coast lines which is identified as an obstacle to safe drinking water. Coastal zone of Bangladesh covered 19 districts and 147 Upazilas of the country. Among 147 coastal Upazila of 17 districts, 48 Upazilas of 12 districts fall on the exposed coastal zone and a total of 99 Upazilas are behind the exposed coast which is treated as interior coast (Sarwar 2005: 6). Drinking water supply for the people of the nineteen coastal districts has to face different types of problem like salinity intrusion[5]. Withdrawal of groundwater in coastal zone for irrigation, household use and industrial use and climate change induced sea level rise are making this problem severe. Salinization in groundwater is depriving a number of populations in coastal area from getting safe drinking water. As the accessibility to IDWS is lessening everyday, it is the moral obligation of the present generation to use water without depriving the future generation.

At present, four types of organizations are involved in water management. These are: (a) government agencies, (b) local government institutions, (c) other organizations, and (d) development partners. The government agencies include 13 ministries and 35 organizations. Department of Public Health and Engineering (DPHE) is the primary agency in rural water supply & sanitation and it has the mandate to supply safe drinking water in both rural and urban areas. As a government institution, DPHE is exclusively responsible for water supply throughout the country excluding Dhaka and Chittagong cities and Narayanganj and Kadamrasul Pourashavas where Water and Sewerage Authority (WASA) operate. It provides advisory service to the Government of Bangladesh (GoB) in framing policy and action plans for Water Supply System (WSS) and support to the local government institutions (LGIs) in the development and operation and maintenance of the water and sanitation facilities during and after the natural disaster and calamities. It also provides technical assistance and carrying out hydro-geological investigations in search of improved drinking water sources (both surface and ground). Functions of DPHE includes social mobilization for awareness raising towards proper management of water supply and

[4] The WATER TABLE is the level at which the groundwater pressure is equal to atmospheric pressure. The upper level of the saturated layer of an unconfined aquifer is also known as the water table.

[5] SALINITY is the saltiness of water due to dissolved inorganic salts content in water. Saltwater intrusion is the movement of saline water into freshwater aquifers. Saltwater intrusion occurs in virtually all coastal aquifers due to withdrawal of fresh water at a faster rate.

sanitation infrastructure and promotion of personal hygiene practices; develop safe water[6] supply technologies in the arsenic affected and other hydro-geologically difficult areas (saline belt, stone problem areas, hilly regions and areas likely to be affected by other micro-pollutants); research and development activities in search of appropriate and affordable options including the indigenous ones of water supply and sanitation in the country; capacity building of the community, LGIs, private entrepreneurs and NGOs with technical know-how, information, training etc. in terms of water supply and sanitation; monitoring and coordination of activities of the stakeholders including NGOs & private operators working in the Water Supply and Sanitation sector; and overall management of the Water Supply & Sanitation Sector Development Program. It is necessary to examine whether DPHE is effectively performing its assigned responsibilities.

This research is aimed to brief on rural people's access to safe drinking water, conceptual framework of water governance and sustainability, water governance practiced by the DPHE to ensure people's access to IDWSs, and findings and recommendations to achieve good governance within the DPHE.

The limitation of this research includes limited availability of reliable data, and short time frame. Many organizations carried out studies on the same issue but findings and conclusions are different. It is difficult to pick up the accurate data from a reliable source. Due to time constraint, primary data has been collected from two districts. The two districts are chosen from Eastern (Comilla) and Western (Chuadanga) part of the country. Interviews of 204 household heads from two districts have been conducted.

1.3 RATIONALE

Pure drinking water is essential for better health as well as for human capital formation. A nation with sound health can contribute more towards the development of the country. Because men with sound health could be a 'factor of production'[7] in the era of globalization and safe drinking water is a crucial determinant of better health. It is the duty of the government to take initiative to secure public health and safe drinking water is one of the most important instruments for good public health. Realizing this, the United Nations as well as Bangladesh has set a goal, known as Millennium Development Goals (MDG), to minimize the proportion of both rural and urban people with no access to IDWSs. According to MDG's progress report of Bangladesh, in 1991 the proportion of the rural population with access to safe drinking water was 93 per cent and in 2006 this rate had declined to 79 per cent (GoB-UN 2007: 32). It indicates that, 21 per cent rural people

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[6] Water is considered safe when it is free from pathogenic agents, free from harmful chemical substances, free from colour & odour and pleasant to taste.

[7] FACTOR OF PRODUCTION is a term of economics. In economics, factors of production are the resources employed to produce goods and services. There are four factors of production namely land, labor, capital, and entrepreneurship.

still have no access to safe drinking water and Bangladesh is seriously challenged to attain the MDG goal with regards to access to safe drinking water in rural Bangladesh. Reasons behind this alarming situation are arsenic contamination in groundwater, pollution of surface water, depletion of ground water level, salinity intrusion both in surface and ground water, drought, natural disaster etc.

Arsenic contamination in groundwater is one of the most devastating catastrophes in Bangladesh and arsenic itself is known as 'the king of poison'. WHO recommends the acceptable level for maximum concentration of arsenic in drinking water is 0.01 mg/L (10ppb) and the Bangladesh government's standard is at 0.05 mg/L (50 bbp). a recent findings show that consumption of water with levels as low as 0.00017 mg/L (0.17ppb) over long periods of time can lead to arsenicosis (Ali and Tarafder 2002: 926). Arsenic is treated as carcinogen[8] and in some cases arsenic affected rural people believed that God has punished them by arsenic poisoning. Its degree of poisoning drinking water in the affected area is beyond control and all mitigation efforts have not yet reached to the rural population (Anwar 2000: 28-30). Tube-well water of most of the districts is contaminated with poisonous arsenic and level of toxicity in the water of affected tube-wells is 25 to 35 times higher than the WHO recommended safety level (Chowdhury, 2001: 7). A study indicates that 1.12 million tube-wells have been contaminated with arsenic and 75 million people of Bangladesh drank tube-well water that exceeded the acceptable level of arsenic poisoning. Most alarmingly, number of arsenic patients already crossed the ten thousand mark in the country (Ali et. al. 2002: 167). To date, scientists have found no preventive option to control spread of arsenic contamination into groundwater rather than mitigation.

Surface water pollution is a result of civilization and direct consequence of so-called development. Industrialization is recognized as the pillar of modern civilization and development. Industries are established by grabbing water bodies and industries discharge its effluents to the remaining water bodies which is the major source of water pollution. Besides that excessive use of chemical fertilizer and pesticides in agriculture, poultry and fisheries, and improper management of solid waste (household, medical etc.) are also liable for water pollution. Improper disposal of medical waste[9] have direct and indirect health impact on human and on the environment. Wastes include infectious, hazardous, and benign materials which may contribute to the spread of water pollution and diseases. Runoff from crude medical and human waste that deserted on the land can contaminate surface and ground water supply (Akter 2002: 674-675). Pollution from waste water can be prevented through treatment and treated waste water has many beneficial uses like irrigation, gardening, flushing etc. In Japan, wastewater effluent is

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[8] The term CARCINOGEN refers to any substance, radionuclide or radiation that is an agent directly involved in the promotion of cancer or in the increase of its propagation.

[9] MEDICAL WASTE is known as clinical waste generally produced from healthcare premises, such as hospitals, clinics, doctors' offices, labs and nursing homes.

used for stream restoration and flow augmentation (Rahman and Bakri 2002: 926-939). But unfortunately industrial effluents[10] are not treated in Bangladesh. Thus, some water bodies are polluted in such a level that it can not be treated for reuse as other countries did.

Depletion of ground water level is one of the important reasons for which rural people are unable to get access to fresh drinking water. People pumped out drinking water mainly from upper aquifer by shallow tube-wells and that aquifer has the same flow as the rivers (Anwar 2000: 55). In the dry season most of the river dried up or water level dropped remarkably. That time it was found that in many parts of the country including hill-tracts shallow tube-wells are not able to pump water from the upper aquifer because groundwater table has depleted beyond the suction level. Over pumping of groundwater for irrigation is the main reason for lowering groundwater table. As a result, people of affected areas who mainly depend on shallow tube-well for drinking water, suffer from getting fresh drinking water. As the poor people have no affordability to install deep tube-well, they are bound to trade-off with food security and practice rationing of drinking water. In the dry season, plenty of newspaper reports found people are waiting in a long queue to collect drinking water or women and children have to collect drinking water from distant sources. Scientists and environmentalists have found that groundwater table has been lowering at an alarming rate. This should provoke us to think about the recharge of groundwater aquifer for its sustainability.

Salinity intrusion both in surface and ground water poses a great threat to the accessibility of people of the coastal zone to fresh drinking water. Climate change[11] induced global warming[12] is the main reason for raising sea water level. On the other hand fresh water flow from upstream gradually decreased specially in the dry season. Combined effect of these two natural phenomena causes incremental salinity intrusion in the coastal zone. It was predicted that in 2050 global average sea level rise will be 32cm, and in 2100 it will be 88 cm (Rahman et. al. 2007: 53-60). Another study found that due to sea level rise the area of fresh water zone will be reduced from 45 per cent to 36 per cent and moderate saline zone will be reduced from 50 per cent to 47 per cent. But the area of salt water zone will increase from 5 per cent to 17 per cent (Rahman and Rahman 2007: 77-83). So, the problem of salinity intrusion needs to be addressed properly by the public institution involved in drinking water governance in rural area.

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[10] EFFLUENT is an out flowing of water from a natural body of water, or from a man-made structure or industries which is mostly liable for water pollution.

[11] CLIMATE CHANGE is any long-term change in the statistics of weather. Factors that can shape climate are often called climate forcings like variations in solar radiation, deviations in the Earth's orbit, and changes in greenhouse gas concentrations.

[12] GLOBAL WARMING is the increase in the average temperature of the Earth's near-surface air and oceans. Increasing greenhouse gas concentrations resulting from human activity such as fossil fuel burning and deforestation are responsible for global warming.

Drought and natural disaster are also liable for drinking water scarcity. Drought is a byproduct of climate change and it also occurs as a long term effect of barrages that are constructed in the upstream of the river and hinder the natural water flow. Especially, Farakka barrage which was constructed 11 miles from the border is affecting the environmental security of Bangladesh. River Ganges is called lifeline of Bangladesh because nearly one-third population of Bangladesh depends on water of the Ganges and it provides water to nearly 37 per cent of total land area. (Ali 2005: 3). The Farakka Barrage has restricted fresh water flows during the dry season and caused serious problems in southwest part of Bangladesh. The withdrawal of Ganges water has contributed to the reduction of surface water availability and aggravated the desertification process in the western part of the country. River morphology, salinity etc. are affected due to the decreased stream flow which results inadequate groundwater storage (GoB 2001: 12). As long term effect of this barrage causes depletion of water table and great part of Bangladesh will face desertification (Shelley 2006: 40). Besides that, during and after any natural disaster it is very difficult to have fresh drinking water in the affected area. During natural disaster water sources are destroyed or became out of peoples reach or out of order, and after disaster water bodies are polluted by degradation of plant and dead animal bodies. North-western part of Bangladesh is suffering for desertification and natural disaster is a common phenomenon of riverine Bangladesh. So, Drought and disaster have negative impact on rural people's accessibility to fresh drinking water.

As discussed above, water sources are becoming out of reach and contamination with unwanted organic and inorganic materials makes fresh drinking water scarce. Therefore, efficient governance and surveillance program is the right way to solve this problem. In order to administer such surveillance, appropriate 'institutional arrangement' is a must (Shamsuddin 2002: 642-662). In Bangladesh DPHE is the public agency that is responsible for the quality of water supply for rural people. They must uphold this service through proper operation and maintenance of water supply infrastructure. As an institution it should ensure efficient and regular quality control initiatives through appropriate training, support supervision and technical advice to the local level staffs. Though people of rural Bangladesh suffer from lack of fresh drinking water, it needs to be diagnosed whether 'institutional arrangement' and 'governance capacity' of DPHE is appropriate or not for delivering high-quality services to the people.

For the above mentioned reasons and since natural drinking water sources are no longer intact, water governance has turned out to be crucial for Bangladesh. Water scarcity has become an everyday problem because of population rising and climate change (Rogers 2008: 1). Climate change has many effects on environment. Possible consequence of climate change that environmentalists predict includes sea level rise, submergence of coastal areas, increase in evaporation, increase in snow melt in Himalayas and polar region, increase in rainfall in monsoon, decrease in rainfall in the dry season, increase in flooding intensity & duration, frequency increase in cyclone & cyclonic surge, increased drought and desertification, increase salinity intrusion etc. All these factors directly and/or indirectly affect on the availability of fresh drinking water in rural area (Faruque 2008: 16). Besides that global warming is coming forward as a curse to human civilization. Bangladesh, a low lying delta, is mostly exposed to consequence of global warming. Besides this, demand for drinking water in rural Bangladesh is increasing due to the high growth rate of population. Rural people's accessibility to improved drinking water sources is being attacked from two dimensions. On the one hand aggregate demand is mounting due to population explosion. On the other hand available natural water sources are becoming out of reach due to natural and human induced pollution. As a result, the crisis for fresh drinking water is worsening and rural people are becoming vulnerable to get access to IDWSs. Therefore, sustainable access to safe drinking water is becoming a crucial problem and efficient water governance of the service providing institute is the demand of time. Though most of the reliable and dependable water sources are no longer intact then good, efficient and effective 'drinking water governance' in service providing public agencies is essential to ensure optimum use of water resources

1.4 OBJECTIVE OF THE STUDY

The broad objective of the study is to assess the governance capacity of DPHE. It will also examine, as a government service providing agency, to what extent it is capable enough to ensure the access of rural people to improved drinking water sources. Besides that, specific objectives are as follows:

1. To understand the present drinking water scenario of rural Bangladesh.
2. To asses the existing governance system of DPHE in delivering safe drinking water to the rural people.
3. To find out some ways to attain good governance that may ensure people's access to IDWSs in rural areas.

1.5 LITERATURE REVIEW

For the understanding of present drinking water scenario in rural Bangladesh, and to understand water governance perspectives and institutional capacity of DPHE, number of articles, books and newspaper reports have been consulted. Among those some leading works are discussed here.

Bangladesh is facing drinking water scarcity especially in rural areas mainly because of arsenic contamination in groundwater, depletion of groundwater table, and salinity intrusion in coastal areas. There is plenty of publication which addressed those issues. Prominent works on drinking water crisis are *'Bangladesh: Sate of Arsenic 2001'* book edited by Quamrul Islam Chowdhury, *'Arsenic Poisoning in Bangladesh: End of a Civilization?'* book written by Jamal Anwar, 'Social and Economic Consequences of Arsenicosis in Bangladesh' article written by Barakat et. al., 'Access to Drinking-water and Arsenicosis in Bangladesh' article written by Bruce et. al., 'Arsenic Contamination of Drinking Water in Bangladesh' written by Turk et. al., and 'Impacts of Sea Level Rise on the Coastal Zone of Bangladesh' masters thesis persued by Md. Golam Mahabub Sarwar.

All these works put emphasis on sources and processes of arsenic contamination in Bangladesh, origin of arsenic in groundwater, threat of arsenic to public health, statistics about people exposed to arsenic, how arsenic is depriving rural people to get access to improved drinking water sources etc. Health hazards of arsenic and social and economic consequences of arsenicosis are described extensively. Besides that those papers also address how salinity intrusion in coastal areas is becoming an obstacle to get fresh drinking water. But all these works do not address how government may intervene in the process of rural water supply to ensure people's accessibility and particularly the role of DPHE in drinking water governance in rural Bangladesh.

Major works on water governance and water resources management are "Water Sector of Bangladesh in the Context of Integrated Water Resources Management: A Review" article written by Gupta et. al., 'A Comprehensive Action Plan to Protect Surface Water in Bangladesh' article written by Md. Khalequzzaman, and 'Experience with the Management and Implementation of Drinking Water Supplies in Bangladesh' article written by C. F. Ramelt and J. Bose. These papers discusst different aspects of water governance in a normative manner. All these works suggest incorporating local government representatives for the better management of water resources. Besides that, an integrated approach for drinking water supply and public private partnership in drinking water management is also suggested. But the authors do not focus what will be the budget flow of drinking water management projects and who will be the implementing agency/authority of projects, what will be the roles and responsibilities of public and private institutes-are not clearly defined. And most importantly sustainability issue in terms of access, availability and purity of drinking water are not addressed properly.

In the area of water governance in rural Bangladesh prominent works includes 'Water Availability and Usage Regime in Rural Bangladesh' study report prepared by Nishat et. al., and 'Local Initiatives: People's Water Management in Rural Bangladesh' article written by Jennifer E. Duyne. Nishat et. al. have been carried out the study in seven selected villages in different hydrological and agro-ecological zones in Bangladesh and examines the socio-economic profiles of the villagers and their dependency on water availability and water quality (Nishat et. al. 2007). This study tries to focus on the concept of water balance and coping measures that villagers followed to solve different water quality related problems, water purification methods that widely practiced in the study area, water-environment and cultural practices exists in study area, participatory approach of water management, sufferings/problems of women in the process of water collection for household use, and most importantly, ecological significance of water. In this paper there is absence of in-depth discussion about the role of public organization to ensure rural peoples' access to improved drinking water sources.

On the other hand, Duyne, aims to find out in that study how people on their own manage surface water, what they did to enhance the benefits or reduce negative impacts of the public water management infrastructure. This study covered the individual and collective initiatives of existing semi-formal and informal organizations in surface water management (Duyne: 2005). This paper mainly emphasizes on the participation of users or locally elected representatives in water management. But it does not consider the water crisis that emerged in the country due to arsenic contamination, lowering groundwater level, salinity intrusion, water pollution and natural disaster etc. This study does not take into account the drinking water governance of public institutions, accessibility of rural people to improved drinking water sources, and sustainability of drinking water sources.

Important works in the area of regional initiatives on drinking water governance are 'Water Conflict in Asia: An Overview' article written by Salman Haider, 'Asian Water Development Outlook 2007: Achieving Water Security for Asia' an ADB publication, and 'Land and Water Governance: IFAD Experience' case study published by IFAD. In these papers, discussions have taken place about indications and implications of Asian people's access to drinking water and sanitation, water resources development in changing Asia, integrated water resources management, and water management experiences in some Asian countries. These works also try to make a forward looking assessment of the possible water future of the densely populated Asian region and discussed about emerging conflicts for water resources and experiences of water governance form Asian and non-Asian countries. These studies mainly focus on surface water management and do not put emphasize on the governance capacity of public enterprises like DPHE.

On the issue of water governance by DPHE, foremost work is *'Public Water Supply in Rural Areas: An Evaluation of DPHE's Performance in Installations of GoB Funded Tube-wells'* which is a research monogram written by Rita Afsar and published by BIDS in 1999. This study was undertaken to asses the performance of DPHE under government funded water supply installation program and result of this assessment was compared with DPHE-UNICEF program. In order to asses the performance of DPHE, the researcher has addressed the role of DPHE in delivering rural water supply, political influence in the distribution process, quality of water in government funded tube-wells, physical condition of tube-wells and platforms, and problems of repairing and maintenance of tube-wells. Throughout the study, the author considered site selection criteria at the household level, involvement of women in the decision of site selection, relation between land ownership and level of education in case of making choice of water supply technologies, and DPHE's performance with regard to imparting training to beneficiaries.

This study is conducted among the families who owned water technologies supplied by government and UNICEF. This study do not focus on sustainability and governance of water resources in terms of emerging drinking water scarcity, contamination of hazardous elements at alarming level both in underground and surface water, lowering groundwater table in many parts of the country, and growing salinity intrusion in the coastal area. Moreover, it did not evaluate the governance capability of DPHE in terms of organizational structure, process of service delivery and availability of tangible and non-tangible resources.

1.6 METHODOLOGY

To assess the governance capacity of DPHE and effectiveness of the services, extensive and in depth interviews of DPHE personals have been conducted. Primary data has been collected by using questionnaire of two hundred people from two districts. Other relevant data are collected from secondary sources for analysis and these are given as reference list after every chapter. Secondary data are used to analyze the governance status of DPHE and to assess the drinking water situation in rural Bangladesh. Official documents, books, published articles, workshop and seminar papers, journals, newspaper articles & reports, and reports published from different national & international organizations, and websites are the sources of data.

2

CHAPTER

DRINKING WATER SCENARIO IN RURAL BANGLADESH

2.1 PRELUDE

Life in riverine Bangladesh is based on water and the availability of drinking water, in both quantity and qualitative terms, is a basic human right for the people of the country. The National Water Policy 1999 and The National Water supply and Sanitation Policy 1998 has recognized water essential for human survival, socio-economic development and preservation of natural environment (GoB: 1998). At times people of rural Bangladesh relied largely on surface water to drink, but the surface water is now contaminated in various ways. Polluted surface water causes diarrhea, cholera, typhoid, jaundice and other life-threatening diseases. It is evident that about 342 children die everyday from waterborne diseases in Bangladesh (New Age: 2005). Environmental organization *The International Union for Conservation of Nature* reported that, the Bangladesh government spent only 1.4 per cent of it's Gross Domestic Product (GDP) for water supply and sanitation (Amader Somoy: 2009). On the other hand, the Government of Bangladesh spent 85 per cent of the total allocation for healthcare services in combating waterborne diseases (New Age: 2005). It indicates government spends more in curative measures instead of preventive measures. After independence, millions of tube-wells were installed in rural Bangladesh and this remarkably reduces the threat of waterborne diseases. Installation of tube-well made rural people dependent on groundwater for their household uses mainly for drinking. Transition from drinking surface water to tube-well water significantly reduced deaths from water borne diseases, but at the same time deaths from arsenicosis emerged as new threat to public health.

Water supply coverage in rural Bangladesh has expanded but it is difficult to keep pace with the rapid population growth. Notably, in rural Bangladesh people have minimum per capita consumption of freshwater. Amount of water that uses only for drinking purpose varied from 3 to 6 liters per person per day (Nishat et. al. 2008: 28). For domestic uses, average per capita withdrawals of freshwater is only 6m^3 per person per year (SOS-arsenic: 2009). On the other hand, for standard living freshwater needs about 6.8m³/person/day[1] (Hossain and Hossain 2007: 7). After having comparatively very low per capita demand, drinking water is now rationing in some part of the country. A family of five members had to survive for twenty four hours with a single pitch of fresh drinking water. If it was finished, family members had no way to take safe drinking water for their consumption (Janakantha: 2009). Simultaneously, it is reported that, 4.5 million tube-wells could not pump water from underground and in remote areas one had to wait for about three hours to collect a single pitcher drinking water (Amader Samoy: 2009). These reports are snap shots of the drinking water scenario of rural Bangladesh. Besides that, saline intrusion into ground and surface water in the coastal areas, flood, drought etc. are making people's access to safe drinking water very difficult nowadays. In the changing situation, people of rural Bangladesh are facing an acute crisis of safe drinking water.

2.2 WATER AVAILABILITY AND USES

Water appears in nature in three common states of matter and may take many different forms on Earth i.e. water vapor and clouds in the sky; seawater and icebergs in the polar oceans; glaciers and rivers in the mountains; and the liquid in aquifers in the ground. The earth contains 1408.10 billion km³ of water in three basic forms. Out of this amount, 97.25 per cent stored in the oceans what is salty and not drinkable. Among the rest only 2.74 per cent is fresh and drinkable. From the total fresh water 2.05 per cent is stored in the polar region as ice caps and glaciers. Only 0.69 per cent water is stored in lakes and ground aquifers. Rest 0.01 per cent water exists as soil moisture and biotas[2] and in rivers and atmosphere (Hossain and Hossain 2007: 6-7). The global availability of freshwater for human consumption is less than 1 per cent (Haider 2002: 1002). This statistics indicates that, all over the world there is scarcity of drinking water compare to total available water. The amount of globally available freshwater and its distribution are shown in chart 1 & 2.

Chart-1: Ratio of Salt Water & Fresh Water

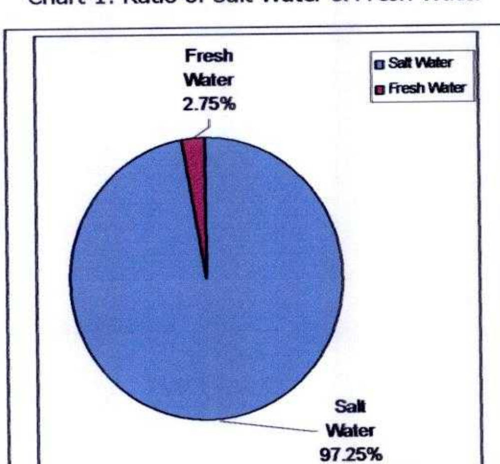
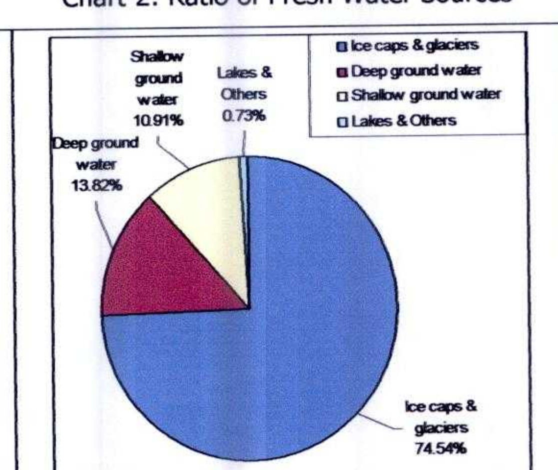


Chart-2: Ratio of Fresh Water Sources



Source: SDP, Self Compiled

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[1] 1 m³ = 1000 liter

[2] Biota is the total collection of organisms of a geographic region or a time period.

Availability and access to fresh drinking water have different dimensions. There is an agreed criterion for different level of water scarcity. When a country's annual water supply drops below 1,700 m^3 per person per year then the country is under water stress. When these levels reach between 1,700 and 1,000 m^3/person/year, it is called occasional water shortage and when the level drops below 1000 m^3/person/year then the country is under water scarcity (Haider 2002: 1002-1003). Water availability and scarcity of a nation is measured based upon this criteria.

Bangladesh has considerable topographical diversity and in terms of water resources it is located in a critical position. It has three distinctive topographic features namely (a) a broad alluvial plain, (b) a slightly elevated relatively older plain, and (c) a small hill region drained by flashy rivers (Banglapedia: 2009). On the south there is about 700 km long coast line which connects the country land directly with Bay of Bengal. Water of the Bay of Bengal itself is undrinkable due to its saltiness and it also made the groundwater water of coastal zone unsafe to drink by salinity ingression. On the other hand, major source of surface water comes form glaciers of Himalaya through transboundary rivers. After its formation it runs through India and comes down in Bangladesh. The Ganges-Brahmaputra-Meghna river system is the third largest freshwater outfall to the world's oceans. China, India, Nepal and Bangladesh share the water of this basin. Bangladesh got 80 percent of its annual fresh water supply comes as transboundary inflows through 54 common rivers with India. The Ganges and the Brahmaputra often overflow during the monsoon months, and the flow reduces dramatically in the dry season. Co-basin countries face two major hazards namely (a) floods during the monsoon and (b) scarcity of water during the dry season. As a downstream country, these hazards become more devastating in Bangladesh. Sustainable water management of Brahmaputra and Ganges river system became more critical because of increasing population and accelerating economic development activities in this basin. This is why, the sharing of water resources has long been a matter of dispute among the four co-basin countries especially between India and Bangladesh (Chowdhury: 2007). Bangladesh faces some constraints when India tried to control the natural water flow and divert plenty of water for their own use with artificial barrages or dams. As the impact of climate change and barrages in the upstream of the transboundary rivers major rivers in Bangladesh became dry in the winter and over flooded in the summer. It is obvious that intervention on the water flow of transboundary rivers may create shortage of surface water in Bangladesh. Then topographic advantage of Bangladesh may not carry any result and conflict on water resources may emerge in this region.

In Bangladesh, the availability of water varies in different season. Bangladesh has an enormous excess of surface water in the summer months (July to October), faces relative scarcity in the winter months. During rainy season country is flooded with plenty of water, but in the dry season there are shortages of water. It is estimated that, on average, every year 20 per cent area of the country is inundated by flood water (Duyne 1998: 2). Unfortunately there is no way to store this huge amount of water and it can not be used for drinking purposes. Bangladesh got 343 billion cubic meters (BCM) water from rainfall and it is drinkable. Internal renewable water resources are about 105 km³ per year, while inflowing transboundary rivers provide another 1,100 km³ annually (average 1977-2001) (WRI n.d.). From 57 transboundary rivers, 250 internal rivers, hundreds of bills-haors-baors, and millions of ponds-ditches Bangladesh got another 1560 BCM water that is known as surface water (Ahmed 2008: 9). Out of 57 transboundary rivers 54 comes from India and 3 comes from Mayanmar (Hye 2007: 4). These rivers have vital role delivering fresh drinking water for the people of rural Bangladesh by contributing natural groundwater recharge process.

In Bangladesh, total useable recharge of groundwater is about 23 BCM and out of this 43.48 per cent is available to pump through shallow tube-wells. Only 3.00 per cent of total water is used for water supply and that amount of water is used mainly for drinking and other household activities. From the rest, 32.00 per cent used for irrigation, 9.00 per cent for environment, fish & forest and 56.00 per cent for instream uses (Ahmed 2008: 9). Chart 3 shows the amount of water that Bangladesh got from three major sources and chart 4 shows the distribution of usable water. According to World Resources Institute (WRI), in Bangladesh 1.00 per cent of total water resources is being withdrawn for human use. Out of the total withdrawal, 86.00 per cent is for agriculture, 12.00 per cent for domestic water supply, and 2.00 per cent for industry (WRI: n. d.). So, a very little portion of total available of water is used for drinking.

Chart-3: Quantity of Water Available in Bangladesh

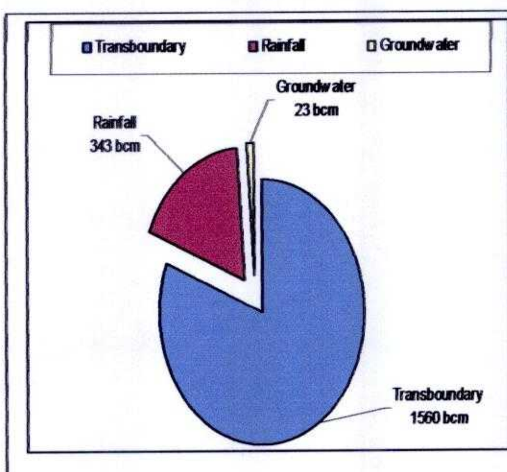
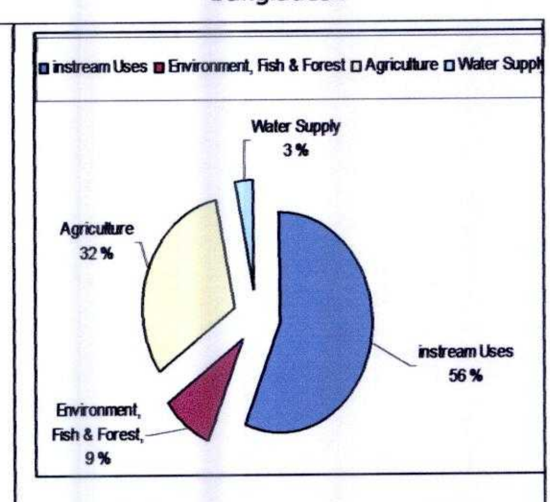


Chart-4: Main Category of Water Uses in Bangladesh



Source: Self compiled

Rural people use various types of technology as source of collecting drinking water. Most commonly used technologies are tube-well, tap and ring-well. People's dependency on different sources for drinking and household use varies significantly. This variation is shown in the table number 1.

Table-1: Dependency on Water Sources for Drinking and Household Use

Source	Drinking Water	Household Use
Tube-well	93.30 %	53.00 %
Tap	0.20 %	0.30 %
Ring-well	3.40 %	6.30 %
Others	3.60 %	46.10 %

Source: Self-compiled

This table shows that, for household use only 53 per cent people depend on tube-well water and 46.10 per cent depend on other sources. On the other hand, for drinking 93.30 per cent people depend on tube-well and only 3.60 per cent depend on other sources (Mahmood and Islam 1999: 12). It proves that, tube-well is the trustworthy source for drinking water in rural Bangladesh.

2.3 DRINKING WATER SOURCES

In Bangladesh, generally we get water from three major sources:

a. Groundwater
b. Surface Water and
c. Rain Water

2.3.1 GROUNDWATER

Groundwater has been treated as the best source of drinking water in Bangladesh with underlain water-baring aquifers, except hilly areas. Depths of aquifers are limited within 20 m below ground surface (Hossain and Hossain 207: 9-10). Huge expansion of access to groundwater was one of the blessings for the rural people to get rid of water-borne diseases. In rural areas, more than 97 per cent of the population relies on groundwater for IDWSs (Haq 2006: 296). Heavy withdrawal of groundwater lowered the water table in various part of the country during dry season. Besides that, groundwater is polluting and becoming unpleasant to drink. Reduction of quantity, depletion of groundwater level and degradation of quality of groundwater altogether reduced rural people's access to safe drinking water. The groundwater source can be classified into four different hydro-geological categories:

a. High Water Table (HTW)
b. Low Water Table (LTW)
c. Coastal Belt and
d. CHT Hilly Area.

In Bangladesh, water supplying technologies are selected based on hydro-geological condition. Relation between hydro-geological category and water supplying technology is shown in the table number 2.

Table-2: The Different Hydro-geological Categories Related to Rural Water Supply

Hydro-geological Categories	Area of the Country	Technologies Generally Used
High Water Table (HWT)	Consists of about two thirds of the country.	Hand pump shallow tube-wells (STW) are extensively used.
Low Water Table (LWT)	Situated in the northwestern and central part of the country.	Deep Set Pump (DSP) tube-wells are used.
Coastal Belt	These areas are along the coast line of the country.	Usually hand pump deep tube-wells (DTW) are used.
CHT Hilly Areas	These hilly areas consist of the three districts of the Chittagong Hill Tracts.	Here alternative technologies like ring wells, DSP tube-wells and some spring sources are used.

Source: SDP, self-compiled

Hydro-geological character is different in various part of the country. Based on this characteristics three types of water technologies widely used in rural Bangladesh. A further discussion is made in later part of this chapter about groundwater table, problems exist in coastal zone, and three hill districts.

2.3.2 SURFACE WATER

In Bangladesh, surface water is abundant during the rainy season, but has shortfall in other seasons. As mentioned earlier, Bangladesh is a country of rivers and in the rainy season the country has an abundance of surface water. Rivers (both domestic and transboundary), ponds, lakes, and water bodies are sources of surface water. During the rainy season, plenty of surface water comes through transboundary rivers. It is estimated that, the river Ganges and Brahmaputra discharge 795,000 Mm^3 of water during the rainy season (June to mid October) and it is equivalent to 5.52 m deep water over total area of

Bangladesh. During the dry season (December to March) 22,1555 km of major rivers, 19,222 Km^2 major standing water bodies and about 1,475 km^2 of ponds are the sources of surface water. Bangladesh has roughly 1.3 million ponds and 17 per cent of these ponds are deserted and dried-up in the dry season (Hossain and Hossain 2007: 9). Surface water is partly refilled by an average annual 2.0 meter rainfall throughout the country. The presence of bacteria and pathogens in surface water makes it impure to drink. Surface water could be an alternative source of drinking water in those areas where ground water is contaminated with excess arsenic and other inorganic salts (Khalequzzaman 2002: 1014-1015). All the reservoirs of surface water is being polluted by bacteria, chemical fertilizer, pesticides, and dead animal bodies. Impure and unsafe surface water can be used for irrigation but it does not carry any value in terms of accessibility of rural people in IDWSs. However, surface water sources are generally polluted and groundwater is contaminated with excess amount of arsenic and iron.

2.3.3 RAIN WATER

In view of the limited access to pure surface water, rain water could be the potential alternative source of freshwater. Rain water is free from any organic and inorganic contaminants and it requires less treatment and no cost to collect. In Bangladesh, 80 per cent of all rainfall occurs between June and mid October and is influenced by south-west monsoon (Ahmed n. d.: 1). The average yearly rainfall in the country during 1987-1996 varied from 1950 mm to 2900 mm. It is estimated that 1.95 to 2.90 m^3 of rain water was available per m^2 of catchments area each year (Ahmed 2006: 4). Amount of rain water varied on frequency and intensity of rainfall along with availability of catchments area. Due to arsenic contamination in groundwater and salinization both in ground and surface water of coastal areas 'rain water harvesting' is becoming popular as an alternative source of drinking water. But rural people are not much aware about its usefulness and they have not enough knowledge about 'rain water harvesting' that they may collect and preserve rainwater during rain for future uses. Having no substantial practice on rain water harvesting rural people is losing plenty of pure water.

There is a close relation between global warming, climate change and rainfall in terms of duration and intensity. Because of its geographical position Bangladesh is vulnerable to the adverse impacts of global warming and climate change. Climate change impacts are adding significant stress to physical & environmental resources, and economic activities of Bangladesh. Sectors where major changes took place due to climate change are water resources, coastal resources, agriculture, health, livelihoods, food scrutiny, and habitant security (GoB: 2007). As a result of climate change, summers are becoming hotter, monsoon irregular, untimely rainfall, heavy rainfall over short period causing water logging and landslides, and very little rainfall in dry season. It has been predicted by PRECIS regional climate modeling that average daily rain will decrease up to 2020, but it will increase in remarkable rate after 2020 (Islam: 2009). So, duration and intensity of rainfall is the key factor of getting much rainwater for Bangladesh which can be used in household purposes in rural Bangladesh.

2.4 DRINKING WATER SUPPLY

Supply of drinking water is correlated with the collection process, availability and reliability of IDWSs. It is important to know from what sources rural households collect their drinking water. According to *Households Income and Expenditure Survey (HIES) 2005*, 95.28 per cent rural households collect their drinking water from tube-well. Rate of drinking water collection for rural households from supply water, pond/river/canal, well/indra, water falls/rain water and other sources are 0.54 per cent, 0.99 per cent, 2.37 per cent, 0.26 per cent, and 0.56 per cent respectively. Table-3 provides the percentage distribution of households by sources of drinking water.

Table-3: Percentage Distribution of Households by Sources of Drinking Water

Sources of Drinking Water Supply	**2000**	**2005**
Supply Water	0.37	0.54
Tube-Well	**95.75**	**95.28**
Pond/River/Canal	2.35	0.99
Well/Indra	0.97	2.37
Water Falls/Rain Water	-	0.26
Others	0.56	0.56

Source: HIES 2005, Self compiled

This table reveals that rural people largely depend on tube-well to collect drinking water and over the period degree of dependency is unchanged. But the most significant change that occurred within the five years is the use of pond-river water reduced remarkably and use of rain water increased slightly (HIES 2005: 20-21). It indicates that rural people are avoiding pond-river water and practicing to use rain water in smaller scale. According to *Demographic and Health Survey 2007*, 96.5 per cent rural households and 96.3 per cent rural population have access to improved source of drinking water. In the same report it is said that, 95.7 per cent households and 95.5 per cent population use tube-well water. So, tube-well remains the ultimate source of drinking water and rain water is becoming popular to the rural people as an alternative source.

2.5 PEOPLE'S ACCESS TO SAFE DRINKING WATER

People's right to get access to IDWSs is recognized internationally by United Nations Commission on Human Rights, International Convention on the Elimination of all forms of Racial Discrimination etc. The concept of 'right to water' contains both freedom and entitlements. Freedoms include the right to freedom from interference with water supplies, disconnection, or contamination and most importantly freedom to choice. Entitlement includes right to a system of water supply and management that provides equal opportunity to enjoy the 'right to water'. Throughout the world rural people's right to get access to safe water sources has become a problem in the early twenty first century. In an official message on World Water Day 2009, UN Secretary-General Ban Ki-moon said:

> Water is our most precious natural resource. More than ever we need to work together to use it wisely. While the world's growing population is consuming more freshwater, climate change is making less water available in many regions as glaciers recede, rainfall becomes less predictable, and floods and droughts become more extreme. Managing water carefully and balancing the varied needs for it is vital. ...our collective future depends on how we mange our precious and finite water resources.

This statement helps us to understand the gravity of water scarcity and peoples' access (global and national) to IDWSs. Empirically, Bangladesh is under stress in getting access to fresh drinking water. Due to existing and upcoming barriers on the accessibility to fresh drinking water, it requires prudent use and efficient management of water resources.

2.5.1 WORLD POPULATION WITH ACCESS TO IDWSS

The earth contains plenty of water because 70.80 per cent of the total area of the world is covered by water and 29.20 per cent is by land (Ittefaq: 2009). Having abundance of water, people suffer from 'lack of freedom' and 'lack of entitlement' on water resources which leads to inaccessibility. Both human civilization and population growth put pressure on IDWSs incrementally. 1200 million of the world population have no access to safe drinking water and 1.8 million children die every year because of having no access to safe drinking water and unhygienic sanitation (Janakantha: 2009). World population with sustainable access to improved drinking water sources is shown in the Table 4.

Table-4: World Population With Sustainable Access to IDWSs

Year	1900	2002	2004
Rural	63 %	72 %	73 %
Urban	95 %	95 %	95 %
Total	77 %	83 %	83 %

Source: WHO Statistical Information System

Table 4 shows that in the year 1990, 63 per cent of world rural people had access to IDWSs and in 2004 this rate was 73 per cent. World rural people's access to IDWSs increased 10 per cent in 14 years. It indicates that accessibility of world's rural people increased nearly 1 per cent per year.

2.5.2 BANGLADESH POPULATION WITH ACCESS TO IDWSs

After independence, Bangladesh achieved a remarkable success in both rural and urban areas in terms of access to IDWSs. According to a Demographic and Health Survey of 2004, 99 per cent of the urban population and 97 per cent of the rural population actually had access to drinking water sources if the presence of arsenic and other contaminants is not taken into account. After discovering arsenic contamination in groundwater in 1993, the share of the rural population with access to safe drinking water decreased remarkably. Progress of rural people's access to IDWSs by over one and a half decades is shown in Table 5.

Table-5: Bangladesh Population With Sustainable Access to IDWSs

Year	1990	2000	2006
Rural	**76 %**	77 %	**78 %**
Urban	88 %	86 %	85 %
Total	78 %	79 %	80 %

Source: WHO Statistical Information System (self-compiled)

According to World Health Statistics 2008, in 1990 the proportion of rural population with access to IDWSs was 76 per cent and in 2006 this rate increases to 78 per cent (WHO 2008: 66). For achieving a 2 per cent increase of rural people's access to IDWSs, Bangladesh took sixteen years. It may be noted that, in 1990 world rural people access to safe drinking water was 63 per cent and in Bangladesh it was 76 per cent. In 2004 world rural people's access to IDWSs was 73 per cent and in 2006 rural Bangladesh's coverage reached 78 per cent. In the base year and recent time, accessibility of rural Bangladesh was relatively high compare to accessibility of world rural people [Confusing]. The reason for lower average of coverage for world rural people, compared to Bangladesh, may be the lower accessibility to IDWSs of some countries in African continent.

2.5.3 CLASS CHARACTERISTICS IN CONSUMPTION

There is a relationship in the rural areas between households by size of land owned and access to drinking water sources. Consumption pattern of different classes of people (based on land ownership) are shown in Table 6.

Table-6: Rural household by size of land owned and sources of drinking water

Size of land owned	Sources of Drinking Water						
	% of Household	Supply	Tube-well	Pond/River	Well	Waterfall	Others
Landless	5.27	0.92	95.88	1.07	0.65	0.33	1.16
0.01-0.04	17.26	1.07	95.60	1.40	1.02	0.29	0.62
0.05-0.49	37.96	0.69	95.59	0.92	2.15	0.41	0.24
0.50-1.49	20.82	0.16	93.47	0.70	5.07	0.08	0.53
1.50-2.49	8.38	0.41	91.74	1.51	4.63	0.62	1.09
2.50-7.49	8.79	0.37	96.18	1.22	1.35	0.20	0.69
7.50 & above	1.52	0.00	**97.32**	**1.68**	0.00	0.00	1.00
Total	100	0.59	94.92	1.05	2.59	0.31	0.54

Source: HIES 2005

This table shows that the land owner class extensively uses tube-well water. But highest percentage (1.07%) of supply water used by land owning group 0.01-0.04 acre and 97.32 per cent households of highest (7.5 acre and above) land owner used tube-well water (HIES 2005, 2007: 22) [Very confusing sentence]. It proves that rich households have more access to tube-well water and the reason may be their higher affordability to install tube-well.

2.5.4 EDUCATIONAL ATTAINMENT AND CONSUMPTION

Knowledge helps to enlighten a man and education is one of the prominent tools to acquire knowledge. Since knowledge is key to understand the difference between good and bad, true and false, sin and virtue, profane and sacred, education has a significant role and influence in promoting people's accessibility to safe drinking water. Relationship between access to safe drinking water and educational attainment of head of household in the rural areas is shown in table number 7.

Table-7: Access to drinking water by educational attainment of head of households in rural area.

Source of drinking water	Educational Attainment							
	No class passed	**Class I-V**	**Class VI-IX**	**SSC/ HSC**	**Graduate/ equivalent**	**Post graduate**	**Doctor**	**Engineer**
Supply water	0.39	0.64	1.11	0.90	2.16	0.00	0.00	0.00
Tube-well	94.79	93.96	95.40	96.01	97.84	100.00	100.00	100.00
Other	4.82	5.40	3.49	3.09	0.00	0.00	0.00	0.00
Total	100.00	100.0	100.0	100.0	100.00	100.00	100.00	100

Source: HIES 2005

Table 7 shows that, access to supply water was highest (2.16 per cent) to the household heads having graduate or equivalent degree and lowest to the household heads with no education. On the other hand, highest rate (100 per cent) of access to tube-well water belongs to heads having educational level of post graduate, doctor or engineer. So, it is evident that, household heads having higher educational qualification have more access to IDWSs.

2.5.5 ACCESSIBILITY BY GENDER, ECONOMY AND RELIGION

Access to IDWSs has also gender, economic and religious dimensions. Traditionally, women and children were mainly responsible for collecting drinking water for the family. In Bangladesh, 96 per cent burden to carry drinking water from distant sources lies on women (UNICEF 2008: 1). Women in rural areas played greater role to collect drinking water for household but due to some socio-cultural reasons they are deprived or harassed to collect water if a tube-well is installed in the premises of a mosque or a school or in public place (Rammelt and Bose 2006: 9). Eventually, premises of influential person's houses are selected to install tube-wells (mainly government funded tube-well). Thus, richer women have more access to freshwater than poorer women. Rich people of rural areas have more access to safe drinking water because of economic solvency and affordability that helps them to choose the alternative sources. Women are the main manager to collect drinking water in rural areas but unfortunately they are more vulnerable to the consequences of arsenic contamination (Sultana and Crow 2000: 416-418). So, access to safe water sources is also differentiated based on stakeholders' socio-economic status, religion and gender.

2.6 NATURAL BARRIERS TO ACCESSIBILITY

Waterborne diseases due to unavailable safe drinking water are one of the leading causes of death in rural areas. Fresh drinking water in rural areas became unreachable due to some natural barriers. Major natural barriers include arsenic contamination in ground water, depletion of groundwater table, and salinity intrusion in coastal zone water sources.

2.6.1 ARSENIC CONTAMINATION

Arsenic is the 33rd most abundant element with an average concentration of 2 ppm in the earth's crust. Permissible dose of arsenic in drinking water of Bangladesh and WHO standard are 0.01 mg/litre and 0.05 mg/litre respectively (Azizan, Evans and Afzal 2002: 201). WHO has identified the arsenic contamination in Bangladesh as the 'largest mass poisoning of a population in history'. The largest mass poisoning of a population in history is now underway in Bangladesh. Arsenic in drinking water has been identified in 61 out of 64 districts of the country (Barkat et al. 2002: 216). In acute arsenic affected areas as many as 3 in 4 shallow tube-wells are contaminated (Faruque and Alam 2002: 3). Arsenic contamination of groundwater has a great consequence in rural drinking water supply coverage. However, the degree of contamination varies from 1 per cent to over 90 per cent and 29 per cent of the total examined tube-wells are contaminated with an average degree of contamination (Janakantha: 2009). Different studies show that, shallow tube-wells (<150 m depth) are mostly affected by arsenic. Deep tube-wells (>150m depth) are safe compared to shallow tube-well.

In 2001, the British Geological Survey and DPHE conducted a study in 433 thanas of 61 districts and tested 3534 tube-wells. Tube-wells with depth less than 150 meters, 72.56 per cent are affected by arsenic <0.05 mg/l and 27.44 per cent by >0.05mg/l of arsenic (Faruque and Alam 2002: 4). On the other hand, tube-wells with more than 150 meters depth, 99 per cent are affected by <0.05mg/l of arsenic and rest are affected by >0.05mg/l of arsenic. Statistics of that study is shown in Table 8. This study empirically proved that shallow depth aquifers are vulnerable for arsenic while deep aquifers are comparatively safer.

Table-8: Level of Arsenic Contamination in Bangladesh in Different Depth

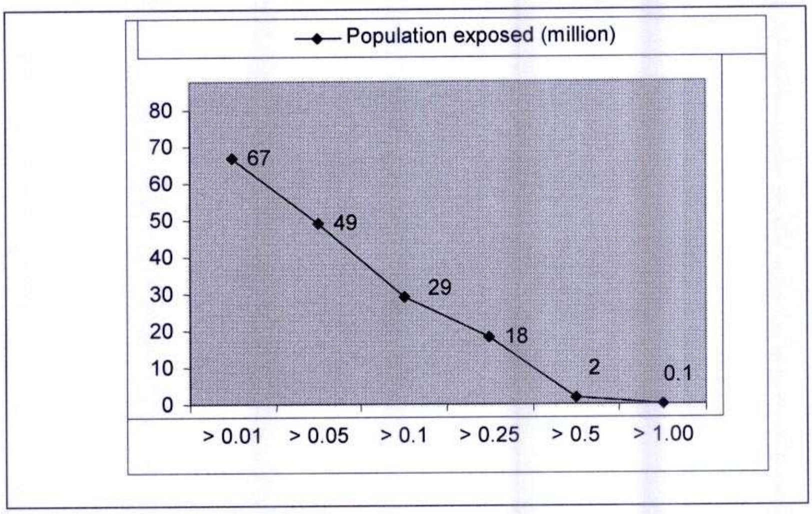
District	Upazila	No of tube-well tested	No. of well depth <150 m	Arsenic conc< 0.05 mg/l	Arsenic conc> 0.05 mg/l	No. of well depth >150 m	Arsenic conc< 0.05 mg/l	Arsenic conc> 0.05 mg/l
61	433	3534	3207	2327	880	327	324	3

Source: DPHE

Different studies carried by different professionals found different results in terms of population exposed to arsenic threat. According to World Bank estimation, 18 million people are poisoning themselves by drinking arsenic contaminated water and the health of 35 to 76.9 million people is at risk of suffering from arsenicosis (Barkat et. al. 2002: 219). Another study estimates that 1.44 million tube-wells are contaminated by arsenic and as a result throughout Bangladesh about 30 million people are severely exposed to arsenic threat (Ahmed 2008: Workshop paper). According to Cadwell et. al., 35 million people drank tube-well water that exceeded the Bangladesh maximum and 57 million drank water exceeded the WHO's recommendation level (Cadwel et. al. 2006: 336-345). In an interview published by the WHO in 2008, Professor Mahmudur Rahman quoted government estimates saying that 70 million people drink water which exceeds the WHO recommended level and 30 million drink water containing more than Bangladesh level (WHO 2008: 11-12). According to WAPRO, more that 20 million people drink water exceeding the national standard for arsenic (WAPRO 2000b). Risberg, in his thesis on 'Planning for sustainable water supply projects in Bangladesh-Public Participation in Practice' said that 30 million people drink water exceeding WHO recommended level of arsenic and 49 million people drink water exceeding Bangladesh level (Risberg 2006: 1-

32). Turk et. al. argued that the health of 35 to 80 million people is endangered due to water contaminated by arsenic (Turk et. al n.d.: 1-6). These statistics shows that rural people's access to safe drinking water is under trouble. Population exposed to different levels of arsenic threat is shown below in Chart 5.

Chart-5: Population Exposed to Different Level of Arsenic Threat



Source: Self compiled

Chart 5 indicates that if the higher concentration (0.5 mg/l) of arsenic contamination in drinking water is considered, then less population is exposed but at the lower level of arsenic concentration (0.01 mg/l), more population is exposed to arsenic threat. So, exposure to arsenicosis varies on the level of dissolved arsenic concentration is present in drinking water.

2.6.2 GROUNDWATER LEVEL DEPLETION

Groundwater levels have dropped for various reasons; the crucial one is withdrawal of groundwater from the different level of aquifers for drinking, irrigation, and industrial uses. Almost 70 per cent of all mobilized freshwater under the ground is used for agriculture by deep tube-wells. Excessive withdrawal of groundwater for agriculture and increased consumption of water due to rapid urbanization and industrialization are the causes of groundwater depletion. Negative effects of lowering ground water table includes drying up of wells, reduction of water in streams and lakes, deterioration of water quality, increased pumping costs and land subsidence.

A study carried out under 'National Water Management Plan Project' reported that the groundwater table has been lowered over the last two decades and every year this rate is one meter per year. A DPHE finding shows that water table has fallen beyond suction limit of about 27 per cent tube-wells in 2004. It is reported that in the Chunaroghat Upazila of Hobiganj district 60 per cent of tube-wells can not pump groundwater both for drinking or irrigation (Jugantar: 2009). And hand operated tube-wells of 50 villages of Putia upazila under Rajshahi district were not able to pump groundwater due to lowering water table (Prathom Alo: 2009). It is estimated that, about 55 million people are denied the use of water from tube-wells due to a fall in groundwater tables during the dry season (UNDP: web report). Even in the Hill Tracts (Kagrachori district) people are suffering from drinking water scarcity because of lowering water table (Ittefaq: 2009). Thus, Bangladesh faces acute water scarcity in the dry season due to lowering of the groundwater table.

2.6.3 SALINITY INTRUSION

Salinity intrusion in surface and groundwater of coastal area is one of the major obstacles getting access to safe drinking water. Bangladesh has a 170 km long coast line along the Bay of Bengal. The coastal zone covers 147 upazilas of 19 districts. Abut 35.1 million people of 6.8 million households live in the coastal zone (Sarwar 2005: 1-3). Due to the geographical position, the country is likely to be affected by climate change and sea level rise (CCSLR) and is identified as one of the most vulnerable countries in the world (Rahman 2009: 1). Salinity in both ground and surface water is one of the common but painstaking problems in 76 upazilas of 19 districts located in coastal zone. Salinization degraded water quality and it is due to the reduction of freshwater flow from upstream (GoB 2001: 50). It is evident that large numbers of people in the coastal area have no access to fresh drinking water.

According to the Third Assessment Report of IPCC, the projected global average rise from year 1990 to 2100 was 9 cm to 88 cm. Being one of the most densely populated countries, more people of Bangladesh are vulnerable to SLR. With one meter seal level rise, 20 per cent habitable land would be inundated and 15 million people need to migrate to other part of the country (Nasreen 2008: 8). Another study estimates that by 2050 the sea level will rise one meter. This amount of rise of sea level combines a 90 cm rise in sea level and about 10 cm local rise due to subsidence (Rahman and Rahman 2007: 79). In the south-west coastal area sea level is raising by 3 to 4 mm every year. It was reported that, eventually [??] women and children of coastal area have to walk 10-12 km everyday to collect on average 3 pitches of safe drinking water for a family (Janakantha: 2009). Sea level rise makes the fresh water of coastal area salty and people are bound to collect fresh drinkig water from distant sources.

Apart form sea level rise, reduced river flows in the dry season, reduction of average rainfall, and over pumping of groundwater for irrigation are major causes of salinity ingression in both surface and groundwater of coastal area. Increased levels of salinity intrusion prohibited about 30 million people's of coastal zone to get access to the nearly available sources and 15 million people are forced to drink saline water having no alternatives (Hossain and Hossain 2007: 23). So, increased rate of SLR and salinity intrusion are creating havoc to the people of the coastal zone getting access to fresh drinking water.

To make the surface and groundwater of coastal areas drinkable and to meet the increasing demand desalinaization technlologies need to be introduced. Some countries are building desalination plants as a small element in addressing their water crises. Besides that, some countries are introducing technological innovations to reduce the capital cost of desalination (www.medrc.org). Leading desalinization technology using countries are Israel and Singapore. They desalinize sea water for the cost of 53 cents per m^3 and 49 cents per m^3 respectively. Along with these two countries, China, India, Pakistan, Saudi Arabia, Australia and United States are also practicing desalination to provide safe water to their citizens (www.hindu.com, www.nzherald.co.nz, www.world-nuclear-news.org). An article in the Wall Street Journal states, "World-wide, 13,080 desalination plants produce more than 12 billion gallons of water a day, according to the International Desalination Association (Kranhold: 2008) [Where does the quote end]. So, the Bangladesh government needs to think about desalinization plant to ensure fresh drinking water for the people of coastal zone.

2.7 MDG AND SAFE DRINKING WATER

The Millennium Development Goals (MDGs) have emerged to reduce extreme poverty, reducing child mortality rates, fighting disease epidemics such as AIDS, and develop a global partnership for sustainable development. MDGs are eight international development goals with 21 targets that 192 United Nations member states and at least 23 international organizations have agreed to achieve by the year 2015. MDGs were developed out of the eight chapters of the United Nations Millennium Declaration and signed in September 2000 (http://www.un.org). Fresh water supply is included in goal 7 and target 10. The goals are the areas where governments have failed to ensure quality service which are the fundamental rights of the citizens. Because of the failure of governments in those sectors, MDGs have emphasized on those life threatening issues.

The Millennium Development Goals have targeted to halve the proportion of people without sustainable access to safe drinking water by 2015. If Bangladesh can achieve this target by 2015, then more than 15 million people will live without having access to IDWSs (Rooy 2009: 4). But Bangladesh is far behind to achieve this target. Current position and target is shown in Table 9.

Table-9: Access to Safe Drinking Water: MDG Status of Bangladesh

Bangladesh Target		**Current(2006)**	**Target(2015)**
Ensure that 100% of urban and 96.5% of rural population have access to safe drinking water by 2015	Rural	**78 %**	**96.5 %**
	Urban	85 %	100 %

Source: Self compiled

In order to achieve the MDG (goal no. 7, target no. 10) Bangladesh needs to increase the accessibility of rural people from 78 per cent to 96.5 per cent by 2015. Statistics shows that, it seems very difficult to achieve MDG's target. For this complicated situation, the process of mobilizing predictable external finance to meet the MDG goals is the main challenge. Quantity of official financing was declining in official development assistance relative to rising demand of the poor countries (Cheru and Bradford 2005: 3). If local effort and donor finance match together in an efficient manner only then Bangladesh has the possibility to achieve the MDG goal in safe drinking water.

amplified all over the world (Corell and Swain, 1995: 126). It is evident that the amount of water is not a big problem to get access of IDWSs rather natural and human induced barriers. Contamination of water by harmful chemical substances (excessive amount of arsenic, iron, salt etc) makes water unpleasant to drink, and lowering ground water table and drought makes it difficult for the people to reach IDWSs. These are the major problems of water resources management in recent days. So, the current crisis of drinking water in Bangladesh is primarily related to water governance. This is why sustainability issue comes in along with water governance. Sustainability is a fast-growing environmental issue such as pollution, population growth, land-use change and climate change. If we do not put greater efforts aimed at sustainability, more extreme and devastating events are expected to occur. For instance, climate change could make droughts disaster more frequently in many areas already coping with water scarcity. So, without making water resource sustainable, only good governance can not ensure rural people's access to IDWSs.

3.2 WATER GOVERNANCE

The term 'water governance' emerged when billions of people through out the world were deprived of getting access to improved drinking water sources. In rural areas of Bangladesh, millions of people have no access to improved drinking water sources too. To minimize the proportion of rural people's access to IDWSs, water governance issue comes in and many intellectuals and academicians define water governance in many ways. UNDP defines water governance as the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of services at different levels of society (UNESCO-WWAP: 2003). Good water governance may resolve the crisis mounting in rural Bangladesh but to achieve good governance in drinking water service delivery system, the stakeholders' participation in decision making process is a must. From a practical sense, it is difficult to encapsulate citizens' participation accurately and it requires social movement which includes different types of engagement and learning (Risberg 2006: 7). Another school of thought argues that water governance enables a proper balancing of the true values of water, and serves to enhance awareness of water problems and acceptance of their solutions. Water governance can also be defined as 'balance of power' and 'balance of actions' of different levels of authority. It necessarily requires favorable political system, laws, regulations and stakeholders' rights[2]. Improvement of governance is one sort of continuous reform process.

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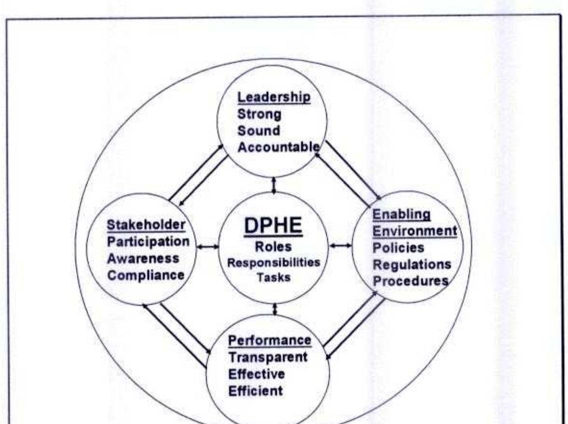
[2] This proposition is taken form a document, Dialogue on Effective Water Governance: Learning from the Dialogues. This report was prepared by The Global Water Partnership (GWP) for presentation at the 3rd World Water Forum in Kyoto, Japan, March 16-23, 2003. GWP was created to foster Integrated Water Resources Management (IWRM), which aims to ensure the coordinated development and management of water, land, and

In the area of public governance there are six principle elements of good governance: (a) accountability, (b) transparency, (c) efficiency and effectiveness, (d) responsiveness, (e) forward vision and (f) rule of law (OECD: 2009). All these elements of good governance are interdependent and work together in a coordinated manner based on the principles of participation and decentralization (Franks 2004: 7). On the other hand, tools of water governance include an institution/service providing agency, stakeholders, leadership and activities of the institution, and finally enabling environment for good governance. The institution involved in management and development of drinking water sources has some roles, responsibilities and tasks. These roles, responsibilities and tasks have to be clearly defined to improve the institutional performance of service providing agency. To facilitate this, water policies, regulations and administrative procedures must be harmonized with the context of the problem for enabling the environment of good water governance. Strong, sound and accountable leadership is indeed as a key feature of good water governance. Activities of the service providing agencies should be transparent and level of institutional efficiency should be high to ensure effective service delivery. Moreover, stakeholders' participation in decision-making process, awareness about hazards of unsafe water and prudent use of water, and compliance to the service proving activities are essential. For optimization of output from the central agency or ensuring good governance for better service delivery, all these elements of good governance are need together in a combined and coordinated manner. This system is shown in a model[3] below:

Diagram-1: Comprehensive Water Governance Model



Source: Royal Haskoning, Netherlands

It is evident that, to solve the crisis of safe drinking water exist in rural Bangladesh comprehensive water governance is essential. Water governance deserves great deal of

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related resources by maximizing economic and social welfare without compromising the sustainability of vital environmental systems.

[3] Royal Haskoning, an independent Netherlands based consultancy firm, with worldwide operation, proposed this model of water governance. Royal Haskoning is a partner in improving water governance. They believe, knowledge creation and its transfer from one country to another can make a significant contribution to better water governance.

focus due to increasing population, rapid urbanization, faster industrialization and essential investment on communication infrastructure. One of the lessons learned from 88 early implementation projects in Bangladesh during two decades is that water resource management systems are socio-technical in nature. Complexity of issue and range of perspective among and between related infrastructures, water bodies, land and people, and institutional issues & frameworks demand an integrated approach of water governance (Bari 1999: 100-102). For effective water governance, improved institutional capacity is essential. Public sector or market oriented private sector alone can not solve all challenges in water resource management. Dynamic but accountable relationship between different service providing agencies and stakeholders, improving coordination and consultation among them, and avoidance of single purpose authoritative and supply driven service strategies are the pre-requisites for the governance procedure in water sector. Effective governance may help to reduce fragmentation and resolve conflict among and between service providing agencies, stakeholders and civil society. Equitable distribution of water services and environmentally sustainable management of water resources are the solutions to overcome the present crisis prevailed in drinking water supply in rural Bangladesh. In this process, along with the service provider and stakeholders, civil society has an important role to play.

Presently, in rural Bangladesh, 78 per cent of water supply infrastructures are managed by private individuals. Therefore, it is clear that contribution of public institution is not significant, particularly, in terms of installation of tube-wells in rural areas (SDP: 2005). Although access to safe drinking water is increasingly barred by natural barriers and human activities, it is not possible to face the challenges only by the effort of private individuals. An effective and sustainable water resource management system requires a strong institutional framework. Datta and Nishat suggested that institutional framework with long term water resource management system involves (a) integrated water resources management, (b) institutional arrangements, and (c) decentralization of decision making and linkages with local government (Datta and Nishat 1999: 154-157). So, integrated approach, strong institutional framework, stakeholders' participation, and decentralization of decision making process are the key issues of effective water governance.

3.3 PRINCIPLES OF WATER GOVERNANCE

The principles of water governance are defined and presented in different ways by different school of thoughts. A seminar on 'The Water Consensus-Identifying the Gaps' organized by Bradford Centre for International Development, proposed some general principle for effective water governance. Effective water governance should be (a) open and transparent, (b) inclusive and communicative, (c) coherent and integrative, (d) equitable and ethical. Its performance and operation should be (a) accountable, (b) efficient, (c) responsive and sustainable (Franks 2004: 2). The UNDP, in its 'Water for Life' report argues that, water governance must include eight elements. These are participation, accountability, transparency, integration, equity, coherency, responsiveness, and most importantly ethics (UN-Water: 2004). Proper application of elements in the process of water resource management may help to provide safe drinking water to the rural people.

3.4 SOCIAL AND ECONOMIC BACKGROUND OF WATER GOVERNANCE

Water governance does not depend only on institutional factors such as legislation and organizational structure but there are also socio-economic circumstances and quality of administration for the sustainable water resource management. A lack of awareness of this reality, coupled with ignorance about drinking water management, can result in the proposal of over-simplified, uniform and generalized prescriptions that are too simplistic, or ideological, and eventually counterproductive. According to Solanes and Jouravlev, water governance has social and economic perspectives (Solanes and Jouravlev 2006). These are as follows:

a. Social, economic and political challenges
    1. Raid population growth and urbanization
    2. low but heterogeneous levels of economic development
    3. high levels of poverty and indigence
    4. important deficits in health
    5. human development
    6. political and social instability
b. issues facing the state and civil society
    1. the inefficiency of public administration
    2. the weak regulatory role of the State
    3. The weakness of civil society
    4. capture and corruption
    5. the emergence of new issues
    6. problems associated with globalization
c. factors favoring the search of solutions

3.5. KEY ISSUES OF WATER GOVERNANCE

Human society is becoming more complex and the intensity of human impact on natural resources is also becoming more severe. This is why the need to integrate the different elements of water management becomes imperative and effective water governance is closely linked to integrated water resource management. Water governance as well as integrated water resource management covers some key issues and socio-economic circumstances of a nation (Solanes and Jouravlev 2006). To understand and attain sustainable water governance it is important to know the key issues related to this concept. Key issues related to the governance of the water sector include:

a. the legal nature of water , water allocation and reallocation, and the role of the State
    1. ownership of water resources
    2. water rights
    3. conditions of water rights
    4. water markets
b. the institutional structure for water management
c. economic rationality and social demands
    1. Drinking water supply and sanitation
    2. State support for irrigated agriculture
    3. priorities in water allocation
    4. water charges
d. the role of the State and the regulation of public services
    1. the weakness of current regulatory frameworks
    2. public services
    3. irrigation and drainage
e. the issue of the appropriate level of government
f. public participation
g. the environmental dilemma
    1. Protection of environmental uses
    2. water pollution control
    3. building major hydroelectric works
h. protection of the interests of ethnic groups and customary users
i. conflict resolution
j. public policy decision making

Another issue that is closely related to water governance is climate change. Climate change has greater impacts on water resources and with sophistication of knowledge and technology, it is now measurable. This paradigm shift induces us to think about harvesting water resources for human need, and reducing the risk of severe situations. But it is noticeable that pressures on the inland water system are increasing with population growth and economic development. It is predicted that, by the middle of the twenty first century, about 7 billion people in sixty countries will be at acute water-scarcity. Recent estimates suggest that climate change will account for about 20 percent of the increase in global water scarcity (UNESCO 2003: 10). So, progressive water shortage is becoming crucial challenge for the people of the world as well for Bangladesh.

3.6 PURPOSE OF WATER GOVERNANCE

Water governance cover many thematic areas that ranges from integrated water resources management, trans-boundary water management, and water supply & sanitation to climate variability, gender and institutional capacity building[4]. Prudent water management is fundamental to ensure rural peoples' access to safe drinking water as well as to the achievement of MDG (target no. 10). There are many purposes of water governance. Main purposes include:

1. improved water governance to achieve socially equitable, environmentally sustainable and economically efficient management of drinking water resources
2. implementation of integrated water resource management at local, national, and regional levels
3. achievement of MDG target for water supply within the given timeframe.

Water governance addresses the formulation and adoption of sustainable legislation, policies and institutions. It also addresses the way legislation, institutions and policies are being established, enforced, and implemented. Clarification of the roles and responsibilities of all involved stakeholders (local and national government, private sector, civil society) regarding ownership, administration and management of water sources are very much pertinent to drinking water governance.

3.7 WATER TECHNOLOGIES AND WATER GOVERNANCE

Pressure on the drinking water resources is increasing alarmingly everyday. Population growth, changing demand of consumption, choice of technology in collecting drinking water from its sources, rapid urbanization, overall socio-economic development influence on scarcity of drinking water resources. All types of pollution, climate change induced SLR which results in seal level rise, lowering groundwater table, natural disaster, excessive amount of dissolve inorganic salts, agricultural inputs (fertilizer, insecticides etc.), and land use created the existing tension of availability of fresh drinking water (Hoekstra 2006: web publication). Considering these obstacles in different problematic areas different water lifting technologies are being used. In rural Bangladesh, people largely depend on groundwater for drinking water and generally six types of technologies are used to collect drinking water from its sources. These are shallow tube-wells (STW), deep set pump (DSP) tube-well, deep tube-well, arsenic mitigation technologies, problem area technologies, and piped water supply (PWS). Besides, intervention is needed during emergency situations. Among these technologies, STW and DSP are easy to install and comparatively cheaper. For these reason, these two technologies are affordable by the rural people and widely used in rural Bangladesh. Deep tube-well, arsenic mitigation

[4] 'Water Governance Facility' a program launched by the UNDP with collaboration with Stockholm International Water Institute to support developing countries to improve water governance comes up with this proposition. This program seeks integrated water development solutions for poverty alleviation and addresses the social, economic and environmental aspects of water challenges.

technologies, and technologies used in problematic areas/zones are technologically rich and expensive. Installation of these technologies is not as easy as STW and DSP. So, high tech and cost intensive technologies can only be afforded by the rich people and not by the mass. Piped water supply and water supply requires huge investment in infrastructure and providing fresh water supply in emergency situation is difficult by private individuals. So, depending on the technology, affordability, burden of collection and geo-hydrological condition of rural areas single type of water governance can not meet this catastrophe. In the light of socio-economic, political and historic contexts, water governance can be divided in three forms (Medalye 2008: 2-3). These are:

a. public water governance
b. private water governance, and
c. public-private partnership in water governance.

3.7.1 PUBLIC WATER GOVERNANCE

Public water governance for rural areas requires enormous infrastructural development. Villages in the rural areas are in clustered form. For this reason, centralized management of drinking water supply is difficult. On the other hand, rural people are accustomed with the use of pond & river water for washing and bathing, and groundwater for drinking. So, in the form of public water governance, government has to install plenty of deep pumps or purification units which may not feasible indeed.

Public water governance is the most widely used governance structure under which the government takes on all of the responsibilities and challenges of drinking water services. Public water governance is popular in developed countries. The USA, Canada, Japan, Australia, New Zealand, and most European Union member states choose public sector management for water supply. In public water management system ministries/divisions, local government institutions, and government line agencies are involved to provide water services in rural areas. In this form of public water governance, decisions and management of infrastructure, and operations and maintenance are taken care of by the government. The government is responsible for oversight, setting standards, allocation budget to line agencies, selecting site and contractor for installation, and facilitating public communication and participation (Medalye 2008: 4). In a nutshell, public water governance is a supply driven service delivery system. Worldwide 85 per cent of drinking water provision lies in public hands.

3.7.2 PRIVATE WATER GOVERNANCE

Private water governance[6] is the opposite of public water governance. However, total transfer of government responsibility to private sector is impractical and exceptional. This

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[6] Private water governance (PWG) is practiced in United Kingdom and France. PWG is partially practiced in Chile.

sort of transfer takes place by inviting private sector to investment in drinking water supply and giving the responsibilities to ensure safe water supply to the citizen. As such, infrastructure, capital investment, commercial risk, and operations and management become the responsibility of the private service provider (Medalye 2008: 8). In turn, private sector sells water to citizens at an affordable cost. But there is little scope for rural people to participate in decision making process regarding quality of supply and cost per unit.

The main motive of private sector is to maximize the profit. If private sector operates drinking water management then efficient water governance may achieve but the price of drinking water will be high. With high price only the people of higher income groups can avail sufficient amount of drinking water when a large number of rural people are suffering from drinking water crisis. It is hard to pay higher price for water supply by the rural people when they have to struggle for survival everyday. In this grave water crisis, private sector's roles and responsibilities for safe water supply may become popular but there must be some sort of controversy in terms of cost and security.

There is another aspect of this governance system. If responsibility of water supply and management of drinking water sources fully transferred to the private sector then another problem might be emerged instead of solution. Private entrepreneurs always try to maximize their profit. When maximizing profit is the motto of private sector — public health and humanity may not be considered by them. If any problem evolved in service delivery system and private entrepreneurs fail to ensure water supply to the citizen, it may create havoc in the safe water supply sector as well as on the status of public health. This is because poor people of rural areas do not have the ability to get fresh drinking water from alternative sources if private sector fails. So, intervention of public sector is a must in water supply system but the degree of intervention might be the question and public-private partnership may bring the best solution.

3.7.3 PUBLIC-PRIVATE PARTNERSHIP IN WATER GOVERNANCE

The concept of public-private partnerships emerged in early 1990s and became a promoter of governance approach to resolving problems. A public-private partnership in the water sector involves transferring some of the roles, responsibilities, authorities, and tasks form public sector to private sector. Gleick noted eleven water system functions that can be privatized. These are:

1. Capital improvement planning and budgeting (including water conservation and wastewater reclamation issues)
2. Finance of capital improvements
3. Design of capital improvements
4. Construction of capital improvements
5. Operation of facilities

6. Maintenance of facilities
7. Pricing decisions
8. Management of billing and revenue collection
9. Management of payments to employees or contractors
10. Financial and risk management
11. Establishment, monitoring, and enforcement of water quality and other service standards

There are a multiplicity of arrangements of public-private participation including budget allocation, authority segmentation, service contracts, management contracts, and decision making (Gleick 1993). In case of decision, new model of decision making process like 'network distributed decision support system' come into consideration (Franks 2004: 9). But it is not empirically validated and in case of Bangladesh, it may fluctuate due to the geo-hydrological condition and socio-economic status of the rural people. In the problematic areas, and after and during natural disasters, government will take responsibilities to ensure safe drinking water for the rural people. In the acute problematic areas i.e. salinity intrusion, arsenic contamination and lowering water table, public-private partnership[7] may bring good result in ensuring rural peoples' access to safe drinking water.

Under these arrangements public water utilities give responsibility to the private sector for operation and maintenance activities. Such arrangement requires managerial and operational expertise. Here, public sector will play the role of steering when private sector will play the role of rowing. This arrangement may be determined by management contracts and arrangements for specific time. It could be short-term or medium-term and tend to be paid on a fixed or performance basis. In a service contract, a private entrepreneur takes responsibility for a specific task, such as installation and maintenance of water pumping stations & meters, maintenance and repair of equipments (water pumping technologies and pipe etc.), building water and sewerage networks, and collection of bills etc. In this governance process, demand driven service delivery and participation of rural people in decision making process need to be ensured.

3.8 SUSTAINABILITY

Science proved that everything in the earth is constant and one thing can only be transformed into another by various processes and the total amount of "energy" is constant in the "universe" which can be transformed to various forms including matter. For example, the amount of water in the earth is constant but the amount of liquid water can be reduced if it is transformed into ice or vapor and it can be increased if solid ice is melted or vapor is concentrated. It can be noted that, melting of ice caps is bad for us although it technically gives us liquid water. So, we should consider sustainable use of

[7] This model is found in the Netherlands, Poland, Chile, and the Philippines.

water by keeping the ice of polar region intact. In this context, once American President John F Kennedy stated that, "the supreme reality of our time is the vulnerability of this planet". This notion helps to understand the gravity of water scarcity (for variety of uses) exists in the world, as well as in Bangladesh. To some extent human beings are totally helpless upon this natural game. The very term 'sustainability' evolved to reduce the vulnerability of this planet through prudent use i.e. reduce, reuse and recycle, of natural resources (Brower and Leon, 1999). Reuse and recycle helps to make a resource sustainable. Another term 'sustainable development' is first introduced to the international community in 1987. It was first coined in the *World Commission on Environment and Development* (commonly known as Brundtland Commission) report named 'Our Common Future'. This term was characterized by the United Nations to examine the planet's critical social and environmental problems, and to formulate realistic proposals to solve them in ways that ensure sustained human progress without depleting the resources of future generation.

Scholars and academicians define 'sustainability' and 'sustainable development' in different ways. According to Brundtland Commission, the goal of sustainable development is to create a new era of economic growth to eliminate poverty and extending to all people the opportunity to fulfill their aspirations for a better life. The commission stated that, 'an equitable distribution of benefits requires political systems that secure effective citizen participation in decision making and by greater democracy in international decision making.'

In plain terms, sustainability means:

Rate of depletion/consumption/use ≤ Rate of production/reformation/recharge

The idea of sustainable development is sometimes viewed as an oxymoron because development inevitably depletes and degrades the environment (Redclift 2005: 212-227). The most popular and widely accepted definition of sustainability is given by Brundtland Commission which is 'to meet the needs of the present without compromising the ability of future generations to meet their own needs'. It means improvements in human well-being that can be extended or prolonged over many generation rather than just a few years. The hope of sustainable development is that if benefits are truly enduring, then they may be extended to all human rather than just the members of a privileged group of present generation.

3.8.1 PRINCIPLES OF SUSTAINABILITY

The concept sustainability is developed based on four principles (James 2003: web publication). These are:

1. Reduce dependence upon fossil fuels, underground metals, and minerals.

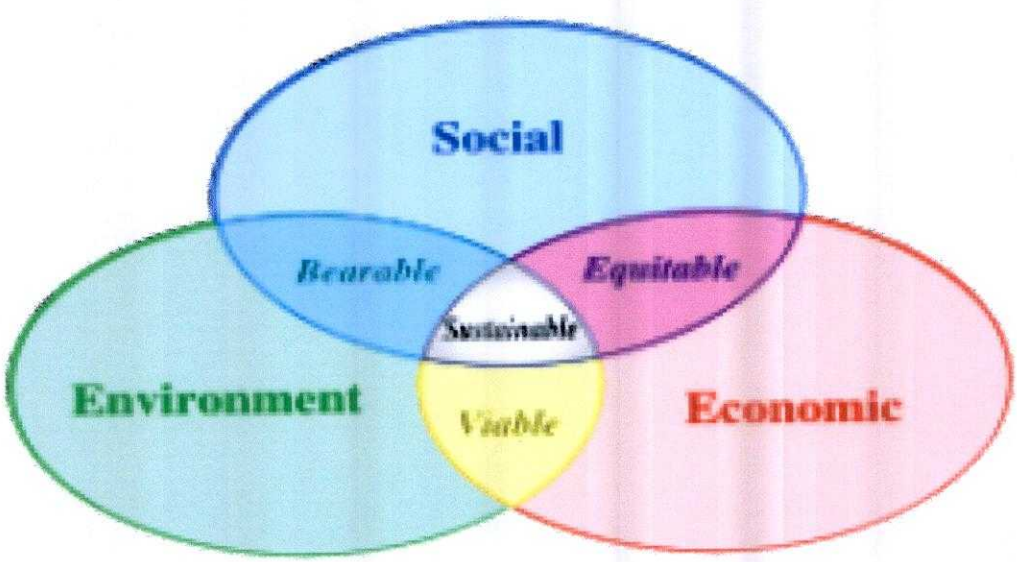
2. Reduce dependence upon synthetic chemicals and other unnatural substances.
3. Reduce encroachment upon nature.
4. Meet human needs fairly & efficiently.

Essence of these principles is based on renewable and non-renewable resources of the nature. In case of non-renewable resources it is mandatory to reduce dependance on it and search for alternative sources. On the other hand renewable resources requirs efficient use and prudent management.

3.8.2 DIMENSIONS OF SUSTAINABILITY

The term sustainability has three major dimensions and these are commonly known as 'three pillars'. Grate Britain Forestry Commission named these pillars of sustainability as environmental, social and economic dimension. These can be depicted as three overlapping ellipses to show that they are not mutually exclusive and can be mutually reinforcing. To understand the sustainability interactions of three pillars is needed and it is shown below:

Diagram-2: Interaction among three pillars of sustainable development.



Source: Grate Britain Forestry Commission

When economic and social values are protected then it is 'equitable', when social and environmental aspects are taken care off, it is called 'bearable' and when environmental and economic values are secured then it is called 'viable'. Equity, bearability or viability alone do not mean the sustainability. A system will be sustainable when equity, bearability and viability are merged together (Adams 2006: web publication). So, considering social, economic and environmental dimensions there are very little space for 'sustainability' which is shown in the center of the three overlapped ellipses.

3.8.3 CONSUMPTION AND SUSTAINABILITY

The concept sustainability is very much related to human consumptions pattern. Before consuming any natural resources (renewable or non-renewable) it need to be kept in mind the following principles:

1. **Integration of all pillars:** integrating environmental, social and economic sectors when developing sustainability policies
2. **Decoupling economic growth from environmental degradation:** managing economic growth to be less resource intensive and less polluting
3. **Intergenerational equity:** providing future generations with the same environmental potential as presently exists
4. **Ensuring distributional equity:** avoiding unfair or high environmental costs on vulnerable populations
5. **Ensuring environmental adaptability and resilience:** maintaining and enhancing the adaptive capacity of the environmental system
6. **Accepting global responsibility:** assuming responsibility for environmental effects that occur outside areas of jurisdiction
7. **Protect ecosystem and human health:** preventing irreversible long-term damage to ecosystems and human health
8. **Education and grassroots involvement:** people and communities investigating problems and developing new solutions

These principles help to formulate a integrated frame work for sustainable development (Stanners et. al. 2007: 156). Now we can look towards water and sustainability.

3.8.4 WATER AND SUSTAINABILITY

Water is a renewable resource. This planet contains plenty of water[8]. All life depends on the global water cycle. Water cycle starts from evaporation from oceans and land water bodies to the form of water-vapor. Later water-vapor condenses and form clouds which then come to land as rain (Clarke and King 2006: 20-21). This water cycle is the renewable process of the freshwater supply on which we all living things depend.

During the 20th century, awareness of the global importance of preserving water for ecosystem services has emerged. Because at that time, it is found that, more than half the world's wetlands have been lost along with their valuable environmental services.

[8] It is estimated that, water covers 71% of the Earth's surface. 97.25% of total water salty water. Remaining 2.75% is fresh and 74.54% of this freshwater is stored in the polar region in the form of ice. The rest is found in lakes, rivers, wetlands, the soil, aquifers and atmosphere.

Freshwater habitats are the world's most vulnerable because freshwater is reducing but it is simultaneously needed for drinking, irrigation, industrial and domestic use. Human freshwater withdrawals make up about 10 per cent of global freshwater runoff and of this 15–35 per cent are considered unsustainable. Proportion of human freshwater withdrawal may be unsustainable in a higher rate because climate change worsens, populations increase, aquifers become progressively depleted and other supplies become polluted and unsanitary. Increasing urbanization pollutes clean water supplies and still many people of the world do not have access to clean, and safe water (Clarke and King 2005: 22-23). So, it is important to address the issue of freshwater scarcity immediately. Besides, giving emphasis on improvement of efficiencies and infrastructural development, importance on the improvement of 'blue (harvestable)' and 'green (soil water available for plant use)' water management need to be taken into consideration.

Groundwater withdrawal was becoming high throughout the world in the mid 20th century for the sake of food security. In the decade 1951-60 human water withdrawals were four times greater than the previous decade. This rapid increase of withdrawals resulted from scientific and technological developments impacting through the economy. Groundwater mainly increased for irrigation, production of water intensive high yield crop, growth in industrial and power sectors. This altered the water cycle of rivers and lakes, affected their water quality and therefore potential as a human resource and, most significantly, altered the global water cycle (Shiklamov 1998: web publication). Over the period 1961 to 2001 there was a doubling of demand and over the same period agricultural use increased by 75 per cent, industrial use by more than 200 per cent, and domestic use more than 400 per cent (Millennium Ecosystem Assessment 2005: 51-53). Irrigation in agriculture put tremendous pressure on groundwater source. Nearly 75 per cent of cultivable lands are irrigated by groundwater. This is one of the main reasons for lowering water tables in rural areas. As a result of more dependency on groundwater for irrigation, most irrigation pumps become out of order after few years of its installation (Jansen, 1986: 40). Groundwater withdrawal for many purposes leads to drinking water scarcity. So, it is important to make groundwater sustainable by initiation short time and long time measures.

3.9 Measures to Make Drinking Water Resource Sustainable

It is obvious that water resource management include drinking water management. To ensure sustainability of water resources it is important to increase the level of efficiency regarding water resource management (Hoekstra and Chapagain 2007: 35-48). For an effective WRM coordination between and among all relaevant agencies is essential. Involvement of all stakeholderss in the process of decision-making, implementing and operation in the water resources management system need to be ensured. In order to maximise the utility of both surface and ground water there must be a proper balance of regulatory and incentive mechanisms. This sort balance requires certain process of the necessary monitoring, control and enforcement of management strategies (Alam and Koudstaal 2001: 2). An operational and effective Integrated Water Resource Management may be the key to make water resource sustainable and theoraticlly it can ensure the optimization of use and reduce the wastage of this valuable resource. Literaly, prudent WRM includes:

1. demand management
2. maximizing water resource productivity of agriculture
3. minimizing the water intensity of goods and services
4. short-medium-long term planning for facing the challenges of climate change
5. prudent use of drinking water sources
6. development of indigenous technologies to solve water quality problems
7. protection of water bodies and
8. recharging of groundwater.

These activities are the long term measures to make water resources sustainable. Immediate measures need to be taken to keep the drinking water resource within the reach of the commonly used water lifting technologies. As we consider groundwater as a common source for drinking, irrigation, industrial use and household uses then the drastic reduction in the availability of drinking water is not surprising. To keep pace with the increasing demand for freshwater supply, it is necessary to go for artificial recharge of groundwater to meet the immediate requirement. Equal or more recharge of freshwater sources than its withdrawal may make fresh drinking water resources sustainable. Though groundwater is the most reliable source both for drinking, irrigation and industrial uses then efficient groundwater, recharge may be one solution to drinking water scarcity.

3.9.1 GROUNDWATER RECHARGE

The increasing demand for water has instigated people to think towards the artificial recharge of groundwater. Groundwater recharge is needed to make up the deficiency of water in the aquifer. Groundwater recharge occurs both naturally and anthropologically (Bond 1998). Naturally groundwater is recharged in the unsaturated zone by rain and snow melt and to a smaller extent by surface water (rivers, ponds, haor-bils and lakes). Natural recharge may be obstructed by human activities including paving, development, or logging. Anthropological groundwater recharge means artificial groundwater recharge processes.

Groundwater recharge is an important process for sustainable groundwater management (Allison, Gee and Tyler 1994). It becomes effective mainly in the areas where groundwater table is lowered due to excessive and heavy withdrawal of groundwater, coastal area where ground and surface water become salty due to salinity ingression, and water table depleted during dry season due to relatively less recharge. It is a process by which surface water is directed into the ground by using recharge well or by altering natural conditions to increase infiltration[9] to refill an aquifer and an effort to raise the levels of groundwater table through appropriate method (Kumar and Aiyagari 1997: 1). Kumar and Aiyagari suggest two kinds of recharge processes:

a. **DIRECT ARTIFICIAL RECHARGE:** Direct artificial recharge depends on three factors: (a) the infiltration rate, (b) the percolation[10] rate and (c) the capacity for horizontal water movement. Direct artificial recharge could be done by-

i. direct recharge
ii. recharge pits & shafts
iii. recharge ditches and
iv. recharge wells.

b. **INDIRECT ARTIFICIAL RECHARGE:** In the process of indirect artificial recharge, water aquifers are not refilled through injecting water underground but by infiltration. Indirect artificial recharge could be done by-

i. enhance streambed infiltration and
ii. conjunctive wells.

Artificial recharges, both direct and indirect, have some advantages and disadvantages. Potential advantages of artificial groundwater recharge are:

1. The technology is appropriate and generally well understood by both the technicians and the general population.
2. Very few special tools are needed to dig drainage wells.
3. In rock formations with high, structural integrity few additional materials may be required (concrete, soft-stone or coral rock blocks, metal rods) to construct the wells.
4. Groundwater recharge stores water during the wet season for use in the dry season, when demand is highest.
5. Aquifer water can be improved by recharging with high quality injected water.
6. Recharge can significantly increase the sustainable yield of an aquifer.
7. Recharge methods are environmentally attractive, particularly in dry regions.
8. Most aquifer recharge systems are easy to operate.
9. In many river basins, control of surface water runoff to provide aquifer recharge reduces sedimentation problems.

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[9] Infiltration means downward movement of water through soil.
[10] Percolation is a hydrologic process where water moves downward from surface water to groundwater. This process usually occurs in the vadose zone below plant roots and is often expressed as a flux to the water table surface.

10. Recharge with less-saline surface waters or treated effluents improve the quality of saline aquifers, facilitating the use of the water for agriculture and livestock.

On the other hand potential disadvantages of artificial recharge are:

1. The wells may fall into disrepair and ultimately become sources of groundwater contamination if there is no financial incentives, laws, or other regulations to encourage landowners to maintain drainage wells adequately.
2. There is a huge chance for contamination of the groundwater from injected surface water runoff (especially from agricultural fields and roads surfaces) if it is not pre-treated before injection.
3. Recharge can degrade the aquifer unless quality control of the injected water is not ensured.
4. Groundwater recharge may not be economically feasible if significant volumes can not be injected into an aquifer. The hydrogeology of an aquifer should be investigated and understood before any future full-scale recharge project is implemented.
5. During the construction of water traps, disturbances of soil and vegetation cover may cause environmental damage to the project area.

There is another school of thought regarding groundwater recharge. Without overemphasizing the importance of rainwater harvesting and groundwater recharge enhancement– recharge could be done in various means. These are: the use of injection bore holes in hard rock; recharge through tanks wells; siphon recharge; enhancement of run off through treatment of catchments with polyamine material; use of chemicals for control of evaporation and also for stabilising and sealing of soil through hydrophobic chemicals, etc. Another name of these activities is 'water harvesting' (Chakravarty n.d.: 1-4). This school of thought argues for water harvesting instead of water recharge and they claim that water harvesting has more social acceptance.

In the coastal zone there is a different problem. Groundwater recharge in the dry water aquifer and in the coastal area has different methods to follow. To control the salinity intrusion into the freshwater aquifers there are five ways to recharge groundwater in coastal areas.

1. Modification of groundwater pumping and extraction pattern
2. Artificial recharge
3. Injection barrier
4. Extraction barrier
5. Sub-surface barrier

A paper on 'Ground-Water Recharge' prepared by Engineering Division, Soil Conservation Service, US Department of Agriculture, it is stated that groundwater recharge is one sort of management of groundwater basin. For a useful groundwater recharge, following hydro-geological aspects of sites must be taken into consideration in selecting the proper location:

1. availability, source, turbidity, and quality of water
2. surface soils
3. depth to aquifer
4. geologic structure and capacity of the ground-water reservoir
5. the presence of aquicludes
6. movement of groundwater
7. location of withdrawal area
8. pattern of pumping outline
9. cultural and social consideration and
10. costs of recharge.

Depending on topography of a site two technologies are widely used. These are:

a. underground injection and
b. infiltration gallery.

3.9.2 UNDERGROUND INJECTION

Underground injection is one of the 'direct artificial recharge' methods. It is the technology of placing fluids underground through wells or other similar conveyance systems. While rocks such as sandstone, shale, limestone appear to be solid, they can contain significant voids or pores that allow water and other fluids to fill and move through them. In this process water is allowed to pass directly into the deeper aquifer. Water is inserted into the deeper aquifer due to the pressure caused by rise in water level in the well. Main objective of water injection underground is to use surplus water available during the rainy season in order to improve the water supply condition and to recover the lowering groundwater table (Kharal 2002: 1). Before using this technology to recharge groundwater, hydro-geological aspects of a site and all possible adverse affects need to be considered very carefully.

3.9.3 INFILTRATION GALLERY

Infiltration gallery (IFG) is an 'indirect artificial recharge' method. It is a sub-surface groundwater collection system. An infiltration gallery is a structure used to supplement a storm drain by directing storm runoff from non-road areas. It is an artificial groundwater storage tank installed below the bed of ponds, rivers, streams, and other surface-storage to collect fresh water (WaterAid Bd. 2006: 4). Horizontal drain made from open-jointed or perforated pipes, or a block drain, which is laid below the water table and collects groundwater. Usually it is shallow in depth and located closer to mother source i.e. streams or ponds. Infiltration galleries need soils that are permeable to allow sufficient water to be collected. To build an infiltration gallery, it is important to protect it from contamination by locating it uphill and the minimum 30 meters distance from a latrine (Infiltration Galleries n.d.: 49-52). Besides, it should be constructed such a way that unfiltered surface water could not enter. Size of an IFG varies from a few meters to many kilometers.

To ensure a continuous water supply, IFG needs to be built at the end of the dry season and should be at least one meter under the dry season water table. The sites of an IFG need to be supported by protection tools during excavation. Infiltration galleries can be built in the following ways:

a. excavate a trench to at least one meter below the water table, supporting the sides to prevent collapse.
b. lay graded gravel on the base of the trench
c. lay the pipe or drain blocks on top of the gravel. Cover the top and sides with more graded gravel.
d. cap the gravel with an impermeable layer of puddle clay to prevent surface water entering gallery.

It is important to select an appropriate mother source for IFG and to keep it safe. Because, the water collected in IFG is often not as safe as well or spring or rain water is and it may be more venerable to contamination. Before identify and selecting a mother source of an IFG, following criterion need to be considered:

a. the mother source will not be contaminated by unsystematic use of others
b. it will be closer to majority of the community
c. it will be easily accessible to all
d. it will have proper drainage facilities
e. it will be free from detergents or pesticides or other chemicals
f. it will not be connected with any sewerage and waste water drainage system
g. the water will be available round the year
h. the hand pump sets will be set comparatively at higher and wider place.

4
CHAPTER

WATER GOVERNANCE BY DPHE

4.1 PRELUDE

DPHE is a department of Local Government Division under the ministry of LGRD and Co-operatives to oversee the drinking water infrastructure of Bangladesh. The mandate of DPHE includes exclusive responsibility for water supply and sanitation facilities throughout the country excluding Dhaka & Chittagong cities and Narayanganj and Kadamrasul Pourashavas where WASAs operate; providing advisory service to GoB in framing policy and action plans for WSS; and providing support to the local government institutions (LGIs) in the development and Operation & Maintenance of the water & sanitation facilities (DPHE: 2009). In order to promote public health through ensuring provision of pure drinking water, DPHE was established in 1935 and it is the national lead agency for drinking water supply and waste management in rural Bangladesh. With the challenges generated by arsenic contamination in groundwater, salinization of both surface and groundwater in coastal areas, and incremental fall of groundwater table in dry season in different parts of the country, DPHE with its development partners is trying to reduce the sufferings caused due to lack of safe water. Alternative options for safe water supply are being catered in worse affected areas. But with over 10 million tube-wells in Bangladesh for about 1500 million people, access to IDWSs does not seem bad. However, if we consider equity and quality, then the picture is not so rosy. DPHE with its development partners is putting their effort to ensure rural people's access to IDWSs by carrying out their functions efficiently.

4.2 EXISTING WATER GOVERNANCE IN RURAL BANGLADESH

In the existing water governance framework, three actors are playing active role in rural Bangladesh to provide fresh drinking water for rural people. These actors are (a) public sector organization (DPHE), (b) NGOs and (c) private individuals. Private individuals dominate by installing 78 per cent of widely used tube-wells. Besides, DPHE and NGOs installed 18 per cent and 4 per cent tube-wells respectively (SDP: 2005). According to the objective of the study, water governance by DPHE is given preference.

Private individuals installed most of the tube-wells in rural areas to cater drinking water. But the DPHE, as a public sector organization, paid its effort to increase the coverage of rural people access to IDWSs and to oversee the water quality of existing water supply infrastructures. In this process central government provides budget to DPHE through LGD under the Annual Development Plans (ADPs). The allocations are made against different development projects and are transferred to a DPHE Project Director leading a Project Management Unit (PMU). The PMU itself or through relevant Executive Engineers at district levels contracts out the implementation works to a private contractor. In a similar fashion, the ADP block grants from the central government are allocated to LGIs (the UPs). The UPs, according to the government's prescribed guidelines, plan and implement development works (SDP: 2005). Implementation of water supply projects is carried out by DPHE in the process of appointing a private contractor. LGIs have a very limited involvement in this governance process.

Statistics reveal that, DPHE does not have the capacity to ensure safe water supply according to the people's needs. Institutional capability of DPHE is not flourished due to lack of accountability to the stakeholders. Presently DPHE is not accountable to the stakeholders rather to the higher-level offices and Local Government Division (LGD). It is a top-down approach of decision making process and LGIs have no significant role in planning and implementation process. It is reported that lack of cooperation with LGIs and stakeholders is the main reason for which access to safe water supply is not ensured amongst the rural people (Ittefaq: 24 March, 2009). Supply-driven service delivery system and absence of stakeholder participation in decision making processes are the main cause to make the water supply infrastructures unsustainable.

4.3 MAJOR FUNCTIONS OF DPHE

The government has a target of providing safe drinking water to all by year 2011 and DPHE is the only public sector organization to cater safe water services for the people of Bangladesh. As part of the national water policy, DPHE is running projects in the arsenic affected and geologically difficult 135 municipalities throughout the country to provide safe drinking water to the people of those areas (Daily Star: 2009). On the other hand, in order to achieve government's target, DPHE has a great role and it has many functions that is pronounced in the official website. Major functions of DPHE include:

1. DPHE is responsible for the water supply of the whole country both in rural and urban areas. Urban area includes City Corporation, Pourashava, Upazila HQs and growth centers. But DPHE has no operation in Dhaka and Chittagong city areas and Narayanganj town where WASA operates.

2. DPHE assists Local Government Institutions i.e. City Corporations, Pourashavas, Union Parishads etc. in the Operation & Maintenance of the water supply infrastructure & services including technical assistance.

3. To ensure safe water supply for the people of rural and urban areas DPHE want to strengthen water testing facilities at different levels of the country. In order to institutionalize water quality monitoring and surveillance program DPHE want to establish water testing laboratories throughout the country.

4. DPHE has aim to carryout hydro-geological investigations in search of safe sources of water supply.

5. DPHE paid attention to develop safe water supply technologies for arsenic affected areas and other hydro-geologically difficult areas like coastal zone, hilly regions etc.

6. Continuous research and development activities in search of appropriate, indigenous, and affordable options of water supply in the country.

7. DPHE is responsible to ensure drinking water supply services during and after the natural disasters.

8. DPHE is engaged in the process of capacity building of the actors that involved in water supply services with technical know-how, information, training etc. in terms of water supply both in rural and urban Bangladesh.

9. DPHE has the sole authority for monitoring and coordination of activities of the stakeholders working in the water supply and sanitation sector.

10. Mobilization of social awareness towards proper management of water supply infrastructures and overall management of the water supply sector development programs (DPHE: 2009).

All these activities are to ensure peoples' access to safe drinking water rural Bangladesh.

4.4 TYPOLOGY OF WATER SUPPLY

People of rural Bangladesh mostly rely on groundwater and manually operated handpump tubewell (HTW) is widely used for lifting groundwater. Due to the difference in hydro-geological condition different types of tube-wells are used in Bangladesh for groundwater abstraction. Women mainly bear the burden of collecting drinking water from the nearest sources for the family and tubewell technology is predominately popular among them. Women collect water form HTW mainly for drinking, cooking and washing (SDP: 2005). Nevertheless, rural water supply technologies can be broadly divided into four categories. These are (a) tube-well technology, (b) alternative water supply technologies, (c) arsenic mitigation technologies, and (d) rural piped water supply system.

Tubewell technologies are classified into three categories depending on hydro-geological conditions of rural areas. These are (a) shallow tube-wells, (b) deep set pump tube-wells, and (c) deep tube-wells. Under these three categories there are some other tube-wells namely number 6 pump, and Tara pump are used in rural areas to abstract groundwater (Banglapedia: 2009) . Out of these three, highest numbers of users depend on shallow tubewell because of its affordable features but deep set pump tube-wells and deep tube-wells are becoming popular because of some emerging natural barriers against purity concern of drinking water.

Alternative water supply technologies are used for drinking water supply in the problem areas of Bangladesh where the tubewell technologies are no longer effective. These are effective in the coastal areas where both surface and groundwater are salty, arsenic prone areas where groundwater is contaminated with high concentration of arsenic, and hilly areas where installation of tube-wells is difficult due to stone layers. These technologies can be divided into four categories, namely (a) dug wells,,(b) pond sand filter. (c) rain water harvesting, and (d) arsenic removal technologies (SDP: 2005). These four categories of alternatives have different features.

In case of drinking water concern arsenic was first emerged as a problem in the early 1990s. Arsenic can cause cancers of the skin, lung and bladder and it has other severe effects on public health. Available data show that there are 40,000 cases of early onset (non-cancer) arsenicosis in Bangladesh. Besides that, arsenic has brutal social consequences and it is found that divorces are occurring because of arsenic, especially when wife is suffering from arsenicosis (GoB: 2006). This severity of arsenic contamination in groundwater first induces public and private organization to think about arsenic mitigation technology for the arsenic affected areas and researchers are trying to develop appropriate arsenic mitigation technologies which are different from arsenic removal technologies. In rural areas, piped water supply still in the piloting stage. Only limited number of rural piped water supply schemes is seen in the water-scarce northwestern part of Bangladesh (SDP: 2005). General features of rural water supply technologies and their features are shown in the following matrix.

Table-10: general features of different types of rural water supply technologies

Name of the Technology		Depth Covered (m)	Other features
Tube-well Technologies	Shallow Tube-well	20 – 30	• The most common technology in Bangladesh. • Handpump technology commonly known as No. 6 handpump. • Can only extract water when static water level is within 7.5 m • It is low cost, easy to operate and maintain, robust technology

Name of the Technology		Depth Covered (m)	Other features
Tube-well Technologies	Deep Set Pump Tube-well	100 - 150	• Used in the area when shallow tube-wells are not functional. • The most common DSP TW is all Tar Pump and Tara II pump. • It is relatively difficult to operate and requires higher maintenance. • Can extract water when static water level is 15 m and more
	Deep Tube-well	75 – 300	• Used to extract water from deeper aquifers • Mostly used in coastal zones • It is high cost, easy to operate and robust technology • Only a limited number of houses can afford a private Deep Tube-well.
Alternative Water Supply Technologies	Dug wells	< 10	• Oldest method of groundwater withdrawal • Easy to operate and maintenance • It is susceptible to bacterial contamination • Generally used in hilly areas and hydrogeologicaly difficult areas but recently used in arsenic contaminated areas
	Pond Sand Filter	-	• It is a sand filter installed on the bank of a pond. • Requires proper maintenance • It is used coastal belt and in arsenic affected areas
	Rain Water Harvesting	-	• It is a technique of collecting water from roofs and stores them in concrete or earthen reservoirs. • Reserve in rainy season to meet the requirement during dry season. • It is used in coastal belt and arsenic affected areas
Mitigation Technologies	Arsenic Mitigation Technologies	-	Appropriate technological solutions are still in a development stage
Piped Water Supply	Rural Piped Water Supply System	-	• Alternative source of water supply in low water table areas and arsenic affected areas • Favorable for the villages where socio-economic condition is good

Source: SDP, 2005

Among several water lifting technologies, DPHE identified six types of different technologies being used or have the potential of future use in rural Bangladesh. These are (a) Shallow tube-wells (STW), (b) Deep Set Pump (DSP) Tube-well, (c) Deep Tube-well, (d) Arsenic Mitigation Technologies, (e) Problem Area Technologies, and (f) Piped Water Supply (PWS) (SDP: 2005). There are three major actors that install these tube-wells are

(i) the government through DPHE (ii) the NGOs and (iii) the private individuals. According to DPHE estimation ratio of tube-wells installed by three major actors is shown in Table 11.

Table-11 : Ratio of Private and NGO Tube-Wells to DPHE Tube-Well

Tube-well Type	DPHE	Private	NGO
Shallow TW	1	6.0	0.2
DSP TW	1	0.9	0.2
Deep TW	1	0.1	0.2

Source: SDP, 2005

In 2005, DPHE estimated that the amount of different types of tube-wells were about 7.0 million in Bangladesh. According to a WHO estimation, there are between 8-12 million tube-wells in Bangladesh (WHO: 2008). In a seminar, organized on 'International World Water Day 2009', UNICEF country representative claims that Bangladesh has 10 millions of tube-wells (Rooy 2009: 1). Total number of tube-wells estimated by UNICEF may be considered pragmatic. Percentage of different types of tube-wells and percentage of tube-wells installed by three major actors are shown below:

Chart-6: Tube-Wells Installed by DPHE, Private Sector and NGOs

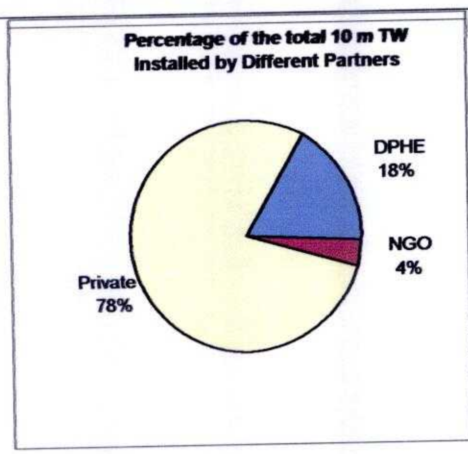
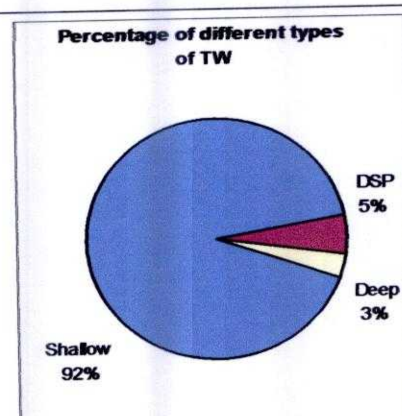


Chart-7: Percentage of Shallow, DSP and Deep Tube-Wells



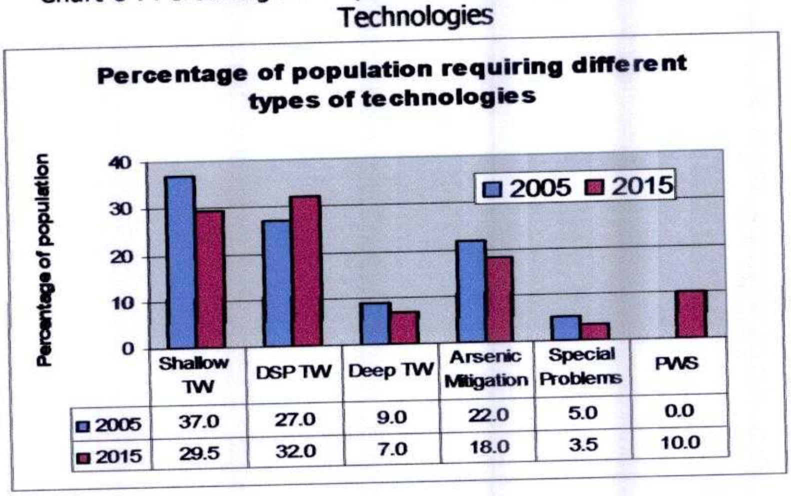
Source: SDP, 2005

According to SDP, tube-wells installed by private individuals, DPHE, and NGOs are 78 per cent, 18 per cent and 4 per cent respectively. If UNICEF study is considered, private individuals, DPHE and NGOs respectively installed 7.8 million, 1.8 million and 0.4 million different types of tube-wells in the country. Among the total tube-wells, 92 per cent is shallow tube-well while DSP tube-wells 5 per cent and deep tube-wells is only 3 per cent. Thus, among the three actors, private individuals are in leading position in terms of installing tube-wells and shallow tube-wells dominates in case of abstracting safe groundwater for drinking purposes.

4.5 DEPENDENCE of POPUATION ON DIFFERENT TYPES OF TECHNOGIES

Water supply projects taken by DPHE are being replicated all over the country through their organizational structure but citizens' demands are not taken into consideration in the process of service delivery. Many technologies used for water supply in rural Bangladesh and different numbers of population depend on different technology but stakeholders' participation in decision making process is not ensured when projects are designed and implemented. Water supply infrastructures are not installed or constructed according to the demand of the stakeholders and because of this reason, dependence of population on different types of technologies varies. Sites of different water supply technologies have impact on dependence of number of population. On the other hand, dependence on a particular technology varies when shift from one technology to another takes place due to its ineffectiveness and changing hydro-geological phenomenon. Statistics on population versus different types of technology is shown in Table 8.

Chart-8 : Percentage of Population Requiring Different Types of Technologies



	Shallow TW	DSP TW	Deep TW	Arsenic Mitigation	Special Problems	PWS
2005	37.0	27.0	9.0	22.0	5.0	0.0
2015	29.5	32.0	7.0	18.0	3.5	10.0

Source: SDP, 2005

Chart 8 shows that, in 2005, 37 per cent of the population depends on shallow tube-wells which are affordable by the poor people. Besides that, 27 per cent and 9 per cent of the population depends on DSP TW and deep tube-wells respectively. Therefore, 73 percent of the population depends on tubewell technology. On the other hand, 22 per cent and 5 per cent rural population depend on arsenic mitigation technologies and special problems technologies, and no people depend on piped water supply (SDP: 2005). Due to the acute problem with groundwater there is a chance of shifting dependence for shallow tubewell to deep tubewell and piped water supply in future.

This chart also extrapolates that, in 2015, 68.5 per cent people will depend on tube-well technology. Besides that, 18 and 3.5 per cent people will depend on arsenic mitigation technology and special problem technologies. That means 4.5 per cent people will refuse tubewell technology and 1.5 per cent people will refuse special problem technologies for water supply. This refusal may take place because of high cost. In future, people of rural areas will rely more on DSP TW and PWS because of their ability to provide better water quality in affordable cost. Populations depend on piped water supply will be increased from 0 percent to 10 per cent (SDP: 2005). So, people will shift from traditional shallow tubewell to DSP tubewell and piped water supply. This is why, there is a need for proper investment planning considering the migration from one option to another and this may lead to better drinking water management.

4.6 DPHE : In Response to Problems

There are plenty of tube-wells in rural Bangladesh but many of them are not in operation due to various reasons including lowering groundwater level, bacterial infection, arsenic contamination, salinity intrusion, and technical problems. It is estimated that, about 10 million tube-wells are installed through the country but 22 per cent of the shallow tube-wells are contaminated with arsenic all over the country (Prothom Alo: 2009). Besides that, some privately installed shallow tube-wells in LWT areas can not pump water during dry seasons. According to LGD calculation, the total number of effective tube-wells is 5.6 million but according to UNICEF's estimation, numbers of effective tube-wells are nearly 8 million. In a recent study it is found that, 29 per cent of shallow tube-wells and 9 per cent of deep tube-wells are contaminated with arsenic and/or bacteria (Unicef 2000: 5). This is mainly because of poor maintenance of the tube-wells and their surrounding. Therefore, effective number of tube-wells for supplying fresh drinking water is in between 5.6 million and 8.0 million.

In rural areas, water supplies are generally provided by hand pump tube-wells which tap water from underground, but rural people's access to safe drinking water by HTW is being prohibited due to various reasons. Reasons which induces severe problem with HTW includes lowering of water table, water quality problem, absence of suitable water bearing formation, and arsenic contamination problem (SDP:2005). DPHE is putting its efforts to increase the accessibility of rural people to IDWSs by making water drinkable when it is unsafe due to arsenic contamination, lowering groundwater level and salinity intrusion.

As part of water governance, DPHE has been building water supply infrastructures and conducting research & development activities to improve existing technologies, develop cost effective alternatives, and innovate alternative technological options to provide water in the problematic areas. DPHE's efforts can be categorized in three broad types: (a) options for arsenic mitigation, (b) options for lowering groundwater level, and (c) options for water quality problems. Different mitigations options developed by DPHE are discussed below.

4.6.1 OPTIONS FOR ARSENIC MITIGATION

Arsenic mitigation options developed by DPHE are described below:

a. POND SAND FILTERS

Pond Sand Filter (PSF) is an alternative and popular option of drinkable water supply in coastal belt and arsenic prone areas. It is a package type slow sand filter unit developed to treat pond water for household water supply. Sand filter is installed on the bank of a pond. The water from the pond is pumped by hand pump tubewell to feed the filter bed and it is raised from the ground. Adjacent to the filter bed there is a storage tank where treated water is stored and from the storage tank treated water is collected through tap (WaterAid: 2006). Initially, DPHE designed PSF with the capacity of 200 users and estimated cost TK. 30,000 and users have to contribute 20 per cent of estimated cost. Now, there are two models of PSF with the capacity of 300 users to 500 users. Construction and maintenance of a PSF is costly and difficult for local private users. It has been tested and found that water that collected from pond sand filter is usually bacteriologically safe or within tolerable limits.

According to PSF guidelines, for an effective PSF unit selection pond in very important and the following things should be considered carefully before selecting a pond.

a. The pond should be large enough and water remains available throughout the year.
b. Washing and bathing should be strictly prohibited in the pond.
c. Cattle washing, bathing and other domestic material washing like-plate, glass, bowl etc. should be prohibited in the pond.
d. The pond can not be used for poultry rearing and pisciculture. Use of any chemical fertilizer or insecticides or pesticides in the pond should be prohibited.
e. Before rainy season the pond dike should be repair protecting agricultural, domestic and other waste runoff into the pond.
f. The pond should be at a safe distance from latrines and cowsheds.
g. The salinity of the pond water shall not exceed 600 ppm at any time of the year.
h. The pond should be closer to the user community and particularly the women must have full access.
i. Rotten leaves, weeds, kitchen garbage etc. should not be thrown into the pond.

Outside wall, platform, drain and surrounding places of PSF should be cleaned up at least twice a month and waste water should be disposed properly in the kitchen garden or any other agriculture field.

b. RING WELL/DUG WELL

Dug well is an indigenous technology of abstracting water by digging a hole and using a bucket with a rope. It can be constructed with locally available resources and can provide safe water to several families. To construct a dug well, it costs TK. 60,000 – 70,000 (SOS-arsenic.net: 2009). Now it is upgraded by setting a hand pump and covering the top of the well. Many of them are shallow above the contaminated aquifer, but it has a secondary risk of bacteriological contamination. Dug wells should be installed with safety from sanitation where deep tube-wells are not successful. A survey conducted in 181 dug-wells in Bangladesh by SOES, it is found that only 22 per cent dug-well is contaminated with more than 100 microgram/liter of arsenic and 40-60% of arsenic may be eliminated from arsenic contaminated dug-well water when it is settling (Chakraborti: 2006). Study result is shown in Table 12.

Table-12: Dug wells and concentration of arsenic contamination

State/ Country	No. of dug-wells analyzed for arsenic	Arsenic con. in µg/L				
		<3	4-10	11-50	51-100	>100
Bangladesh	181	59	28	67	5	22

Source: SOES

Nowadays, dug wells are very rare and almost vanished after the introduction of tube wells.

c. CHULLI WATER PURIFIERS (CWP)

The chulli water purifier is an indigenous water purification system and was designed to treat contaminated surface water. The chulli water purifier uses both sand filtration and heat pasteurization to eliminate microbes from water and it can be an alternative to arsenic affected tubewell water. It was first introduced in 2003 and with the support of the DPHE and UNICEF almost 3,000 chulli water purifiers have been installed in Bangladesh. A recent survey identified that, durability of the chulli water purifier is a major problem along with many different types of mechanical problems. This study also reveals that, the rate of discontinuity is high and reasons for discontinuing use among 80 of 101 persons included mechanical problems (49 per cent), inconvenience (35 per cent), and high cost (10 per cent) (Gupta et al: 2008). Installation cost for per unit of CWP is only Tk. 450.00 and flow rate is 30 liter per hour. Low cost and high flow rate is the major feature of CWP but it wastes (emanates) heat.

d. EFFECTIVENESS OF SEALING ON DEEP TUBE-WELLS

Deep tube-wells sealing is done to prevent the leaching of arsenic in deep aquifers through drilling holes. But the procedure of clay sealing raised some confusion regarding its effectiveness. In this context initiatives have been undertaken to find out the best possible procedure of clay sealing and to examine its effectiveness. Two tube-wells of 1.5" diameter were installed at first for experimenting with gravel shrouding and clay sealing with clay balls (Clay: Bentonite = 1:1). Three tube-wells of 3" diameter were installed and among those one was sealed with cement, one was sealed with clay ball and the remaining one without any sealing. Tracer element tests were carried out to verify leaking of sealed and without sealing wells. Water samples are now in the lab for chemical analysis. Results of tracer element tests for these tube-wells are yet to complete. All the tube wells are installed in Kadamtal, Benapole upazila.

4.6.2 OPTIONS FOR LOWERING GROUNDWATER LEVEL

Since 1986, DPHE has been monitoring the fluctuations of the groundwater table using a measuring network having one tube-well in each union of the country. Measurements are taken once annually during peak dry season. The data indicates the area where the water table has fallen beyond the suction limit and it has increased from 12 per cent in 1986 to 20 per cent in 1990. A study carried out during 1992-95 predicts that water table has fallen beyond suction limit about 27% in 2004 (DPHE: 2009). As a result a large number of tube-wells fitted with no. 6 suction pump have become non-functioning during the dry season. To solve the problem of depletion of water the table, DPHE introduced some initiatives which are as follows:

a. DEVELOPMENT OF TARA PUMP

Due to depletion of the water table, a large number of no. 6 suction pumps started to be inoperative particularly in the dry season in different parts of the country. To cope with the problem, the Tara pump has been developed based on the principle of displacement pump. The pump is submerged in water connected with a handle through a piston rod. This pump is made of non-corrosive materials and safe form bacteriological contamination. It can lift water from 15 meter water table and gives water in both the upward as well as the downward stroke of the handle.

b. DEVELOPMENT OF MINI TARA PUMP

It was estimated that a sum of 360,000 public tube-wells would be inoperative in the near future due to gradual depletion of water table. To replace these wells by 2-inch dia TARA tube-wells was considered to be expensive. In that context, with the support of UNICEF, the R&D division had initiated in 1991 the use of a modified TARA pump that can fit in the existing diameter of no. 6 pump shallow tube-well with minimum modification. The conversions were called MINI TARA. After trial and error this pump is installed all over the country. In an evaluation over the performance of Mini Tara, it was found that these pumps operated well for up to 2-3 years. But some difficulties were faced during repairing and assembling the pump. In that case, back up support is needed to make it sustainable.

c. TARA-II AND TARA DEV HAND PUMP

TARA hand pumps were installed at 15m depths in low water table areas. In some parts of North Bengal the water table was declining beyond the capacity of the Tara pump. To cope with the situation TARA II have been developed and field tests conducted in 1988 to lift water from 30 meters depth. An evaluation by the R&D Committee in early 1992 indicated that Tara-II fitted with no. 6 pump head could be used as an interim solution. Accordingly 150 TARA-II tube-wells have been installed in the later part of 1992-1993 fiscal year. However, further study on these pumps fitted with no. 6 head has been carried out to improve the vertical movement of the pump rod. Tara technology having lever action pump is termed as TARA Dev.

d. CONVERSION OF DSP INTO TARA

The conventional deep-set pumps were becoming obsolete due to difficulties & expensive maintenance. These wells could easily be converted into TARA, provided the upper well casing remains within the water level. 10 such conversions have been made in Ghatail thana of Tangail district. It was proposed to install further 40 such wells to observe the performance, maintenance and construction defect, if any, to standardize the design. It is under trial.

e. MARK-3 AND AFRIDEV TECHNOLOGY

It was reported that some part of the country, particularly Rajshahi zone, was facing acute lowering of the water table exceeding 100 ft. In these areas Tara-dev is not suitable. So Mark-3 and Afridev pumps capable of lifting water from a water table around 150 ft. have been taken for piloting under DPHE-UNICEF R&D activities. Five such tube-wells (1 in Tongi, 2 in Chapai Nawabganj and 2 in Rajshahi) have already been installed. These technologies will be monitored, reviewed, and modified to make them more suitable in terms of performance and cost of the technology as well.

4.6.3 OPTIONS FOR WATER QUALITY PROBLEMS

To address the water quality problem, DPHE developed some processes. These are as follows:

a. Coastal Belt Mapping Updating

In coastal belt areas, the major problem encountered in tube-wells was salinity of excess concentration. Besides this, in some places no suitable aquifer was available. In 1990-91, a detailed map of the coastal belt was prepared showing different problem areas. After that, extensive work to find a suitable water bearing layer was done. The exercise was started in 1993 by conducting 4 workshops. The activities continued up to 1995 and the maps were updated incorporating any change found in this period.

b. RAIN WATER HARVESTING SYSTEM

The research and development division has designed and piloted a community based Rain Water Harvesting System (RWHS) to serve 3 to 5 families i.e. about 25 to 30 users for drinking and cooking purposes. Average storage capacity of a RWHS tank is 2,500 liter. The construction cost is about Tk. 11,000. The user contribution in construction is 20% of the estimated cost. The models are designed to ensure 7 months water security. Two hundred and sixty eight RWHS is constructed in two upazilas of Rajshahi district (Bhagha and Charghat) with the capacity of 300 liter to 3200 liter. A study showed that, rainwater harvesting is a potentially safe, reliable and affordable alternative source of water supply for drinking and cooking. A RWHS reservoir can supply water for drinking and cooking for at least 8-10 months of the year. Because of its potentiality in terms of purity, safety, technological simplicity, and affordability to mass people, RWHS can be widely used in rural Bangladesh (Rahman and Jahra: nd). DPHE suggested monitoring a RWHS after every 7 months period.

c. IRON REMOVAL UNIT

As a part of the DPHE-UNICEF R & D activities, 10 Iron Removal Units have been constructed with different models including using VS ring. Water quality monitoring including its performance evaluation as regard to O&M and acceptability by the community started at the end of February 2008. Removal of manganese will also be included in the water quality monitoring program.

4.7 GOVERNANCE STATUS OF DPHE

Present service delivery system is centralized in nature and existing governance does not meet the demand of rural people in terms of accessibility. Roles, responsibility and tasks of DPHE are not clearly defined. Level of awareness & compliance of rural people is very low and citizens as well as people's representatives are not given importance in the present governance system. Absence of strong, sound, and responsible leadership is the barrier to make the performance of DPHE transparent, effective and efficient enough to attain good governance. There are sufficient policies, regulations, and strategies for enabling the environment which leads to better water sources management, but those are rarely followed or considered in implementation processes. Centralizing attitude of the high officials, avoidance to reform existing system, and lack of harmonized coordination among and between the components of good governance made it difficult to attain desired rate of accessibility of rural people to IDWSs. It yields a supply-driven service delivery system that hinders optimum outcome from DPHE's efforts.

In order to diagnose the drinking water governance survey has conducted in two districts. Over two hundred respondents from different segment of the society, in terms of economical, educational, cultural, and religious status, are interviewed focused on the objectives. Peoples of rural areas of two districts asked to disclose their views about present drinking water governance and what should be the responsibility of the government agencies to ensure rural peoples' accessibility to fresh drinking water.

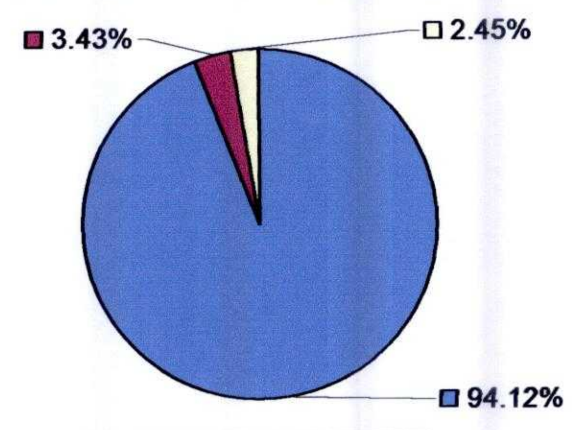
Table-13: Source of drinking water, tubewell in own premises, government service and assistance for installing tubewell.

No. of Respo-ndents	Source of water (%)			Owner of tubewell (%)	Assistance for installing tube-wells (%)			Satisfied with govt. service (%)
	Tubewell	DTW	Others		Govt.	NGO	No assistance	
204	94.12	3.43	2.45	80.39	3.42	1.96	94.12	16.67

Source: Self Compiled

Table reveals that 94.12 percent people of study area collect drinking water from hand pump tubewells, only 3.43 from deep tubewells and 2.45 per cent from other sources. In the study area 80.39 per cent respondents have tubewell in their own premises. Almost 20 per cent people collect drinking water from the tubewell or deep tubewell which is owned by neighbor or government. Hardly any family found that collect drinking water from unprotected open sources i.e. pond, river, lake etc. Percentage of people that collect drinking water from different sources is shown in Chart 9.

Chart-9: Source of Collecting Drinking Water



Source: Self Compiled

Table 13 suggests that people installed tubewells on their own initiatives. In very few cases rural people got assistance at the time of installation of water lifting technology and this rate is only 5.38 per cent (government assistance 3.42 per cent and assistance form NGO or other sources is 1.96 per cent). Among the respondants 16.67 per cent people are satisfied with government assistance. So, government assistance in case of providing technical support is very insignificant.

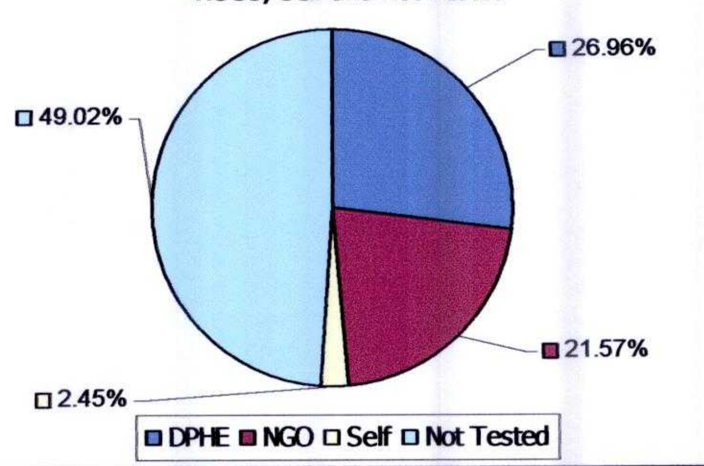
Table-14: Peoples' Awareness about Purity and Hygiene of Drinking Water

Know about the purity of his own source (%)	Know the hazards of drinking unsafe water (%)	Tubewells tested by (%)				Tubewell regularly tested (%)	Willing to pay for fresh water (%)
		DPHE	NGO	Self	Total		
61.28	86.28	26.96	21.57	2.45	50.98	3.43	74.51

Source: Self Compiled

Table 14 shows peoples' level of awareness about the quality of their own drinking water sources and knowledge about drinking safe or unsafe water is considered. It is found that 61.28 per cent people know about the source whether it's water is pure or impure and 86.28 per cent people know about the effect of drinking unsafe water. In the study area, 50.98 per cent tubewell water is tested and only 3.43 per cent tubewells are tested regularly. Tubewell water tested by DPHE, NGOs and self initiative are 26.96 per cent, 21.57 per cent and 2.45 per cent respectively. Most alarmingly 49.02 per cent tubewell water has never been tested and out of 50.98 per cent tested tubewells 47.55 per cent has been tested once only. It is indicated that, a large number of people are drinking unsafe tubewell water or they did not know whether it is pure or impure because it is not tested on a regular basis. Most importantly, 74.51 per cent people are willing to pay for getting fresh drinking water throughout the year. Evidence suggests that monitoring and surveillance of water quality is inadequate. Tubewells that are tested by DPHE, NOGs, self initiative, tubewells that are not tested and percentage of people willing to pay for fresh drinking water is shown in the Char 10.

Chart-10: Tubewells That are Tested by DPHE, NOGO, Self and Not Tested



Source: Self Compiled

Chart 11 reveals that, as alternative source of collecting drinking water rural people largely rely on deep tubewell. Besides that, a significant number of people rely on mitigation technology. Besides that 2.94 per cent people depend on dug-well, 6.86 per cent on RWH and 7.35 per cent on TW. But 11.28 per cent people made no comments about alternative source of drinking water. This ground reality should be taken into consideration in framing water resource management plan.

Out of 204 respondents 137 commented about the reasons for which rural people deprived from fresh drinking water throughout the year and 67 respondents made no comment on this issue. Percentage is made based on 137 respondents.

Table-15: Reasons for not getting fresh drinking water throughout the year and people having alternative source

Get water over the year (%)	Reasons of not getting fresh drinking water over the year (%)				Have alternative source (%)
	As	Fe	LWT	Drought	
31.37	7.30	18.25	12.41	2.19	31.37

Source: Self Compiled

Table 15 indicates that 31.37 per cent people have alternative source of drinking water and they also get drinking water throughout the year. It is identified that people of rural areas do not get fresh drinking water throughout the year mainly because of arsenic contamination, presence of excessive iron, lowering groundwater table, drought and different combination of those factors. Table 15 also shows that people deprived of getting fresh drinking water due to presence of excessive arsenic and iron, lowering groundwater table and drought are 7.30 per cent, 18.25 per cent, 12.41 per cent and 2.19 per cent respectively.

Table-16: Different combination of factors for not getting fresh drinking water throughout the year and people having alternative source

LWT+ Drought	Fe+ LWT	As+ LWT	As + Salinity	As + Fe	As + Fe + LWT
17.52%	20.43%	5.11%	2.19%	7.30%	7.30%

Source: Self Compiled

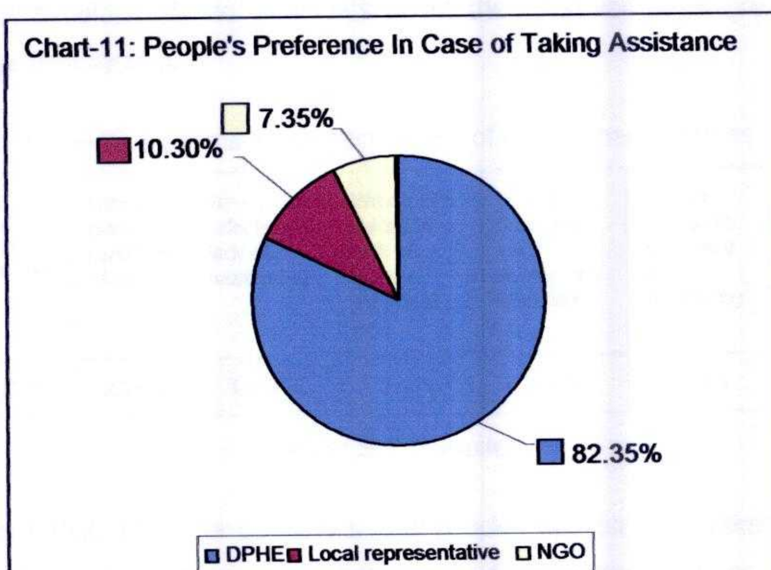
Combination of different factors that deprive rural people to have fresh drinking water is shown in Table 16. Combined effect of LWT and drought causes 17.52 and LWT and excessive iron causes 20.43 per cent deprivation in case of getting safe drinking water in the rural area. Other combination of factors that causes negative effect on the availability of safe drinking water is not significant. Among all factors, LWT and presence of excessive iron in groundwater is the major hindrance to deprive rural people having fresh drinking water.

Table-17: Type of assistance want to ensure safe drinking water

Financial	Technical	Monitoring	Decentralization	Financial + technical	Technical + monitoring	No assistance
40.69%	24.02%	21.57%	3.92%	2.94%	1.96%	4.90%

Source: Self Compiled

It is evident that government assistance is inevitable to ensure rural people's access to safe drinking water. People want different types of assistance that can help them to get safe drinking water. People mainly expected for financial assistance, technical support, continuous water quality monitoring, decentralization of drinking water management and combination of those assistance. Table 17 reveals that 40.69 per cent people want financial assistance, 24.02 per cent people prefer technical support in installing water pumping technology, 21.57 per cent people desire continuous water quality monitoring and 3.92 expect decentralization of drinking water management but 4.90 percent people seek no assistance. In case of multiple assistance 2.94 percent people want both financial and technical assistance, and 1.96 per cent people expect strengthening of water quality monitoring with adequate and appropriate technical support.



Source: Self Compiled

It is found that, people have different choice in case receiving assistance regarding installation of water lifting technology. In the study area, 82.35 per cent people want to get assistance from government agencies, 10.30 per cent from local representatives and 7.35 per cent from NGOs. It is shown in Chart no. 12. Facts and figures suggest that, rural people's preference is to get financial and technical support for installing water pumping technology with continuous water quality monitoring.

Table-19: Responsibility of government to ensure fresh drinking water for the rural people

Strengthening water quality monitoring (%)	Project implementation by local representative (%)	Awareness about the hazards of drinking unsafe water (%)	Supply free water pumping technology (%)	Ensure safe water through ppp (%)
22.50	5.00	3.50	15.50	6.00

Source: Self Compiled

Out of 204 respondents 200 respondents suggested what should be the responsibility of government to ensure safe drinking water for the people of rural Bangladesh throughout the year. But 4 respondents made no comments. Percentage is calculated based on 200 respondents. Throughout the study it is found that, 22.50 per cent people suggested for strengthening water quality monitoring system and 15.50 per cent for supplying water lifting technology at free of cost. Besides that, government responsibility to ensure rural people's access to safe drinking water includes project implementation by local representatives, building awareness among rural people about the hazardous effect of drinking unsafe water, ensuring safe water for rural people by introducing public-private-partnership in drinking water governance process. But, rural people emphasis mainly on strengthening the water quality monitoring system and delivery of water lifting technology at free of cost.

Table-20: Combination of government responsibilities to ensure safe drinking in rural Bangladesh

Supply free water pumping technology + ppp	Installation of tubewell + Awareness about the hazards of drinking unsafe water	Supply free water pumping technology + installation of tubewell	installation of tubewell + Strengthening water quality monitoring	Strengthening water quality monitoring + Awareness about the hazards of drinking unsafe water	Strengthening water quality monitoring + Supply free water pumping technology	Strengthening water quality monitoring + ppp	Strengthening water quality monitoring + Project implementation by local representative
3.00%	3.50%	5.00%	5.00%	7.00%	12.50%	6.50%	5.00%

Source: Self Compiled

Empirically it is found that, 52.5 per cent people suggest government has single responsibility to ensure fresh drinking water for the people of rural Bangladesh but 47.5 per cent people thinks government has multiple responsibilities. Different combination of responsibilities that people suggest is shown in Table 20.

Based on primary data it may predict that, for different water lifting technologies and different problems different types of service delivery system would bring good result. But in the centralized service delivery system, the UPs have a little role to play in terms of number of installation, choice of technology and site selection. DPHE officials decide how many installation need to grant, which technology and where it needs to be installed. So, this service did not meet the demand in terms of quantity of water lifting technology, location and most importantly water quality monitoring and surveillance. This affects the sustainable use of the installed technologies. The present governance system does not give adequate opportunity to build the capacity of LGIs by actually letting them carry out the works by themselves. LGIs do not get budget allocation, they have no monetary power and they are not able to take decision in terms of number of technology, types of technology, site of installation. Therefore, due to the top-down approach, they have no chance to efficiently and effectively participate in decision making and implementation process.

4.8 FINANCIAL ASPECTS OF DPHE

DPHE dispense its services through projects which lead to the infrastructural development of water supply in rural Bangladesh. Projects that are implemented by DPHE to reduce the proportion of rural population without having access to safe drinking water sources are financed by the Government and development partners. Development partners who provide financial assistance and technical support to the DPHE are World Bank, World Health Organization (WHO), Danida, Japan International Cooperation Agency (JAICA), Asian Development Bank (ADB), Islamic Development Bank (IDB), United Nations Children Emergency Fund (UNICEF), and Canadian International Development Agency (CIDA). Local NGOs like WaterAid and NGO Forum also work as development partners of DPHE. Funds that are received from local or international development partners are used to implement projects related to water resource management.

4.8.1 ADP ALLOCATION TO DPHE

DPHE get ADP allocation from local government division to implement projects which may help to make water supply infrastructure safe from various contaminants. Following table shows ADP allocation to DPHE for implementing water and sanitation projects. ADP allocation for five fiscal years is shown in Table 21.

Table-21: Year wise ADP allocation and Project Aid ADP Allocation

Fiscal year	Total ADP Allocation (million Taka)	Project Aid ADP Allocation (million Taka)	Project Aid ADP as the percentage of total ADP
2000-2001	2,774	1,359	49.00 %
2001-2002	3,169	1,853	58.47 %
2002-2003	3,546	1,889	53.27 %
2003-2004	2,298	1,158	50.39 %
2004-2005	1,959	1,229	62.74 %
Total	**13,746**	**7,478**	**54.40 %**

Source: SDP, 2005

This table reveals that, from the fiscal year 2001-2002 onwards, ADP allocation to DPHE is decreasing gradually. In 2001-2002, ADP allocation was Tk 3,169 million, but in 2004-

2005 it decreased to Tk 1,959 million. With the passage of time it is becoming difficult to get fresh drinking water all over the country, but ADP allocation is reducing alarmingly. With reduced allocation it is a great challenge for DPHE providing services to make the drinking water infrastructures safe.

DPHE distributes its allocation for water supply and sanitation sector. Allocation of water supply again divided in tow head i.e. rural water supply and urban water supply. The table below shows the ADP allocation for urban and rural water supply in five different fiscal years. Breakdown of ADP allocation in urban and rural water supply is shown in Table 22.

Table-22: Breakdown of ADP allocation in Urban and Rural Water Supply

Fiscal year	Total ADP Allocation for Water Supply (million usd)	ADP Allocation for Urban Water Supply (million usd)	ADP Allocation for Rural Water Supply (million usd)
2000-2001	69	45	24
2001-2002	62	29	33
2002-2003	68	27	41
2003-2004	49	23	26
2004-2005	40	20	20
Total	**288**	**144**	**144**

Source: SDP, LGD, GoB

This table shows that ADP allocation for water supply has been reduced over the period. In the fiscal year 2000-2001, ADP allocation was USD 69 million but in 2004-2005, it was reduced to USD 40 million. Over the five years, ADP allocation for water supply decreased about 42 per cent. It may be noted that, in 2001, rural population was 79 per cent and in 2005, rural population has decreased to 75 percent (www.discoverybangladesh.com and www.globalis.gvu.unu.edu). In five years, rural population decreased only 4 percent due to rural-urban migration but ADP allocation for water supply decreased by as much as 42 percent. On the other hand, in 2000-2001 fiscal year, from the total ADP allocation for water supply, allocation for urban water supply was 65.22 percent and for rural water supply it was only 34.78 percent. And in 2004-2005 fiscal year, ADP allocation for urban and rural water supply was equal, that is, allocation for urban water supply was 50 per cent and allocation for rural water supply was 50 percent. In terms of percentage allocation, rural water supply is increased but in terms of amount, it is decreased by USD 4 million (16.67%). With reduced allocation, it is very much difficult to combat increasing natural barriers of fresh drinking water.

4.8.2 WATER SUPPLY INFRASTRUCTURE AND CONTRIBUTION MONEY

There is an option of cost sharing for different water supply infrastructure by the users. Technological option of rural water supply, approximate cost of installation, and contribution money for the option from the users are shown in Table 23.

Table-23: Technological option, approximate cost and contribution form the users

Technological Option of Rural Water Supply	Approximate cost of Installation (Taka)	Contribution from the users (Taka)
Shallow Tubewell	7,600 – 12,000	1,000
Deep Tubewell (No. 6 Pump)	40,000 – 55,000	4,500
Tara	14,500 – 20,400	1,500
Tara (Deep)	53,000 – 56,400	4,500
Ring Well	63,000 – 70,000	2,000
Pond Sand Filter (PSF)	36,000 – 40,000	3,000
Shallow/Very Shallow Shrouded Tubewell(SST/VSST)	8,000 – 10,200	1,500
Rain water Harvesting System	8,000 – 10,000	10-15% of cost

Source: DPHE website

This table shows that installation cost of widely used shallow tubewell is Tk. 7,600 to 12,000 and users of this technology have to share only Tk. 1,000. Users share for shallow tubewell is affordable for the rural people but this technological option is becoming obsolete due to arsenic contamination, salinity intrusion and lowering water table. Options which can be effective and efficient in delivering safe drinking water i.e. deep tubewell, pond sand filter, tara (deep) pump are becoming popular in problematic areas, but those technologies are difficult for poor rural people to afford. So, technological options which can effectively mitigate the problems to get fresh drinking water in rural areas need to be low cost and users share should be at affordable limit.

4.9 POLICY SUPPORT FOR WATER GOVERNANCE

The government has adopted a number of policies to remedy the challenges in the rural water supply sector. These policies emphasize decentralization, user participation, the role of women, appropriate price sharing, and prudent water resource management through institutional water governance. For example, The Arsenic Mitigation Policy gives preference to surface water over groundwater because groundwater became too obnoxious to drink. At the operational level, there has also been a conceptual shift from single-use of water (such as through handpumps for drinking water and motorized deep tube-wells for irrigation) to multiple use of water from deep tube-wells since the 1990s. The government promulgated the National Water Policy (NWPo) in 1999. The six national goals of the NWPo were economic development, poverty alleviation, food security, public health and safety, a decent standard of living for the people, and protection of the national environment. The other related government policies that have direct bearing on water sector are the National Environment Policy 1992, Water Resource Planning Act 1992, National Forestry Policy 1994, Environment Conservation Act 1995, Water Supply and Sewerage Authority Act 1996, National Energy Policy 1996, Environment Conservation Rules 1997, National Policy for Safe Water Supply and Sanitation 1998, National Fisheries Policy 1998, National Agriculture Policy 1999, Industrial Policy 1999, Environment Court Act 1999, Bangladesh Water Development Board Act 2000, Urban Water Body Protection Law 2001, Millennium Development Goals 2004, National Policy and Implementation for Arsenic Mitigation 2004, Coastal Zone Policy 2005, Pro-poor Strategy for Water and Sanitation Sector 2005, National Water Management Plan 2004, and Poverty Reduction Strategy Paper 2005. These policies, acts and regulations give the service providing agencies legitimacy to ensure water supply for the people of Bangladesh.

5 CHAPTER

CONCLUSIONS AND RECOMMENDATIONS

This study focused on the state of governance offered by the DPHE in Bangladesh. Throughout this study, sources and amount of water available in Bangladesh, present governance and service delivery system, and hindrances that affect rural people's accessibility to IDWSs are discussed. Considering those things, governance capacity and effectiveness of service delivery provided by DPHE are tested. It shows that after enormous effort by DPHE, still nearly one fourth of the total rural population have no access to IDWSs and nearly half of the total population use unsafe drinking water and are exposed to water borne diseases due to lack of governance capacity and efficient service delivery. In terms of governance capacity of DPHE, some findings are as follows:

FIRST: DPHE is playing dominating role in the process of decision making and implementation of projects related to operation and maintenance of drinking water infrastructure. Stakeholders', specially women, are not consulted in case of selecting a site for hand pump tubewell. As a result, supplied technologies are installed in a place where the women, who mainly collect water for drinking purposes or household use, have limited access.

SECOND: Rural people mostly rely on groundwater but it is not used prudently. Besides, pollution of groundwater is increased because of inadequate surveillance and monitoring program by DPHE. A large number of tube-wells could not provide fresh drinking water to the people's of rural Bangladesh due to lowering groundwater table or groundwater contamination by arsenic or iron and/or salinity. Tubewells that installed in the rural area are not tested regularly to diagnose whether its water is safe to drink or not.

THIRD: People of rural areas preferred DTW and mitigation technology as alternative source of drinking water, but they can not afford to install appropriate water lifting technologies or can not meet the expense of mitigation technology because of their poor economic condition. They expect financial assistance form government agencies.

Besides that, people of rural areas are willing to pay monthly basis to ensure fresh drinking water throughout the year.

FOURTH: Rural people largely rely on government agency for any sort of assistance and people are not satisfied with present government service. But, as a service providing agency DPHE is lacking of accountability and efficiency in service delivery system. DPHE officials are not accountable to their stakeholders, rather they are obliged to their high offices and officials. Top-down and supply-driven approach in service delivery of DPHE have failed to keep pace with the needs of rural people. In rural areas the rate of population growth is comparatively high that accelerate the demand for drinking water.

FIFTH: Poor budget allocation to DPHE is one of the most important factors for not achieving success in providing safe drinking water for rural people. Most of the stakeholders want financial and technical assistance to make fresh drinking water available throughout the year. People of rural areas want water lifting technology (tubewell and deep tubewell) at free of cost. Budget allocation for the treatment of waterborne diseases is higher than water supply.

SIXTH: LGIs have lack of institutional capacity and they are not properly empowered to participate in drinking water management. This is why LGIs can not contribute in optimizing services i.e. increasing monitoring of water quality, maintenance of infrastructure, proper site selection, creating sense of ownership among the people etc.

SEVENTH: Political interference in governance process creates discrimination in effective and equitable service delivery. Inequality of income distribution in the society is one of the important reasons for not getting access to fresh drinking water by the rural poor. As a result, rich and influential people enjoy more freshwater resources than the poor.

EIGHTH: DPHE has no reliable database that may help to cater safe drinking water to the rural community. Although policy, planning, budget, action plan etc. are taken on the basis of related data, but DPHE as a government leading institution for providing safe drinking water in rural areas has no specific research and reliable data bank regarding its strengths and weaknesses.

RECOMMENDATIONS

This study was undertaken to assess the governance capacity of DPHE in case of providing safe water supply in the rural Bangladesh. It also aimed to assess the effectiveness of DPHE run GoB funded water supply installations in terms of ensuring peoples' access to IDWSs in rural areas. Based on the findings, some recommendations are made which may lead to attain good governance in DPHE and may help to increase citizen's access to safe drinking water. Some specific recommendations are:

ONE: Reform needs to be taken in governance process and service delivery system of DPHE through compliance of existing policies and regulations. Bottom-up decision making process and demand-driven service delivery may help to attain good governance in water resource management sector. For different water lifting technologies and different problems different types of service delivery system would bring good result. Depending on this argument, three types of service delivery system is proposed involving LGIs and stakeholders in Table 24.

Table-24: Technology Type and Service Delivery Systems

Technology Types	**Decision Making Process**	**Implementation Process**
Shallow Tube-wells	Bottom-up	Decentralized
Deep Tube-wells		
Deep Set Pump (DSP) Tube-wells	Mix of Top-down and Bottom-up	Semi Decentralized
Arsenic Mitigation Technologies		
Piped Water Supply		
Special problem area technologies	Top-down	Centralized
Intervention during emergency situations		

Source: SDP, 2005. Self Compiled

One size does not fit all. According to this proposition, centralized implementation process in water governance framework may bring better result for special problem area technologies and interventions during emergency situations. Centralized, semi-decentralized, and decentralized implementation process is designed with modification of SDP proposed system.

A. CENTRALIZED SERVICE DELIVERY SYSTEM

In this system Local Government Division (LGD) allocates development and revenue budgets to the DPHE. DPHE would work out the type and number of installations required in different Upazila Parishads. In turn, Upazila Parishad would allocate them to Union Parishads (UPs) and then UPs to the communities. After getting the hardware distribution list from the UPs and Upazila Parishad, DPHE would engage a private sector/contractor for their installation. It is a top-down approach of decision making process and local government institutions have no role in planning and implementation process. A model of Centralized Service Delivery System is given in the Appendix-A. Centralized service delivery system may bring better result for special problem area technologies and interventions during emergency situations. Because in these cases government can not infrastructure will be borne by the cooperative, which make them more liable to look after the infrastructure and it may help to increase community participation than before.

The money form the government budget would go directly from LGD to the lowest tier of LGI, i.e. UP, for which the latter remains accountable. The UPs with the consultation of cooperatives will take scheme regarding number of tube-wells, selection of location and technology, and monitoring and surveillance program for a specific area. UPs will take measures to inform the communities about the availability and the process of preparing schemes. LGIs will implement schemes in consultation with the communities. DPHE will provide necessary expert opinion and technical assistance in scheme preparation and implementation process. Decentralized service delivery system includes following stages:

- Scheme preparation by village cooperatives
- Scheme compilation by UPs
- Validation and co-ordination by Upazila Parishad
- Technical assistance by DPHE
- Financing by LGD through DPHE and UP, and by village cooperative
- Appointment of contractor for project implementation by LGI under the supervision of village cooperatives and technical support by DPHE

TWO: Groundwater quality surveillance and monitoring system should be strengthened to identify the contaminated and inactive tube-wells. Easy, cheap, and user-friendly indigenous technology needs to be discovered and brought within the reach of the poor people that any citizen can test the water quality with the guidance of DPHE. Besides that, installation of alternative source of drinking water should be dispensed easily for the rural people.

THREE: In order to establish a comprehensive database for planning priority in intervention areas, national screening of all existing tube-wells is essential. A systematic scientific study and data base management system need to be established that may help to take appropriate plans to get maximum outcome. Besides, it is essential to build awareness among rural people to create pressure on service providing agencies as well as local government institutions for facilitating safe drinking water. As part of the awareness program, health education may be included in the curriculum of primary and secondary education, and poverty eradication program needs to be given priority. Optimum utilization of water resources needs to be ensured by changing the behavior of the citizens.

FOUR: Low cost, and indigenous chemical, and/or non-chemical mitigation technology for treating contaminated unsafe water need to be invented through institutional and individual research. Invented mitigation options should have reliability, social acceptance, and most importantly, should be affordable by the poor and available to the poor.

FIVE: Parts of the country, where rural people's access to IDWSs is prohibited due to salinity ingression and lowering ground water level, needs special treatment. Groundwater recharge may solve this problem. It can be done by 'infiltration gallery' process or artificial recharge (injection of water to underground) process. To make the drinking water resource sustainable, groundwater recharge is a must. Cost, technology, limitations, adverse affects of these processes need to be taken into consideration before implementing this sort of projects.

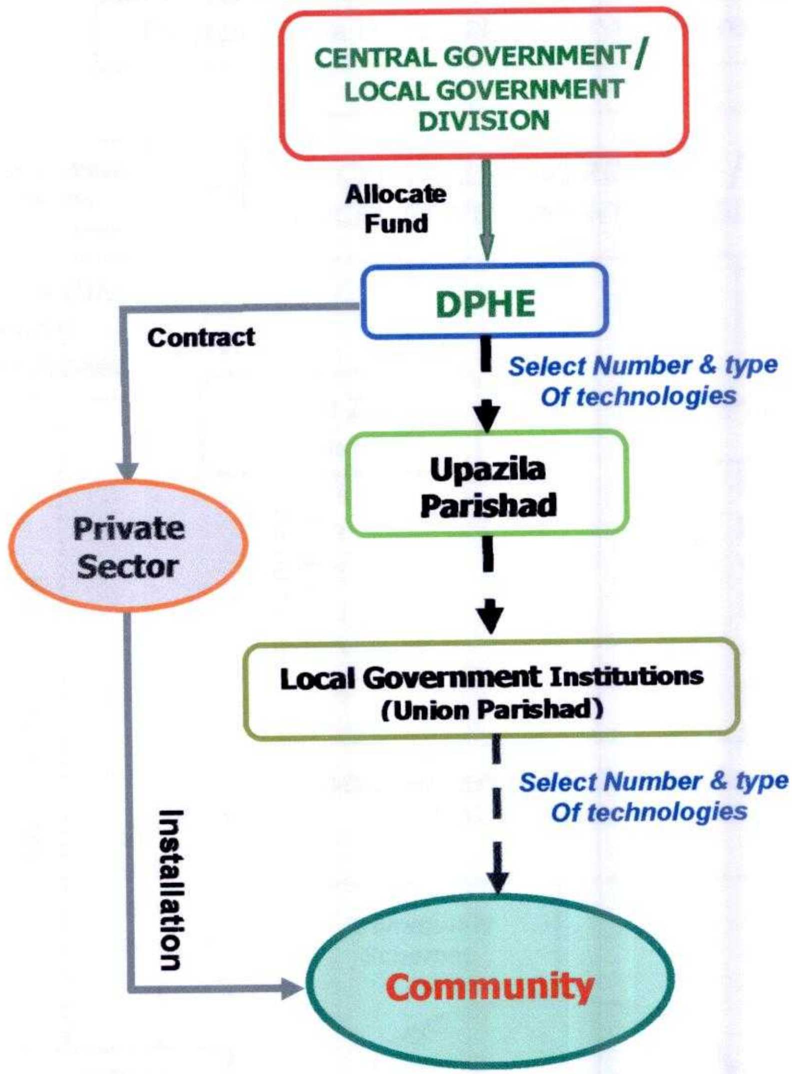
SIX: Rain water harvesting and storage for household use need to be encouraged. Rural people should be trained and motivated, technological support should be given, and awareness building program should be taken by DPHE to install appropriate RWH system. Financial support through 'low interest rate and long term credit program' to the rural households can be provided by financial institutions with the proper guidance of the government.

SEVEN: Pressure on groundwater needs to be reduced by increasing the use of surface water after proper treatment. Actions should be taken to protect drinking water sources from pollution. Excess water, that we get during the rainy season, need to be stored up by making reservoir where population density is comparatively low.

Access to safe drinking water in rural Bangladesh appeared as a problem by the end of twentieth century and at the beginning of twenty first century it emerges as a curse to the rural people. Limited governance capacity of DPHE is unable to solve the problem prevailing in the rural water supply. Unwillingness or limitations to comply policies and strategies by the service providing agencies; absence of coordination among and between service providers and stakeholders; poor budget allocation to DHPE; wastage of water resources due to inefficiency and proper maintenance; absence of strong, sound, and accountable leadership; weak institutional capacity of LGIs; absence of active community participation; and unwanted political interferences in service delivery system are impediments to attain good governance. Integrated effort by service providing agencies, introduction of transparent and efficient implementation process, public-private partnership in service delivery system, and attainment of good governance may effectively reduce the threat of water crisis and enhance the rate of accessibility to IDWSs of the people of rural Bangladesh. Finally, watery Bangladesh is very much in need for a strong, capable and efficient public sector organization to cater safe drinking water.

APPENDIX-A: CENTRALIZED SERVICE DELIVERY SYSTEM

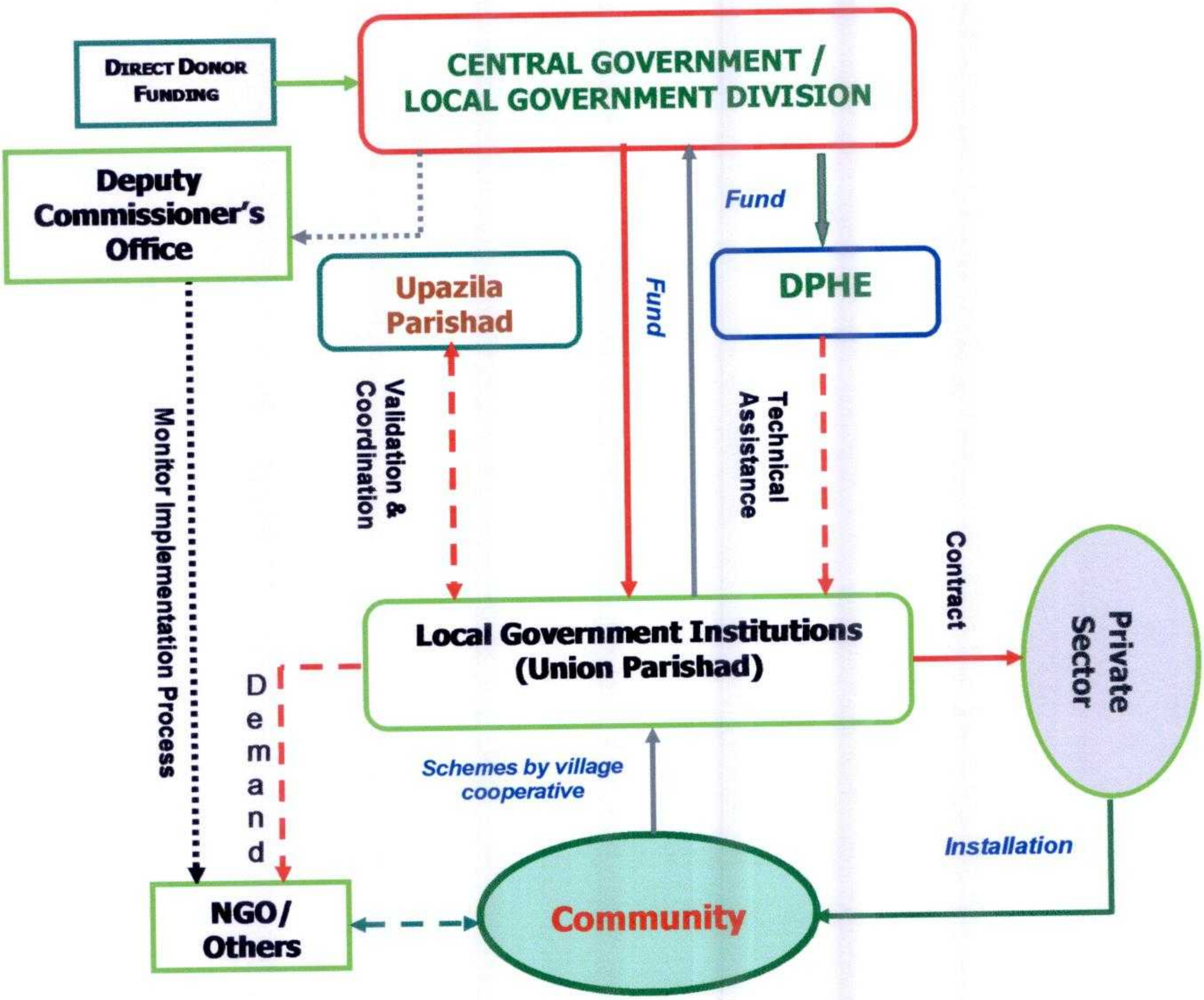
Diagram: Centralized Service Delivery System



Source: Self Compiled

APPENDIX-C: DECENTRALIZED SERVICE DELIVERY SYSTEM

Diagram: Decentralized Service Delivery System



Source: Self Compiled

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