Study On Water Supply And Drainage Problem

in

Khulna City

By

GAZI MOHAMMAD MOHSIN

A thesis submitted to the Department of Civil Engineering of Khulna University of Engineering & Technology (KUET), Khulna in partial fulfillment of the requirements for the degree

Of

Master of Science in Civil Engineering

November 2007

APPROVAL

This is to certify that the thesis submitted by Gazi Mohammad Mohsin entitled as "Study on Water Supply and Drainage Problem in Khulna City" has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh in November 2007.

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To

departed souls of my parents

and

my two loving sons

Declaration

This is to certify that the thesis entitled as "Study on Water Supply and Drainage Problem in Khulna City" has been carried out by Gazi Mohammad Mohsin in the Department of Civil Engineering, Khulna University of Engineering & Technology (KUET), Khulna, Banglagesh. The above thesis work or any part of this work here in has not been submitted anywhere for the award of any such type of degree or diploma.

Dr. Md Rezaul Karim
Professor
Department of Civil Engineering
Khulna University of Engineering & Technology
Khulna

Gazi Mohammad Mohsin
Roll No. 0401553

ACKNOWLEDGEMENT

All praises and gratitude is to almighty, Allah, the most merciful. It is well known that for any accomplishment requires the sincere efforts of many people and this thesis is not out of this nature of the rule. It owes a great deal to a number of people without whose wholehearted efforts it would have remained incomplete.

The author, with deep sense of reverse, wishes to express the deepest gratitude, sincere appreciation and the heartiest gratitude and profound indebtedness to his supervisor Dr. Md Rezaul Karim, Professor, Department of Civil Engineering, KUET, for his incessant guidance, spirited encouragement and constructive censure at every stage of this thesis. His interest in this topic and valuable advices were the source of author's inspiration.

The author expresses his heartfelt indebtedness to Dr. Muhammed Alamgir, Professor, Department of Civil Engineering, KUET, for his valuable advices and inspirations to complete the course and the thesis.

The author expresses his profound gratitude to Dr. Quazi Hamidul Bari, Professor; Department of Civil Engineering, KUET, for his worthful suggestions and inspirations to complete the course and the thesis.

The author remembers with indebtedness for the worthy co-operations and advices of Dr. Kh. Shafiul Islam, Associate Professor, Department of Civil Engineering, KUET, to enrich this thesis.

The author gratefully remembers the heartiest inspiration and sincere cooperation of Md Liakat Ali Sharif, Chief Engineer, KCC and Md Abdul Hannan, Executive Engineer, KCC, for providing the access to their library to collect valuable reports, documents that enrich the author ideas and knowledge to write this thesis.

The author is, indeed, thankful to Sayed Ahsan Ali, Laboratory Technician and Sarder Shahidul Alam, Laboratory Assistant, Environmental Civil Engineering Laboratory; Sk. Monirul Islam, Laboratory Technician, Geotechnical Engineering laboratory for their sincere assistances in conducting different types of tests essential to complete the thesis.

The author expresses a lot of love and affection to his sons for their endless inspirations and continuous encouragements to complete the course and the thesis.

Finally, the author prays to almighty Allah for prosperous and peaceful life for all of us in future

GAZI MOHAMMAD MOHSIN

November, 2007

Abstract

Khulna, the third largest divisional as well as the metropolitan city of the country, is located in the south-western region between 22° 30′ N latitude and 89° 20′ E longitude. It is an industrial as well as the second seaport city. The population of the city has been increasing along with the development of the city since the early eighties. At present, the population in KCC area is about 0.80 million. According to forecast, the population in the city will be 103.64, 133.82 and 171.67 million in the year 2011, 2021 and 2031 respectively.

Khulna City Corporation is the responsible authority to supply water to the city dwellers. Ground water is the main source of KCC supply; apart from this a small quantity of water is supplied from the surface water source. At present, KCC is supplying water at the rate of about 27300m^3/day of which 97.44% from ground water source and 2.56% from surface water source. KCC water supply network is working only in 23 Wards out of 31, no water supply network there in 8 Wards (Ward-1 to Ward-8).

Apart from KCC wells, ground water is being carried out by public, private, industrial and institutional wells. At present, about 120400 m^3/day waters are abstracted from the ground and surface water sources. Of this, only 700 m^3/day (0.58%) comes from surface water source and the remaining 99.42% are from ground water source. About 26600 m^3/day (22.1%) is abstracted by KCC wells, 43600 m^3/day (36.2%) by industrial and institutional wells and 49500 m^3/day (41.1%) by private and public wells. The drinking water requirement of city people are met taking only 4.2% from KCC supply, 89.9% from other wells and 5.9% from ponds and rivers. The major fractions of water requirements of city people for cooking, washing and bathing are met from ground water abstracted by other wells.

It reveals that huge quantities of waters are abstracted from ground water source and day by day it is increasing. But groundwater resource may not be unlimited. KCC undertook few hydrological studies to quantify the ground water resource in KCC area. None of the study reports clearly specified the quantity of the groundwater resource in KCC area. The last hydro-geological study was undertaken by KCC in 2005 and the consultants finally estimated that the ground water reserves in KCC area may continue up to next 25 to 30 years at the present rate of abstraction (BRGM/LGED, 2005).

Physical, chemical and bacteriological quality of KCC supply water was determined in three seasons. Physical and chemical quality parameters were within acceptable limit with a minor seasonal variation according to BDS and WHOGV but bacteriological tests revealed that the supply waters were microbiologically contaminated. Substantial numbers of contaminants- TTC and E.coli were observed in almost all samples. Quantitative health risk was assessed with QHRA model and it was found that due to the presence of TTC and *E.coli,* the KCC supply water is associated with high risk of disease burden to the users.

It was found that due to the presence of TTC, the KCC supply water is associated with viral burden varying from 2.033 μDPY to 3.4μDPY, exceeding the allowable limit 1.70 μDPY; bacterial burden varying from 0.73 μDPY to 3.33 μDPY, where the allowable limit is 0.40 μDPY and protozoa burden varies from -1.56 μDPY to 0.83 μDPY, where the allowable limit is -1.90 μDPY according to WHOGV.

Similarly, due to the presence of E.coli, the KCC supply water is associated with viral burden varying from 1.67 μDPY to 3.43 μDPY, exceeding the allowable limit 1.70 μDPY; bacterial burden varying from 0.33 μDPY to 2.20 μDPY, where the allowable limit is 0.40 μDPY, and protozoa burden varying from -1.93 μDPY to 0.47 μDPY, exceeding the allowable limit -1.90 μDPY according to WHOG . Then it can be said that KCC supply water is associated with high disease burden.

In KCC area, there are about 528.120 km drainage network of which 175.43 km (33.22%) are primary drain, 150.45 km (28.49%) are secondary and 202.24 km (38.29 %) are tertiary drain and among those 291.230 km (55.14%) are pucca, 51.790 km (9.81%) are *semi-pucca* and 185.10 km (35.05%) are kutcha drain. The average drainage density in the city is 11.79 km/km^2, the lowest density is 3.06 km/km^2 in ward 31 and the highest drainage density is 33.88 km/km^2 in ward 23. All the drains have 49 major outlet points in the four main rivers as Bhairab, Rupsha, Mayur and Gallamari around KCC. It is revealed from the KDA, 2002 report that around 68% households of the Khulna city have no planned drainage facilities and only 32% have some sorts of facilities in and around their premises. The cleaning and maintenance performance of drains in KCC is very poor.

Waste loadings in drains due to some wastewater parameters were assessed. The waste loading of the parameters vary with the seasonal variation of flow rates. All the drains have the flow in rainy season but there is no flow in some drains in other seasons. It is revealed that waste loading for most of the parameters is the maximum in rainy season and minimum in spring because the flow rate is the maximum in rainy season than that of spring.

A questionnaire survey was carried out among 385 residents within KCC area. The main objective of this questionnaire survey was to assess the perception of the city dwellers on the services provided by KCC in regard to water supply, drainages and its maintenances and cleaning, related health and hygienic environmental conditions. The people are not satisfied with the water supply from KCC and very much dissatisfied with the services provided for the cleaning and maintenance of drains.

KCC organizational structures were evaluated and it was identified that Water Works Department of KCC does not have sufficient technical staff and no planned activities exist to assess the quantity as well as quality of KCC water supply. Some recommendations were placed to improve the overall water supply system of KCC, including preparation of water safety plan and establishment of a technical surveillance unit for routine monitoring the quantity and quality of water.

This thesis has identified the major problems in KCC water supply; there is no organized and planned water supply plan, mechanism to monitor the production and yields of wells, routine checking and maintenance of wells and pipe line connections, plan to explore the new water supply network to the new settlements, no quality assurance activities, no skilled manpower for checking the water quality parameters etc. Dependency on ground water source is increasing and KCC has no report on quantity of groundwater reserves, how long abstraction can be continued and abstraction rate etc. The major problems related to drainages are mainly the lack of proper cleaning and maintenance, unplanned drainage construction and encroachment of drains paths for developments of other infrastructures.

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ABBREVIATIONS

APSU	Arsenic Policy Support Unit
BDS	Bangladesh Standard
BRGM	Bureau of Research for Geology and Minerals (Franch)
DALY	Disability Adjusted Life Year
DPY	DALY Person-Year
DPHE	Department of Public Health Engineering
ECR	Environmental Conservation Rules
EC	Electrical Conductivity
E.coli	Escherichia coli
FCEAL	Farhat Consulting Engineers and Architects Ltd.
HIV	Human Immune Deficiency Virus
HSD	Housing and Settlement Department
KDA	Khulna Development Authority
KCC	Khulna City Corporation
LGED	Local Government Engineering Department
LGD	Local Government Division
MSP	Municipal Services Projects
MASL	Mean Average Sea Level
NRPL	National Resource Planners Limited
QHRA	Quantitative Health Risk Assessment
RAAMO	Risk Assessment of Arsenic Mitigation Option
TC	Total coliform
TTC	Thermotolerant Coliform
UNDP	United Nations Development Program
UNICEF	United Nations Children's Education Fund
WHO	World Health Organization
WHOGV	World Health Organization Guidelines Value
YLD	Years Lived With Disability
YLL	Years of Life Lost

CHAPTER I

INTRODUCTION

1.1 General

Khulna is the third largest metropolitan city as well as one of the divisional headquarters of Bangladesh. It is located on the banks of the rivers Bhairab and Rupsha. The geographical location of Khulna City Corporation lies between 22° 30' N latitude and 89° 20' E longitude and its elevation is about 2.13 metre above the mean sea level (BRGM/LGED, 2005).

Considering the importance of resources and geographical location, Khulna Municipality was established in 1884 with an area of only 12 km^2 and a population of few thousands. The urbanization started since then and went one step ahead when the Khulna railway station was established in 1885. But Khulna received a fresh impetus to grow demographically after the partition of the then India creating Pakistan in 1947, huge populations migrated from India and settled here. Again a new urbanization started after the establishment of Khulna divisional headquarters here in 1960. A lot of industries, banks, insurance offices, educational institutions, trade and commerce centres and other government offices of all levels were established here have increased its importance further.

Considering the importance as a Municipality in divisional head quarter, Khulna Municipality was upgraded to the status of Khulna City Corporation in 1984. During this long period, Khulna has experienced continuous population growth accompanied by periodic changes to its jurisdiction. In 1974 its area was only 38.52 km^2 and by 1981 it was expanded to 40.41 km^2 with 14 wards. In 1993, the area of Khulna City Corporation was further increased and the wards were reshuffled and increased. Now the area of Khulna City Corporation is about 45.65 Km^2 comprising 31 wards with the population of about 0.90 millions (NRPL, 2004). As per population forecasting, the population in Khulna City will be 1036440, 1338160 and 171660 in the year 2011, 2021 and 2031 respectively.

Khulna City Corporation is the responsible authority to provide adequate potable water to the city for drinking and other purposes. But KCC has not yet been able to supply adequate water to the people as per requirements; even it has not been able to bring all wards under its water supply network. At present, 23 wards are under it water supply network and 8 wards (ward-1 to ward-8) have not yet got the water supply access from City Corporation. Even KCC has not yet been able to cover the total area of 23 wards. Though the population of the city has increased and its area has been expanded, the water supply has not been increased accordingly; rather the supply has decreased suabstantially.

Groundwater is the main source of water supply in the KCC area. The people are getting the supply from KCC production wells, private and public tube wells, ponds and rivers. At present KCC is providing about 26700 m^3 water per day from ground water resource abstracting by production wells and only 700 m^3/day from surface water source (Bhairab river) to the city through the network against the city demand of about 71000m^3/day. It means KCC is supplying about 38.56% of the total demand of water of the people. There are huge gaps between the supply of water from KCC and demand of the people.The supply to demand ratio is 1:2.60 and day by day the difference is increasing because the demand is increasing along with the increased population whereas the supply is decreasing. Other than KCC, water is abstracted by private and public tube wells, by institutional and industrial wells and very few (0.80%) from rivers and ponds. These wells are contributing to meet the remaining about 43033 (60.6%) per day water demand of the city abstracting from ground water resources either from deep or shallow aquifers. So, about 98.2% waters are being abstracted from ground water resources to meet the demand of the people.

The dependency on ground water source is increasing continuously putting heavy pressure on its reserves. But ground water resource is not unlimited. KCC should try to find the alternative sources to meet the demand of the city, reducing pressure on groundwater resource. Surface water may be the best alternative source and in this case possibility to install surface water treatment plant may be investigated.

1.2 Background of the Study

All over the World, particularly during the last few decades, there is the rapid growth of urbanization. Bangladesh is not out of this race, here the urbanization has started after the independence in 1971 but it has been flourishing fast since eighties after decentralizing the administration, upgrading the then thana into upazila and establishing 64 districts. In responding to the felt need of the people and to provide the all sorts of civic facilities, the divisional level six municipalities were upgraded to City Corporation. But though the City Corporation was established with the aspiration of growing populace for better services but appropriate measures in some cases had not been taken to provide the proper and requisite facilities to the city dwellers. Similar situation is also prevails in the Khulna City Corporation particularly in water supply and drainages.

The extent availability of safe drinking water supply and proper healthy drainage system is the indicator of the standard of the quality of life in an urban area. Khulna City Corporation had taken some measures in this regard to provide the drinking water and drainage facility to the city having about 0.80 million people, but those initiatives had not met the requisite demand and necessity of the ever growing population due to a lot of limitations such as limitation of financial resources, scarcity of the water resources, inadequate planning and technical assistance etc. The City Corporation had undertaken some studies through some consulting firms and individuals to identify the constraints, limitations and sought some recommendations to bring about improvement in the sectors mentioned.

This thesis has been undertaken in order to make a comprehensive review of water supply and drainage situation in KCC area. This thesis focuses on evaluation and analysis of the existing services such as present status of water supply and drainage system, trend of population growth, people's perception and assess the future need of water supply and drainages, to identify the problems associated with the operation and maintenance etc and formulation of guide lines for sustainable water supply and drainage system in Khulna City.

The projected population and its trend can be used in undertaking the water supply and drainage schemes, modification and upgradation for the existing infrastructures. The administration can be able to understand the necessity and to take the requisite measures regarding the health risk in relation to the water supply and sewerage. It may be used as a tool by the KCC to take the initiatives to increase awareness of the users in proper utilization of water and drainages without wastage of water and blocking the drainage system.

1.3 Objectives of the Study

The major objectives of this study are to evaluate and analysis of the existing services prevailing in the Khulna City in relation to water supply and drainage system. The major objectives of the study are outlined as below:-

(i) To study the trend of population growth and to assess the present status of water supply and future demand of water in Khulna City Corporation area.

(ii) To assess the water quality of supply water in City Corporation area and also the associated health risk in regard to water supply.

(iii) To evaluate the drainage systems of the city as well as wastewater quality and waste loading to the nearby rivers.

(iv) To evaluate the people's perception regarding present water supply and drainage system in the Khulna City.

(v) To identify the problems associated with the operation and maintenance of existing facilities in relation to water supply and drainage system and to formulate a guideline for sustainable water supply and drainage system for Khulna City Corporation area.

1.4 Application of the Research

The application applications of this study may comprise as follows:-

- The projected population and its trend can be applied in undertaking in water supply and drainage schemes and to modify the existing infrastructures and system as per the need.
- To understand the requisite measures regarding the health risk in relation to the water supply and drainage.
- To increase awarenesses of the users in proper utilization of water and drainage without the wastage of water and blocking the drainage system.
- To use it as a guideline in taking schemes, which will be service oriented - particularly in relation to the water supply and drainage.

1.5 Methodology

The required and pertinent information on population, hydrology, water resources etc as required for the study were obtained from the primary as well as the secondary sources. Some information were taken from the available study reports, booklets etc of KCC as well as from other organizations like BWDB, DPHE, Meteorological Department, KDA and NGOs working in Khulna. Based on the secondary data, population projection, future water demand calculations etc were undertaken. Water samples were carriedout from 23 Wards of Khulna City and tested for the physical, chemical and bacteriological water quality parameters in order to assess the suitability of the supply water for drinking. Water samplings were under taken in various seasons in 2006-2007 to evaluate the seasonal variation of water quality parameters. Based on the water quality data especially bacteriological data, a quantitative health risk assessment (QHRA) model (Howard et al., 2006) was used to assess the microbiological health burden associated with water supply in the city.

Available literatures, reports were reviewed to study the drainage condition of the city. Physical observations of the drainage networks were done to assess the real situation of the drains. Moreover, sampling of wastewater and laboratory analysis were undertaken to characterize the quality and waste loading associated with wastewater discharged from the city. Rainfall data were collected from meteriological department from 1954 to 2002. The intensity data of the rainfall in KCC area was not available, so exceeding probability curve for 10 years, 20 years and 30 years duration from the available rainfall data were prepared. Comparison among these three exceeding probability curves was made. It was revealed that the 75% of the exceeding probability of 20 years rainfall data curve was the best fitted and more reasonable. This value of rainfall from the 20 years exceeding probability curve was used in area-velocity formula (Q= AV) to calculate discharges of the drains. These discharges were compard with the discharges calculated by rational formula (Q= FCIA). It was concluded that the drain sections in KCC area were quite enough to dispose of the wastewater.

A close-ended questionnaire was designed to gather and analyze the people's perception on several services providing by City administration regarding the water supply and drainage in KCC area. Total 385 questionnares were distributed among the different sections of people living in KCC area. The respondants were of different sexes, ages, education level living in resident areas and slum areas. The main objective of this questionnaire survey was to assess the perception of the city dwellers on the services provided by KCC in regard to water supply, drainages and its maintenance and cleaning, related health, hygienic and environmental condition.

1.6 Scope and Limitations of the Study

In order to achieve the objectives of the study, a through study in this sector of water supply and drainages was undertaken. An extensive literature review was conducted to know the existing water resources, both surface and ground, uses of the water from surface source and abstraction from ground resource, problems related to water supply and drainages. Door to door visit with the questionnaires containing questions on water and water supply, quality and services, related questions on drainages; its adequacy and maintenance, health and environment aspect was an interesting experience. Over all, to have the collective information on the topics and also people perceptions on the quality and adequacy of civic facilities providing by Khulna City Corporation was an added experience that helps enormously to write the thesis and facilitate to come in a conclusion for making recommendations.

The limitations faced in accomplishing this research were mainly time and the authentic data. The data were scattered, multifarious and with different departments, organizations. And as the practice has not been developed here to preserve the data in order in different levels, it required huge times and efforts to formulate, accumulate and analyze in systematic manner.

1.7 Organization of the Thesis

This thesis consists of eight chapters and eight appendixes as follows:-

Chapter – 1	:	This chapter includes general introduction, background, objectives, methodology, scope and limitations of the study.
Chapter – 2	:	This chapter details review the literatures covering the water supply system, water and water supply related general information in relation to Khulna City Corporation Vis a Vis with the other similar organizations.
Chapter – 3		This chapter brifly discussed the population growth pattern in different wards and forecasts city population of the projected period. It has elaborately discussed the water demand and related issues of water use.
Chapter – 4	:	This chapter elaborately discussed the water quality issues in KCC, different water quality parameters, seasonal variation of water quality parameters, associated health risk in KCC water supply.
Chapter – 5	:	This chapter focuses on the details drainage of network in KCC, drainage system along with the types and patterns, outfalls and natural topography; quality of wastewater and waste loading from the waste water disposal network in Khulna City.
Chapter – 6	:	This chapter analyzes the questionnaires distributed among the city dwellers to get their perceptions on the services provided by the KCC on water supply, drainage and its maintenance and cleaning, health and hygienic environmental condition.
Chapter – 7	:	This chapter narrated the problems related to water supply and drainages in the city, presents guideline for sustainable water supply and drainage in KCC area.
Chapter – 8	:	This chapter includes conclusions and recommendations.

CHAPTER II

Literature Review on KCC Water Supply

2.1 Introduction

Khulna is the third largest city as well as the third metropolitan city of Bangladesh, situated on the bank of the Rivers Rupsha and Bhairab in the south-western part of the country. The major part of the city stretches about 15 kms along the River Bhairab. The two rivers are influenced with the tidal effect of the sea and the surrounding areas of the city are also affected by the on rush saline water from the sea. There is the huge population rushing from the rural areas starting from the late eighties to live here to avail the civic facilities of this metropolitan city. The present population of the city is about 0.80 millions within the area of about 45.65 square kms (NRPL, 2004). The city authority has undertaken a lot of programs to meet the basic need of the ever growing population living in this city. To ensure adequate water supply to the city dwellers is the most important service among others to the city administration. The present state of water supply, its future prospects and available resources are presented in this chapter.

2.2 Histoty of Water Supply in KCC Area

The water supply of Khulna City is operated and maintained by Water Works Department of Khulna City Corporation (KCC) and mainly relies on ground water as its source. Apart from this, a small quantity of water is supplied from the surface water source.There is a small water treatment plant to purify the surface water before supply it to the pipelines.The source of this surface water is the water of the River Bhairab and it is abstracted to an open storage reservoir (KCC pond) at the treatment plant during the period of low salinity in the river but this is for a few months only. The distribution network was less developed and so the water supply was pumped from this open reservoir and it had been continuing since 1921 (MSP, 2001). This pond, which is filled up from the intake of the water from the River Bhairab, still used for water supply and accounts for a small portion of total supply. The water pumps having yielding capacity about 112.5 m^3/hr, pumped intake water towards the storage reservoir with an average 4 hours per day, which is treated by coagulation, flocculation and filtration only represents about 2.56% of KCC total production. The detail of the treatment plant is presented in Table 2.1.

Table 2.1 Details of Surface Water Treatment Plant of KCC (MSP, 2001)

Collection	Capacity	Remarks
River intake	90 m^3/hr	Low lift pump
Rising main	-	150 mm dia cast iron pipe
Primary settling pond	45000 m^3	Used as reservoir when river is saline (100 days storage at 450 m^3 per day)
Low lift pump	90 m^3/hr	-
Secondary settling tank	360 m^3	2 number of similar capacity
Filtration unit (With backwash)	23 m^3	1 unit, Approximate 9 m^2 filter area
Under ground storage tanks	180 m^3, 90 m^3	-
High lift pumps	68m^3/hr,100 m^3/hr	-
Overhead tank (Steel plate)	90 m^3	Height 15 metres
Daily production	450 m^3/d	Approx. 4 hour/day operation
Potential capacity	2000 m^3/d	24 hour operation

It found from the KCC record and other reports that upto 1979, there were only 10 production wells in the city to abstract water from ground resource. But later on, KCC had taken initiatives to increase its production well and up to 1988 the number of wells increased to 45 of which only 35 were in operation. Up to 1996, the number of production wells increased to 64 but some old wells were replaced and some became unproductive and hence only 50 were in operation with a production capacity 34590 m^3/d. Henceforth, Khulna City Corporation had taken a crash programme to increase the production wells further as yield of most of the old production wells reduced remarkably and some wells were abandoned. A survey report in 2004 reported that the yield of individual well ranges from 6 m^3/hr to 129 m^3/hr with an average of 64 m^3/hr. The poorest 20% of wells yielded less than 25 m^3/hr while the best 20 wells were producing over 95 m^3/hr (FCEAL, 2004). The total productions were reduced substantially and to meet the required demand of the city, KCC installed 20 more production wells with the help of Directorate of Public Health Engineering (DPHE) and Housing and Settlement Department (HSD). In the mean time some of the lower yielding wells were abandoned (FCEAL, 2004). In 2004, there were 81 wells out of which only 50 wells were in operation with an average production capacity of 26590 m^3/day is shown in the Table 2.2.

All the wells, with the exceptions of two PTW in shallow aquifer, are 150mm to 300mm diameter deep tube wells with depths between 200m-300m drawing water from deep aquifer. Tube wells are generally equipped with 10 to 13 stage vertical turbine pumps connected to 150mm diameter rising mains and powered by vertically mounted electric motors, generally rated at 20 HP or 25 HP, few wells are equipped with submersible pump sets. Most pumps have nominal capacities of about 70 m^3 per hour at 40 m head. Most pumps are set at 23 m with well drawdowns of 10 m to 20 m with the exception of five wells connected to over-head tanks, the pumps discharge directly into the distribution system, where the system pressure varies between zero and 6 m (MSP, 2001).

It is also reported that the total wellhead productions in 1990 was 37150 m^3/d, that was the maximum production of KCC history and the minimum production was 16183 m3/d in 1983 and latest in 2004 it was 26590 m^3/d. The waters are discharging from the pumps through 226.43 kms pipe lines and 50 production wells and are served twice daily, the average pumping period for the well is 12-16 hrs/day. But yet it has covered areas accommodating only about 37% of the neat population within the KCC service area (MSP, 2001). The operation of these production wells are continuing but by this time the yielding capacity of some wells would fall down and some would be abandoned. To keep these productions atleast in steady position initiative to be taken to install more wells. KCC recently had undertaken a program to install twenty wells in Phultala to increase about 4 lakh gallons water per day (1500 m^3/day) to the city water supply.

The wells are operated 12-16 hrs daily and the water produced are distributed by rotation within the areas served by wells or group of wells acting as a network. The system is generally unpressurised and is characterized by high losses in the distribution system, estimated at 30% of the supply (MSP/LGED, 2001). A similar quantity is wasted - **(a)** within consumers' premises from leaking connection and **(b)** from ground tanks close to the supply sources and poor system control, which overflow during the supply periods depriving the consumers located further from the source. The total quantity of water waste is about 60% (MSP/LGED, 2001).

It is observed from the analysis that though different types of production wells were installed in different years to increase the production capacity of KCC but the result have not changed remarkably as some wells were installed and at the same time some were abandoned and the yielding capacity of some wells were reduced. As a result the ultimate goal to meet the demand of water supply to the city people was not achieved. During 1995 to 2004, though huge numbers of wells were installed but at the same time a large numbers were abandoned simultaneously. In 1995, there were 64 wells where 51 were in operation but in 2004 though the total numbers of wells were increased to 81 but only 50 wells were in operation. The total water abstracted by 50 KCC wells in 2004 was 26590 m^3/day. In last 20 years statistics from 1984 to 2004, the number of wells were in working and were not working with the production of the respective year were furnished in Table 2.2 and the total scenario of production of individual wells with its location is shown in Annexue A (BRGM/LGED, 2005).

The KCC was not able to supply water over the whole city as mentioned earlier that eight wards are out of this important facility. So the populations not served or not connected to the KCC supplies and in addition the people of the nearby industrial zone in Khulna have to rely on private tube wells, both motorized and non-motorized hand operated.

Table 2.2 Information of the production of wells and numbers of wells in operation year wise from 1984 to 2004 (BGRM/LGED, 2005)

Year	Production, m^3 / day	Number of wells operating	Number of wells not operating
1984	16572	21	5
1985	16183	27	2
1986	20403	28	2
1987	23553	26	6
1988	31314	35	10
1989	36736	31	14
1990	37150	37	8
1991	36621	37	8
1992	34063	37	8
1993	36329	35	10
1994	32602	34	11
1995	32420	51	13
1996	34590	50	14
1997	35465	56	14
1998	36379	47	26
1999	34352	46	27
2000	27419	45	28
2001	27664	51	28
2002	27659	51	29
2003	26590	50	31
2004	26590	50	31

2.2.1 Water Supply Network in Khulna City Corporation Area

Water supply in Khulna City is operated and managed by Water Works Department (WWD) of Khulna City Corporation through 226.43 Kms pipelines and 50 production wells. The following are the main features of water supply pipelines in Khulna city. The network and other related information in connection to water supply are presented in the water supply network map in Figure 2.1, Table 2.3 and Table 2.4.

Table 2.3 Pipe line Distribution Network in Khulna City Area (KCC, 2006).

Sl. No.	Pipe materials	Diameter (mm)	Length (Km)			
			DPHE	KDA	Total	Percent of total
1	GI PVC	75	25.60	0.40	26.00	11.48 %
2	GI, PVC	100	95.93	7.50	103.43	45.68 %
3	PVC, AC	150	68.50	4.00	72.50	32.02 %
4	PVC, AC, MS	200	18.00	4.00	22.00	9.72 %
5	MS, AC	250	2.50	-	2.50	1.10 %
Total			210.53	15.90	226.43	100.00 %

Table 2.4 Information of Water Supply Network in Khulna City Area (Rahman and Murtaza,2003).

Sl. No.	Items	Quantity / Number
01	Distribution pipe line (75-250 mm)	226.43 Kms
02	Pipe line connections	11000 nos.
03	Production tube-wells	50 nos.
04	Street hydrants	503 nos.
05	Public hand tube wells	956 nos.
06	Public hand tube-wells (Shallow)	4753 nos.
07	Private had tube-wells (Estimated)	1500 nos.
08	Over head tanks	5 (Total capacity 8 lakh gallons)
09	Mini surface treatment plant	1 (Capacity 1 lakh gallon)

Figure-2.1 Water Supply Network of KCC

2.2.2 Overhead Tanks in Khulna City Corporation Area

There are five overhead tanks in the Khulna city with the total capacity of 3044m^3 (6.7 lakhs gallons). None of the overhead tanks are active now all the tanks to be maintenance for further operation. The location and capacity of the tanks are shown in the Table 2.5.

Table 2.5 Capacity and location of overhead tank in KCC (Rahman and Murtaza, 2003)

Serial. No.	Location	Capacity m^3 (gallons)
1.	KCC head office	91 m^3 (24,000)
2.	Ferry ghat	909 m^3 (240,000)
3.	HSD new colony	680 m^3 (180,000)
4.	HSD	455 m^3 (120,000)
5.	DPHE, Rupsha	909 m^3 (240,000)
Total	-	3044 m^3 (800000)

2.2.3 Service Connections of Water Supply in KCC Area

The total service connections in the city for supply the water are through 11000 connections including domestic and industrial connections. The details along with the diameter are shown in the Table 2.6.

Table 2.6 Service Connections of KCC Water Supply (FCEAL, 2004)

Diameter (mm)	Domestic connection	Industrial connection	Total connection
15	2667	-	2667
20	7294	-	7294
25	915	-	915
40	-	64	64
50	-	55	55
75	-	2	2
100	-	3	3
Total (No.)			11000

2.2.4. Tube Wells in KCC Area

The wardwise statistics of the tube wells both shallow and deep in Khulna City Corporation area are presented in the Table 2.7.

Table 2.7. Location and status of tube tube wells in KCC Area (Rahman and Murtaza, 2003)

Ward No.	Deep Tube wells		Shallow Tube wells	
	Working	Inactive	Working	Inactive
1	14	-	216	2
2	12	-	224	1
3	17	-	242	1
4	39	-	182	1
5	19	-	193	2
6	18	-	201	2
7	19	-	186	4
8	21	3	194	9
9	61	3	177	2
10	30	1	128	5
11	23	1	163	4
12	24	1	213	4
13	23	-	184	3
14	84	-	181	3
15	25	-	197	10
16	82	-	210	-
17	76	-	180	3
18	57	3	164	-
19	43	7	172	4
20	57	5	185	8
21	42	3	194	12
22	76	4	162	8
23	47	2	165	1
24	71	4	176	8
25	52	1	181	1
26	51	2	174	1
27	57	2	196	5
28	56	1	182	2
29	50	-	193	4
30	64	3	181	14
31	83	7	194	4
Total	**1393**	**53**	**5790**	**128**

2.3 Water Supply Coverage in KCC Area

The total coverage of water supply as used by the city dwellers through piped water, street hydrant, tube wells and others (pond, river) etc are shown in Table 2.8. It is observed that about two thirds of the water needs by the city dwellers are abstracted from tube wells (deep or shallow).

Table 2.8 Water supply coverage in Khulna City Corporation area (KDA,2002).

Area	Estimated Population	Source	Population Coverage
KCC	900,000	- Piped water (KCC)	25.70 %
		- Street hydrant (KCC)	04.50 %
		- Tubewells (Deep and Shallow)	63.80 %
		- Others (Pond, Wells, Rivers)	06.00 %
Total			100 %

2.3.1 Information of Sources of Water for Different Uses

The different sources of water used by the city dwellers for drinking, cooking, washing and bathing purposes are summarized in the Table 2.9. The details of sources (ward wise) for drinking, cooking, washing and bathing water in Khulna City Corporation area are presented in the Annexes, B, C, D and E respectively. The information was taken from the Environmental Maps and Work Book for Khulna City, Khulna University, prepared for USAID, Dhaka, Bangladesh, PP.175, 1999 (USAID,1999).

Table 2.9 Sources of water for various use (Rahman and Murtaza, 2003)

Type of Water use	Percentages of different sources					Total
	Pipe	Hand Tube-well (Deep)	Hand Tube-well (Shallow)	Pond	River and other	
Drinking	4.20	45.80	44.10	2.40	3.60	100
Cooking	32.90	21.60	40.50	4.60	0.40	100
Washing	39.50	17.70	37.40	10.70	0.70	100
Bathing	39.30	11.90	35.50	12.40	0.80	100

The entire drinking water supply in the city comes from three major sources such as piped, deep and shallow hand tube wells. Hand tube wells both deep and shallow are the most widely used source of drinking water. About 94 % of the households of the city use tube well as sources of drinking water. Peoples are reluctant to use piped water for drinking purpose as it is often found contaminated, filth and bad odor. Piped water is mainly used for cooking (32.90%), washing (39.50%), and bathing (39.30%) and for drinking only (4.20%). For drinking, most of the people rely on deep tube wells (45.80%) and shallow tube wells (44.10%) respectively.

It is observed form the Table 2.9 that about 40.50 % of the households are depended on shallow tube well for cooking purpose, which is followed by pipe water supply representing 32.90%. 39.50% household used piped water for washing their utensils and clothing. A large portion of the city dwellers is depended on piped water supply for their bathing purpose as about 39.30%.

Moreover, all the industries in Khulna namely Jute mills, News Print mills, Hardboard Mills, Cable Factory, Khulna Shipyard and other use large amount of water for their various purposes. The waters of these industries are drawn either from river, ponds or from their own water supply system, namely tube wells.

Apart from the rivers Rupsha and Bhairab, there are a lot of water bodies within the Khulna city corporation area. These are mainly ponds and ditches and the waters from these water bodies are somewhere used as washing and bathing. Previously, most of these ponds were the places served as retention pond, but now many of them have already been filled up to accommodate new development.

2.4 Water Resources for Water Supply in KCC Area

There are of two major sources of water for water supply in Khulna City Corporation area:–

(i) Surface water source
(ii) Ground water source.

2.4.1 Surface Water

The two main Rivers Rupsha and Bhairab and several ponds and ditches are the main sources of surface water supply in Khulna city areas. The percentage wise users of these waters are only about 6 % of the population of the city as shown in Table 2.8. Khulna water supply system dates back to 1921 when the only source of supply water was the surface water. The raw water was collected from the river Bhairab to an open reservoir (KCC pond). The pond is filled with the river water during the period when river water is fresh that is less salinity. Khulna City Corporation has a small surface water treatment plant. The collected water from this pond is then pumped towards the reservoir of the water treatment plant before supplying it to the consumers' tap. Initially the production capacity of the treatment plant was 900m^3/hour but at present it has reduced to only 112.5m^3/hour pumping about 4-6 hours per day.

Khulna water supply system has been working since 1921 along with the treatment plant. The yielding capacity of the plant has decreased substantially from 900m^3/hour to 112.5m^3/hour. Moreover salinity in the river water has increased tremendously in the recent years. To meet the increased demand of water, KCC started installation of production wells from early seventies to supply water abstracting from ground water source and at present the KCC water supply depends on ground water. But the ground water reserve is not unlimited and abstraction can not be continued for a longer period once it will be diminished and the total supply system will break down. KCC management has realised this alarming scenario and tried to find out the alternate solution to reduce the pressure and dependency on ground water source. In light of this realization KCC engaged a consulting firm, Farhat Consulting Engineers and Architects Ltd, to carry out a study on "Surface Water Treatment Plant of Khulna City by Producing Surface Water from North of the City Area" to identify suitable surface water source; to prepare appropriate development plan for potential utilization of surface water as a source of potable water; to design surface water treatment plant that would be economically and financially feasible, technically viable and environmentally friendly. The consultant recommended undertaking a program to collect fresh surface water from Arua at the meeting pont of Atai River and Mujudkhali khal at about 20 Kms north of KCC where the sufficient fresh water will be available round the year. The water will be supplied to the KCC network in the city through a treatment plant adding about more three million gallons water per day to its main supply system in KCC. But the program has not yet been undertaken KCC by KCC possibly due to financial constraint rather another program has been undertaken to supply water to its main network from Phultala region abstracting from ground water reserves but out side the ground water reserve in KCC area.

2.4.2 Ground Water

Ground water is the main source of water supply in Khulna City Corporation area. The ground water is abstracted by Khulna City Corporation from the deep aquifer and by the private well operations drawn in a greater degree from the shallow aquifer. At present, about 97% of the KCC supplied waters are abstracted from the ground water source. In 1985, Mott McDonald undertook a details hydrological study in KCC area to quantify the sustainable ground water collection. It was estimated that the deep municipal aquifers in KCC area could sustain with a minimum yield of 59000 m^3/day fresh waters for next 30 years. They also mentioned that the estimate was made on the basis of certain conservative assumptions, so it may continue more than the period stipulated. In 2003, MSP conducted a study on Khulna water supply and indicated that ground water is available in and around Khulna in the shallow and deep aquifers. MSP studies have led to conclude that the Mott McDonald's estimation was overly conservative and hence there is a high probability of recharging from the deep aquifer and is capable of sustaining continuous abstractions for a substantially longer period than previously estimated. It is also revealed from the MSP report that the ground water in shallow aquifer is sufficiently available and can be abstracted in longer period but there is the possibility for intrusion of saline water from the upper aquifer. MSP concluded that deep aquifer response for continuous abstractions to be fully verified by monitoring and subsequent mathematical modelling to determine the maximum sustainable abstraction rate (MSP, 2001).

In 2005, KCC undertook a program to study "Groundwater Resources & Hydro-Geological Investigations in and Around Khulna City" under guidance of LGED. They evaluated the groundwater reserve estimation made by Mott McDonald and MSP reports. The consultant also realized that estimation of the groundwater reserves in KCC area is difficult as it needs reliable and sufficient data on existing abstractions but those are not available. So they worked on the basis of previous reports, available data, studied on few areas and concluded with certain observations and recommendations.

Based on the analysis of water level monitoring and water quality analysis the following observations were made by BRGM:

- The upper and shallow aquifers in KCC area are to a large extent unfit for human consumption and do not present any substantial resources that would justify its consideration in the long term planning of drinking water supply of Khulna city.
- The shallow and upper deep aquifers are hydraulically disconnected. Both groundwater quality data and piezometric data clearly show that both aquifers are not connected, except may be at some points in non-cemented walls.
- The deep aquifer is confined and it is assumed that no direct recharge from the surface takes place.

It is revealed from the report that the deep aquifer in KCC area is sandy layer of thickness ranging from 20 m to more than 150 m. From North to south, the deep aquifer layer is increasing in thickness and gently sloping southward. From West to East the thickness of the aquifer is increasing from a thin deep layer to a wide and thicker layer. This is linked to the variation in thickness of the clay layer which separates the shallow from the deep aquifer.West of the river Bhairab exists a massive layer of clay materials of up to 260m in thickness, while the east of the river, the thickness decreases to a few metres. It reveals that on the eastern and southern border of KCC, the clay layer which separates the shallow from the deep aquifer disappears allowing mixing of the two layers (BRGM/LGED, 2005).

But in 1984, IWACO undertook another study in KCC area titled "The Geohydrological Investigation in Khulna", the report provided an important information concerning the water table below Khulna City. It reveals from their monitoring reports that the position of the water table varies between 0 masl in pre-monsoon to 1.50 masl in monsoon season. It is also important in this context to check the depletion of water table due to the abstractions. The depletion curve due to abstractions from the period 1984 to 2005 as calculated by BRGM in their study is shown in Figure 2.2. It can be observed that the fluctuation of the water table is directly correlated with the variation of abstractions in KCC area (The abstraction from 1984-2004 is shown in Figure 2.3).

Finally, on the basis of study report on "Groundwater Resources & Hydro-Geological Investigations in and Around Khulna City" by BRGM/LGED, 2005 the following conclusions may be made. It has given the indication of how long the present abstraction be continued with the available ground water reserves.

- The deep aquifer reserve is quite able to sustain the present day level of abstraction rate for a fairly longer time span
- The deep aquifer can not sustain any increase in ground water withdrawal. This may accelerate the pollution of fresh water resources by inflowing highly mineralized water
- In case of increasing ground water abstractions, due to increase draw-down the risk of salt water intrusion from the south may increase considerably, although at present no reliable data is available to determine the distance of the salt/fresh water interface south of KCC.

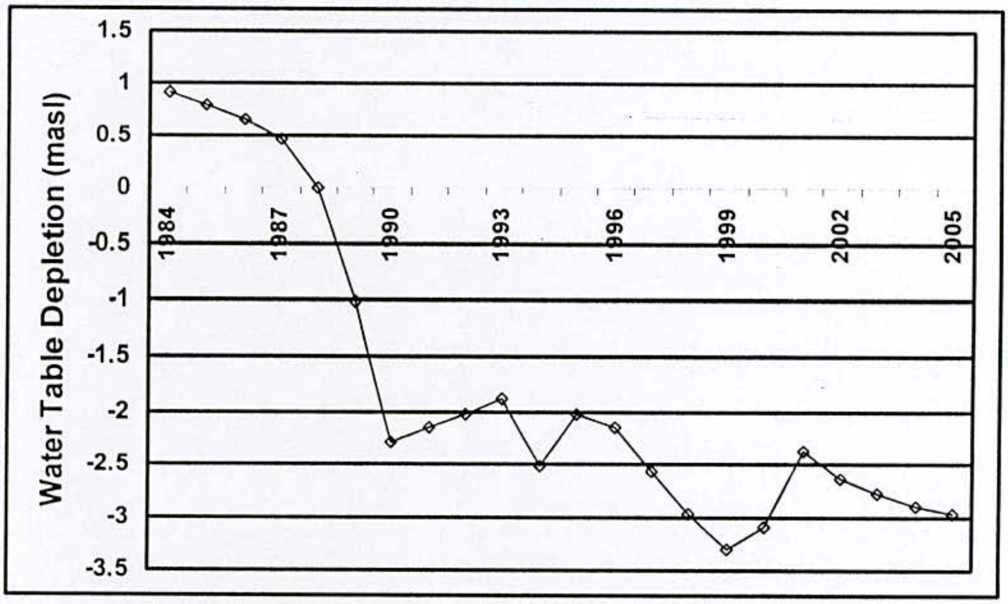


Figure 2.2 Water table depletion due to KCC abstraction between 1984 and 2004

2.4.2.1 Ground Water Abstraction Scenario in KCC Area

Ground waters are abstracted by different shallow and deep tube wells in KCC area. To assess the abstraction of ground water in Khulna city area form aquifers, the following of wells are considered:-

- Production from Khulna City Corporation (KCC) tube wells
- Production from industrial and institutional wells
- Production from KCC hand pumps
- Production from Private and Public wells

2.4.2.2 Groundwater Abstraction by KCC Wells

The productions ofKCC wells are done through pumping about 12-16 hours daily, the total number of wells in operation with the total yearly abstraction from 1984 to 2004 is presented in Figure 2.2. The details year wise total production from the wells, numbers and individual yielding capacity are shown in Appendix-E (BRGM/LGED, 2005).

It reveals from the analysis of the data cited above that the average production of all the wells is close to 26700 m^3/day (9.49 millions m^3 per year), which represents an average discharge per well is 36 m^3/hr (Considering 14-15 hours per day). The maximum production was 37150 m^3/day in 1990 where 37 wells were in operation and the second highest was 36736 m^3/day in 1989 where 31 wells were in operation. The variation of the production may be due to a number of reasons but mainly due to differences in pumping hours and in the yielding capacity of the wells. The production capacity after 2000 decreased as no new tube wells installed, some old ones are abandoned and also the yielding capacity of many wells are also decreased.

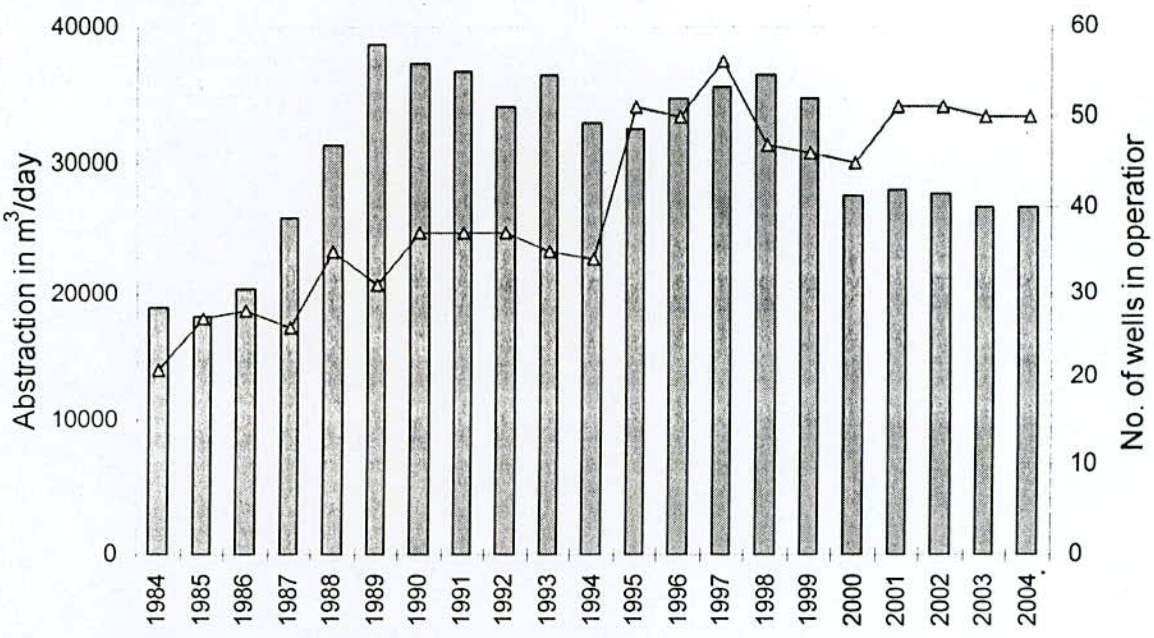


Figure 2.3 Water abstraction from deep aquifers by KCC procuction wells from 1984-2004.

2.4.2.3 Groundwater Abstraction by Industrial and Institutional Wells

In 1994, Mot McDonald Ltd. conducted an inventory for industrial and institutional wells. A new inventory was prepared by BRGM (2005) through Ground Water Resources and Hydro-Geological Investigation in and around Khulna City under Municipal Services

Project (MSP), 2005 in Khulna City Corporation area. Both the survey report provided informed about the abstraction in different aquifers like upper aquifer, shallow aquifer and deep aquifer. They have calculated abstraction considering 37% wells from deep aquifer, 42% from shallow aquifer and about 21% from upper aquifer. In 2004, within the total 10900 tube wells both industrial and institutional, 4000 wells were abstracting from deep aquifer while 2250 wells were abstracting from upper aquifer and remaining 4650 wells were abstracting from shallow aquifer. In 2004, the total waters abstracted from different aquifers was 43600 m^3 /day. The abstractions of industrial and institutional wells during 1984-2004 from different aquifers are shown in Table 2.10 and in Figure 2.4.

Industrial wells are mainly located along the river Bhairab and Rupsha particularly in the industrial belt. But both the inventory pointed out two important facts: -

- 10 years ago the jute factories mainly owned their industrial wells. Some of the jute factories still exist; industrial wells are operated by Sea Food industry, ice factory.
- In 1994, only 22% industrial and institutional tube wells were exploiting the deep aquifer. In 2004, a major change in drilling habits was observed that 90% of the new wells were deep tube wells where as there were no changing pattern observed for shallow aquifersince 1992 and very little growing pattern in upper aquifer since 1994 (BRGM/LGED, 2005).

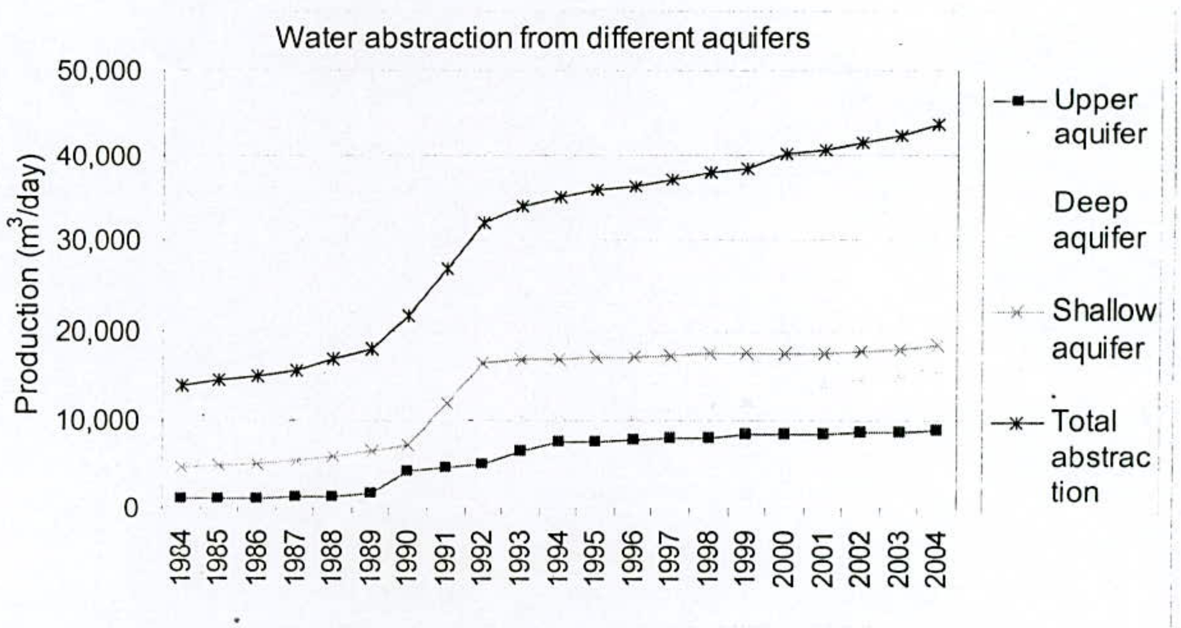


Figure 2.4 Water abstraction by industrial and institutional wells from different aquifers

Table 2.10 Water abstraction by industrial and institutional wells (BRGM/LGED, 2005)

Year	Upper aquifer, m^3/year	Deep aquifer, m^3/year	Shallow aquifer, m^3/year	Total abstraction, m^3/year
1984	400,000	3000000	1700000	5100,000
1985	400,000	3100000	1800000	5300,000
1986	420,000	3200000	1900000	5520,000
1987	440,000	3300000	2000000	5740,000
1988	500,000	3500000	2200000	6200,000
1989	600,000	3600000	2400000	6600,000
1990	1600,000	3650000	2700000	7950,000
1991	1700,000	3700000	4400000	9800,000
1992	1900,000	3750000	6000000	11650,000
1993	2400,000	3800000	6200000	12400,000
1994	2800,000	3800000	6200000	12800,000
1995	2850,000	3950000	6250000	69300,000
1996	2900,000	4000000	6300000	13200,000
1997	2950,000	4250000	6350000	13550,000
1998	3000,000	4500000	6400000	13900,000
1999	3100,000	4500000	6400000	14000,000
2000	3100,000	5100000	6450000	14650,000
2001	3150,000	5200000	6450000	14800,000
2002	3180,000	5400000	6500000	15080,000
2003	3200,000	5600000	6600000	15400,000
2004	3300,000	5900000	6700000	15900,000

2.4.2.4 Water Abstraction by Hand Pumps

In 2001, KCC reported that there were about 7250 numbers hand pumps both deep and shallow aquifers working in Khulna City Corporaton area. Another report was published in the daily Tribune on 01 November, 2003 stated that there were about 2500 deep and 4500 shallow tube wells in KCC area (i,e; 36% are deep tube wells). The later information was considered more authentic by the consultant BRGM, 2005, engaged for Groundwater and Hydro-Geological investigation in and around Khulna City. According to BRGM, by these 7000 pumps, the total water abstraction from ground water source is about 28000 m^3/day of which 10080 m^3/day from deep aquifer (36% are deep tube wells) and remaining 17920 m^3/day is from shallow aquifers by STW considering $4m^3$/day yielding per well (BRGM/LGED, 2005).

There are two assessment procedures followed to assess the water abstraction by the tube wells. The first one is based on the users capacity to draw water from tube wells and the second one is based on the consumption of water per capita per day

Abstraction Assessment Through Number of Wells

If it is considered that one tube well feeds 100 inhabitants and if the average consumption is 40 L/day per capita, the production will be 4m^3 /day. In 2001, Mott McDonald considered this idea because of the better productivity and a better water quality, the solicitation of deep tube-wells reaches 6.6 m^3/day against 3.3m^3/day for shallow tube wells. However, 6.6m^3/day means 660 buckets a day or roughly one bucket each two minutes. But BRGM/LGED in 2005 considered 4m^3/day abstraction per tube well was reasonable irrespective of shallow or deep.

Abstraction Assessment Through Population Statistics

The present population is about 9,00,000 in Khulna City Corporation area. As per the UNICEF / DPHE consideration a net drinking water consumption 90 lpcd is reasonable for a typical city area though it is higher than the normal consumtion. The report considered 92 lpcd for large city and 140 lpcd for Dhaka as mega city. The per capita consumption figure in KCC is higher for several reasons:

- Tapped water changes the habits of the users who consume more water
- Small industries and hotels which are connected to the network are bigger consumers than countryside people
- Leakages of the distribution network are increasing considerably the consumption per capita. Mott McDonald estimated these leakages to be 50 to 60% as mentioned earlier.

A drinking water consumption of 90 lpcd seems reasonable but questions may arise which percentages of the inhabitants of KCC have access to tap water. As per official figure of the Master Plan elaborated by KDA in 2002, only 30% of KCC populations have access to tapped water, the remaining 70% are using hand pumps or private wells.

At present for 9,00,000 population in the City of which 30% are consuming as 90 lpcd who uses tapped water and 70% population are consuming water at the rate of 40 lpcd who are using hand pumps. Hence 30% who are using tapped waters from KCC supplied water amounting abstraction around 24300 m^3/day and 70% are using water from hand pumps abstracting around 25200 m^3/day from private wells that is total abstraction is about 24300 + 25200 = 49500 m^3/day (MSP, BRGM,2005).

2.5 Total Water Abstracted From Wells And Other Sources

The people in the Khulna City Corporation area are meeting their water demand by abstracting water from ground water source falls under three categories given below with the quantities:

(i) The total water abstracted or produced by KCC production wells on an average in the whole year is 26600 m^3/day as shown in Appendix-E.

(ii) By the hand pumps through 7000 numbers of tube wells both private and public- both by deep and shallow aquifers are about 28000 m^3/day

(iii) The waters abstracted from the industrial and institutional tube wells are 43600 m^3/day as shown in the Table 2.10.(From upper aquifer 9000 m^3/day, deep aquifer 16400 m^3/day, shallow aquifer 18200 m^3/day).

So it is concluded that KCC is producing 26600 m^3/day through their production wells and around 700 m^3/day from the surface water treatment plant as pumped from the storage reservoir. Hence, the total water supply by KCC production wells and Water Treatment Plant is about 27300 m^3/day.

The total water abstracted from the ground water sources by KCC, public and private wells, institutional and individual wells and by KCC from surface water source through Water Treatment Plant is shown in Table 2.11 and also in pie chart in Figure 2.5.

Table 2.11 Scenario of total water abstraction in KCC area

Types	Abstraction in m^3/day	% of total abstraction
KCC production wells	26600	22.10%
Industrial and institutional wells	43600	36.21%
Private and public hand tube wells	49500	41.11%
Surface water treatment plant, KCC	700	0.58%
Total of above four types	120400	100.00%

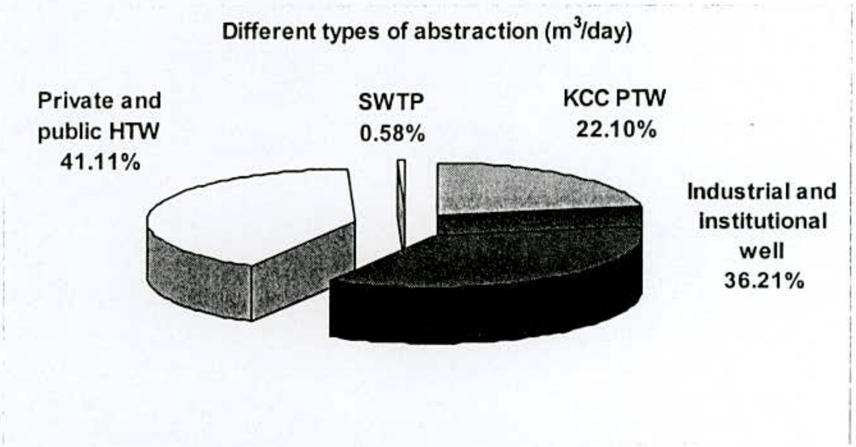


Figure 2.5 Different types of abstraction in KCC area

About 99.4% of the Khulna City water requirement is met from the ground water sources either abstracting by KCC production wells or by public and private wells or by institutional and industrial wells and only 0.58% water is supplied from surface water source. It reveals that KCC is supplying only 22.10% water and 77.32% water is abstracting by other wells. It is also clear from the Figure 2.4 that KCC supply is available only less than 25% of city population. Private abstraction increases the losses and wastages ultimately will create pressure on ground water source. Moreover, there is every possibility of contamination of privately abstracted water and will create disease burden to the users for faecal pollution.

2.6 Conclusion

Khulna Municipality, now Khulna City Corporation was established in 1884. The water supply started in 1921; the surface water from the river Bhairab was supplied to the city people through the surface water treatment plant. The yielding capacity of this treatment plant has decreased to only 112.5 m^3/day from 900 m^3/day at the inception. The surface water is accounts for only about 3% of total production of KCC. At present about 97% waters are abstracted from ground water source.

Khulna City Corporation started to abstract ground water from early seventies when the salinity of river water exceeded the tolerable limit. In 1979, KCC had only 10 production tube wells; the number of wells have been increased at different stages and ultimately in 2004 the total number of wells were 81 where only 50 in operation having total production capacity about 26600 m^3/day. The yielding capacites of wells decrease along with the increase of ages. So to keep the present state of production the city corporation should take necessary measures to install more PTWs and proper repair and maintenance to be continued for the old wells.

Not only KCC wells but also public and private tube wells, industrial and institutional wells are abstracting water from ground water resource. At present, the total about 120400 m^3/day waters are abstracted from the ground and surface water sources. Among those, only 700 m^3/day (0.58%) waters are abstracted from surface water source and the remaining 99.4% are abstracted from ground water source. At present, waters are abstracted about 26600 m^3/day (22.1%) by KCC wells, 43600 m^3/day (36.2%) by industrial and institutional wells and 49500 m^3/day (41.11%) by private and public wells. The drinking water requirement of city people are met taking only 4.2% from KCC supply, 89.9% from other wells and 5.9% from ponds and rivers. The major quantities of water requirements to city people for cooking, washing and bathing are met from the water of other wells abstracting from groundwater source.

Groundwater reserve is not unlimited. KCC conducted a number of hydrological investigations through different consulting firms to quantify the groundwater reserves in

KCC area, to assess the safe withdrawal rates and to define groundwater development strategy for the next atleast 30 years to meet the drinking water demand. In early eighties the first hydrological study was conducted by IWACO. The main observation of IWACO was that the position of water table in KCC area varied only between 0 (zero) masl (Mean average sea level) in pre-monsoon and 1.50 masl in monsoon season. In 1985, Mott McDonald undertook a details hydrological study to quantify the sustainable groundwater collection. It was estimated by them that the deep municipal aquifer could sustain a minimum yield of 59000 m^3/day of freash water for next 30 years with conservative assumption. In 2001, MSP conducted another hydrological study; their main observation was that sufficient groundwater is available in and around Khulna city in the shallow and deep aquifers. MSP studies have led to conclude that McDonald's estimation was overly conservative and there is a high probability that the deep aquifer is being recharged and is capable of sustaining continuous abstraction for a substantially longer period. In 2005, BRGM, MSP undertook another study on Groundwater Resources and Hydro-geological Investigations in and around Khulna City. They also evaluated the studies undertaken earlier and based on the available data, they commented that the ground water resources may sustain for a long time span at present level of abstraction as forecast earlier but it depends on the increase of demand and rate of abstraction in future.They also informed that if the groundwater abstraction is increased tremendously, due to increased draw-down the risk of salt water intrusion from the south may increase considerably in KCC area.

In order to reduce the continuous increasing pressure on groundwater source and to find out a suitable surface water source to meet the water demand in the city, in 2004 KCC engaged a consulting firm, Farhat Consulting Engineers and Architects Ltd, to conduct feasibility study to identify suitable surface water source for supplying drinking water atleast 30 million gallons per day and to prepare development plan that may be economically and financially feasible, technically viable and environmentally friendly. They identified a surface water source at the meeting point of Arua river and Mojudhkhali khal at about 20 kms north of Khulna City. They also submitted a complete development plan along with the details design of SWTP and others to KCC for implementation but KCC has not yet undertaken this progam.

KCC has recently undertaken a program to collect the groundwater from Phultala region through its transmission line to supply water to meet the demand of drinking water in the city. As the source of this groundwater is outside the KCC groundwater belt it will reduce the pressure on groundwater resource in KCC as well meet the partial demand of drinking water. Yet as the population of the city as well as the demand of water particularly the drinking water is increasing, the KCC should undertake such a scheme(s) in long term perspective to meet the water demand of the increased population of the city even if it requires huge investment as mentioned in KDA Master Plan,2002.

CHAPTER III

POPULATION FORECAST AND WATER DEMAND ANALYSIS

3.1 Introduction

Adequate water is absolutely essential to all life both animal and plant for the existence on the earth. Water is not used only for drinking and curlinary purposes but also for bathing, washing and many other important purposes. Invariably, the progress of sanitation throughout the world has closely associated with the availability of sufficient water. Inadequate water supply and sewerage must create health hazards for the inhabitants in the city. It is said that the larger the quantity and the quality of water, the more rapid and extensive has been the advance of the public health. The quantity of water demand for a community fully depends on the population of the community. The quantity of demand is also related on the profession of the inhabitants, number and nature of different facilities such as industry and commerce, educational institutions, offices, hotels and restaurants. Population prediction is the vital and most important element to calculate the demand of water for that particular community or area. An accurate forecasting might provide the opportunity to a designer to estimate the more accurate quantity of water required for the people of that community. Khulna is the third largest metropolitan city of the country where all types of facilities exist like other metropolitan cities of the country. It is obviously essential to forecast the future population for estimating or analysis the future demand of water. This chapter discusses the prediction of future population and water demand in Khulna City Corporation area.

3.2 Population Prediction

Population prediction for future is very important in order to assess the future water demand in a city. The future population for a particular duration of a city is required for designing a water supply project. The past population for a particular administrative area can be obtained from the census reports. An analysis was done to predict the population for the year 2007, 2011, 2021 and 2031 to estimate the water requirement for the respective times.

There are several methods may use to forecast the future population for a water supply project. These include the following (Ahmed and Rahman, 2003).

(i) **Uniform growth rate method** - In this method, a constant increment of growth is added for a period based on the population growth of the same period of the recent past.

(ii) **Uniform percentage growth rate method** - In this method, a constant percentage of growth is assumed for an equal period of time.

(iii) **Decreasing growth rate method** - This method is similar to the uniform growth rate method but with an assumption of a decreasing rather than a uniform rate of increase.

(iv) **Graphical extension or Curvilinear method** - In this method, the population - time curve is extended by eye estimation to obtain the future population.

(v) **Graphical comparison method** - This method involve the extension of population – time curve of the community under study into the future, based on a comparison of population – time curve of similar communities instead of projection by eye estimation.

(vi) **Geometric progression method** - Geometric progression method is also known as empirical method suggested by Hardenberg.

(vii) **Least square parabola method** - This method is most widely used method used in forecasting the future population. In this method an equation of the population-time curve is determined by the least square method using the available data.

For forecasting the population of Khulna City Corporation area, the least square parabolic method is adopted. The population of 45.65 km^2 was considered for which the census report for the year 1981, 1991 and 2001 were available. The population of the census report of 1961 and 1974 was not considered because at that time the city area was smaller than 45.65 km^2. More over the population was very low at that time. The area of the Municipality/City Corpotation was increased in the year 1961 and 1974 and 1993.

The equation of the least square parabola fitting time – population data is assumed to be -

$$Y = a + bX + cX^2 \qquad \text{------------------ (i)}$$

Where a, b, and c are constants that can be found from the normal equation where X and Y are variables denoting the year and population. The normalized equation of the least square parabolic method can be written as:

$$X\Sigma Y = aN + b\Sigma X + c\Sigma X^2 \qquad \text{------------ (ii)}$$

$$\Sigma XY = a\Sigma X + b\Sigma X^2 + c\Sigma X^3 \qquad \text{------------ (iii)}$$

$$\Sigma X^2 Y = a\Sigma X^2 + b\Sigma X^3 + c\Sigma X^4 \qquad \text{------------ (iv)}$$

The parameters values of equation (ii), (iii) and (iv) are presented in the Table 3.1 and the equation for population forecasting can be written as :

$$Y = 663340 + 109770 X + 38390 X^2 \qquad \text{-------------------- (V)}$$

The projected population for the year 2007, $Y_{07} = 932486$

The projected population for the year 2011, $Y_{11} = 1036440$

The projected population for the year 2021, $Y_{21} = 1338160$

The projected population for the year 2031, $Y_{31} = 1716660$

The Population –Time curve in KCC area is shown in Figure 3.1 based on equation (v).

Table 3.1 Parameters values of LSM for KCC Population forecasting

Year	X	Y	X^2	X^3	X^4	XY	X^2Y
1981	-1	591960	1	-1	1	-591960	591960
1991	0	663340	0	0	0	0	0
2001	1	811500	1	1	1	8.12	8.12
	ΣX =0	ΣY =2066800	ΣX^2 =2	ΣX^3 =0	ΣX^4 =2	ΣXY =219540	ΣX^2Y =1403460

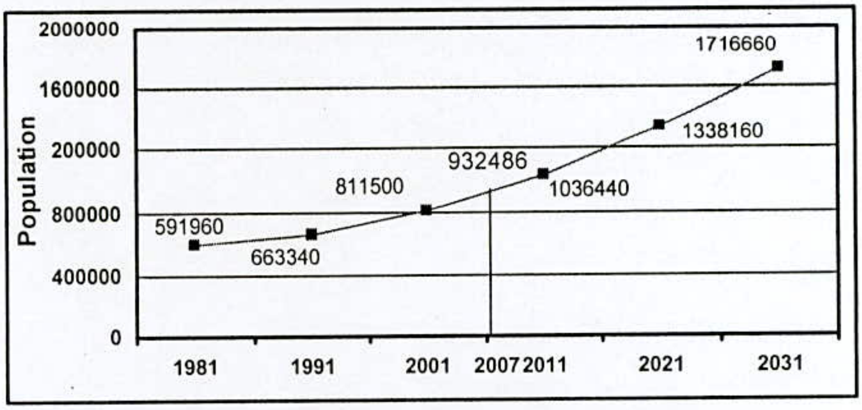


Figure 3.1 Population -Time curve for KCC area

3.3 Water Demand Analysis

In estimating the water demands, the population – time curve for KCC area is used. The population in the intermittent time can also be found from this curve in Figure 3.1.

Water requirement for a city or a particular community depends on the per capita water consumption for various purposes. Again per capita water consumption relies on the nature and type of population living there, their profession, types and nature of industries, commercial volume, types and activities etc. So in a city like Khulna the water consumption may be broadly brought under the following categories:

(i) Drinking
(ii) Cooking
(iii) Bathing, cleaning, washing
(iv) Watering of vegetables and gardens
(v) Sanitation
(vi) Loss and wastage etc.

The per capita water consumption is also greatly influence by various other factors. Some major factors are as follows (Ahmed and Rahman, 2003):

(i) **Population distribution -** The distribution of population of a community is age groups; religious; sex; socio-economic conditions; profession etc greatly influence the per capita water consumption.

(ii) **Climatic conditions -** More water is used in warm and dry climates than in humid and cold climates.

(iii) **Quality of water -**The consumption of good quality water is higher because of good taste, feeling of safety and its suitability for all domestic purposes.

(iv) **Pressure of water from the supply system -** In the case of piped, the rate of water use increases with the pressure in the distribution system.

(v) **Water rates and metering -** If the cost of water is high, people become more conservative in water use. Metered consumers are more likely to repair leaks, close valves and use water with discretion.

(vi) **Nature of supply -** In piped water supply, the rate of use with intermittent supply is much less than the use in continuous supply. The non-availability of water around the clock restricts many uses. Intermittent supplies result in a decrease in losses, and wasteful uses of water.

(vii) **Water source -** The distance between the source of water and the point of consumption play the most important role in water consumption. Accessibility as well as privacy at the source also influences water consumption.

(viii) **Availability of an alternative source -** Availability of an alternative source of water such as rivers, ponds, lakes etc greatly influences the use of a source of water supply for all domestic purposes.

(ix) **Sanitation -** The quantity of water needed for sanitary purposes depends on the type of sanitation facilities. The water requirement is minimal for people using pit latrines and requirements increase for pour-flush latrines.

3.4 Water Requirement

Quantities of water requirement for different purposes are different. The consumption is also different from rural to urban, small town to city, residential area to industrial and commercial area etc.The typical water requirements for domestic purposes are given in the Table 3.2.

Table 3.2 Water requirements for domestic purposes (Ahmed and Rahman, 2003).

Types of water supply	Water consumption range lpcd	Typical water consumption lpcd
Village open/tube wells and stand point:		
Distance > 1000 m	5 - 10	7
Distances 500 - 1000 m	10 - 15	12
Distances 250 - 500 m	20 - 25	15
Distances 50 - 250 m	15 - 40	25
Distance < 50 m	20. - 45	35
Water supply source in yard		
Well in yard	20 - 60	40
Single tap in yard	30 - 80	50
House connection: Single tap	30 - 60	50
Multiple tap	70 - 250	150

In a community, water is not used for domestic purposes only but also for other purposes. So to meet the demand of water for other purposes additional water supply is required. The water requirements in a community for various other purposes are shown in Table 3.3.

Table 3.3 Water requirements for different other purposes (Ahmad and Rahman, 2003)

Nature of consumption	Range of consumption lpcd	Average consumption lpcd
Commercial use	10 – 150	40
Industrial use	30 – 450	120
Public uses	10 – 100	25
Live stock	10 – 35	20
Loss and wastage	20 –150	40

Water requirement may vary widely from place to place and also from town to village. The requirements in urban and rural, upazilla and city used for the design and planning purposes are given below in Table 3.4.

Table 3.4 Water requirement for urban and rural areas in BD (Ahmed and Rahman, 2003)

Areas	Water consumption lpcd
Rural areas	50
Upazila towns	100
Zilla towns	120
City corporation	180

The water consumption showed above for the city corporation is seemed too high. Different consultant groups opined differently on the basis of their survey and experiences that water consumption may vary as per the size and nature of city. For Dhaka City Corporation it may be considered 180 lpcd but in Bangladesh for other city corporation it is too high. So for Khulna City Corporation area maximum water consumption may be considered 140 lpcd including domestic and non-domestic demand. Table 3.5 gives an indication of unit demand / consumption values of water in the different cities of Bangladesh and some cities of South-East Asia (BRGM/LGED, 2005).

Table 3.5 Unit consumption of water in different cities in Bangladesh and South-East Asia (BRGM/LGED, 2005)

Location	Unit consumption (lpcd)	Purpose
Dhaka	135	Mean annual demand for design
Chittagong	130	consumption
Various Pourashava, BD -Single tap connection - Multi tap connection	70 100	Design, 2000 Design, 2000
Mombai	155	Consumption
Kolkata	191	Consumption
Madras	80	Consumption

Surabaya, Indonesia - High income - Medium income - Low income	210 117 90	Consumption 1991
Anglian water, UK	145	Consumption 1991

Several factors have been identified those may govern the future water demand calculation in KCC for the year 2007, 2011, 2021 and 2031. The main factors are the population growth, increased service coverage and increased per capita water consumption. More over, the percentages of non-domestic water use and also the percentages of wastages and losses etc are the factors to consider for water demand estimation for future.

From the analysis of available documents and reports, in 2007 the percentages of losses and wastages, percent population coverage in supply, percentages of non-domestic demand and lpcd have been considered for projected demand calculation as stated below. The system losses and wastages have been considered amounting to 60% at present, so the estimation of future water demand and supply requirement depends heavily on the percentages of system lessees and wastages are reduced gradually in the subsequent years. The population coverage in the KCC supply is around 40% now, it will gradually be increased to around 85%-90% for the better services, the non-domestic consumption will also increase from 20%-25% of net domestic demand at present stage to around 30%-35% in the targeted year, the per capita water consumption for domestic purposes from 70 lpcd to 100 lpcd in the year upto 2031. The all above factors are brought under three major options to estimate the future water demand in KCC for the year up to 2031 are described below. Table 3.9, Table 3.10 and Table 3.11 summarize the estimation of future water demand on the basis of the option-1, option-2 and option-3 respectively. The water demand calculated for different years up to 2031 and the supply scenarios are presented in the subsequent tables and figures.

Option -1 :

Some assumptions are considered here for future water demand calculation based on the observation and recommendation from the available documents and reports of present water supply scenario in Khulna City Corporation.

Table 3.6 Assumptions for KCC water demand calculation as per option-1.

Item	Unit	Year			
		2007	2011	2021	2031
Population coverage	%	60	70	75	85
Population take up from KCC pipe supplies supply	%	70	75	80	80
Unit domestic demand	lpcd	65	65	70	70
Non-domestic demand (% lpcd)	%	25	25	30	30
Overall wastages and losses	%	40	35	30	30

Option -2 :

To calculate the water demand in KCC on various scenarios, some assumptions considered in option -1 are modified, like water consumption per capaita in different years are increased with some percentages and the percentages of losses and wastages are reduced.

Table 3.7 Assumptions for KCC water demand calculation as per option-2.

Item	Unit	Year			
		2007	2011	2021	2031
Population coverage	%	60	70	75	85
Population take up from KCC pipe lines supply	%	70	75	80	80
Unit domestic demand	lpcd	65	75	90	100
Non-domestic demand (%lpcd)	%	25	25	30	30
Overall wastages and losses	%	40	30	25	20

Option -3 :

To calculate the water demand in KCC on various scenarios, some assumptions considered in option -2 are also modified like increasing the percentages of population served and further decreasing the percentages of losses and wastages.

Table 3.8 Assumptions for KCC water demand calculation as per option-3.

Item	Unit	Year			
		2007	2011	2021	2031
Population coverage	%	60	75	85	90
Population take up from KCC pipe lines supply	%	75	80	85	85
Unit domestic demand	lpcd	65	75	90	100
Non-domestic demand (%lpcd)	%	25	30	30	33
Overall wastages and losses	%	40	25	20	20

The summary of future water demand calculation on the basis of the assumption made in the Table 3.6 as per option-1 is shown in Table 3.9.

Table 3.9 Summary of water demand calculation of KCC area as per assumption of option-1

Item	Unit	Year			
		2007	2011	2021	2031
Total population	Nr.	932486	1036440	1338160	1716660
Coverage of KCC piped supplies					
Population coverage	%	60	70	75	85
Population take up from KCC pipe supplies	%	70	75	80	80
Net population served	%	42	52.5	60	68
Net population served	Nr.	391644	544131	802896	1167330
Domestic estimate					
Unit domestic demand	lpcd	65	65	70	70
Total net domestic demand	m^3/d	25457	35368	56203	81718
Non-domestic demand (%lpcd)	%	20	25	30	35
Total net demand	m^3/d	31821	47158	80290	125720
Overall wastages and losses	%	40	35	30	30
Wastages and losses	m^3/d	21214	25393	34410	53880
Total demand	m^3/d	53035	72550	114700	179600
Total unit Demand	lpcd	135	133	142	154

The scenario of water demand, wastages and losses along with the population for the year 2007, 2011, 2021 and 2031 as per the option-1 is shown in the Figure 3.2. The scenaros between water demand and KCC water supply; water demand and total water supply (KCC supply and supply from other wells) are shown in Figure 3.3 and Figure 3.4 respectively.

The KCC water supply for the year 2007, 2011, 2021 and 2031 have been forecast at the rate of 4% per year increase as assumed by BRGM/LGED, 2005. The water supply or abstractions by other pumps have been considered average 2% increase per year, BRGM/LGED, 2005. These assumptions for calculation of water supply from KCC and other wells in different years are similar as presented in Table 3.10 and Table 3.11.

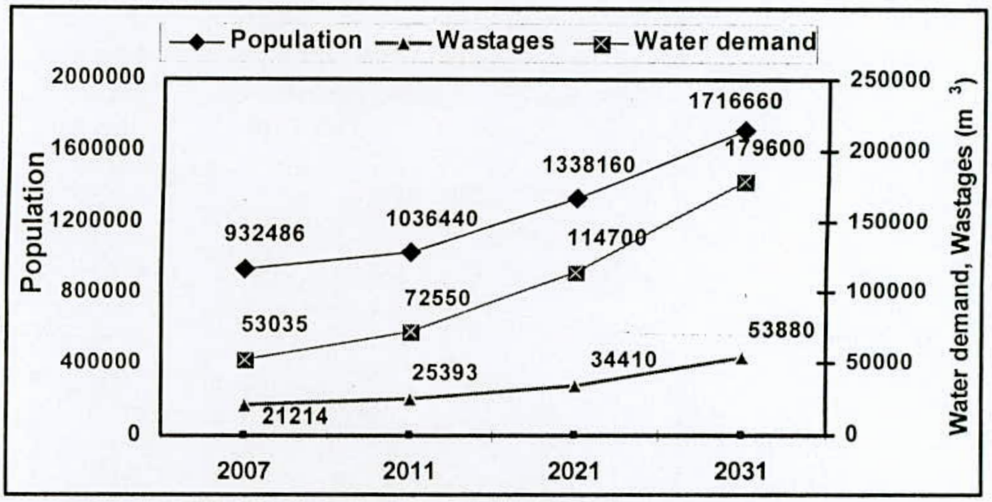


Figure 3.2 Population – Water demand and wastages curve as per option-1.

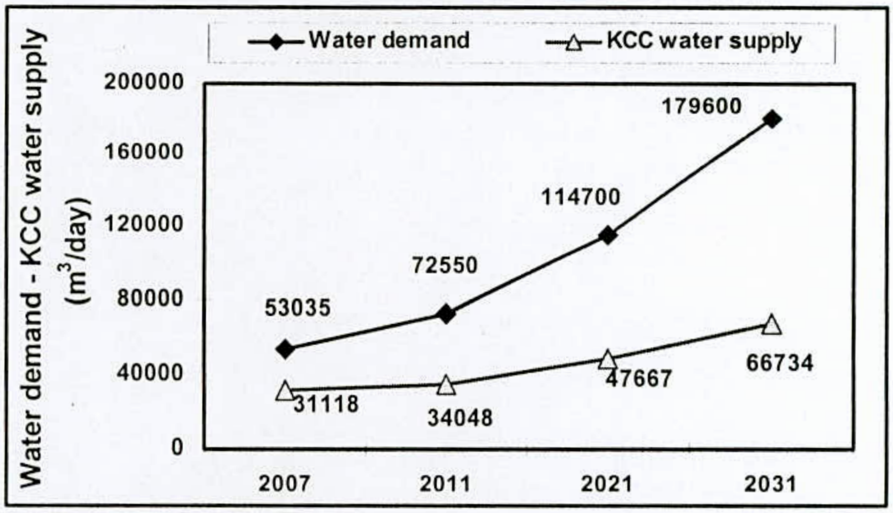


Figure 3.3 Water demand – KCC water supply curve as per option-1

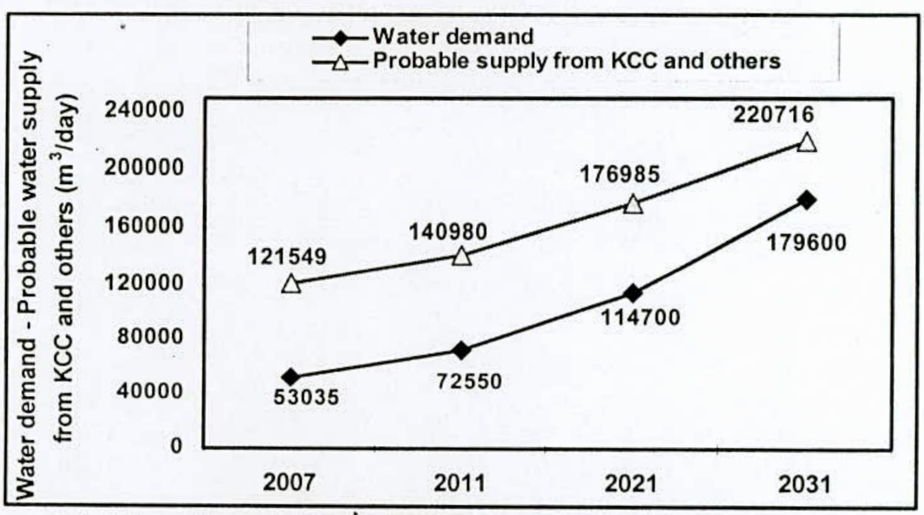


Figure 3.4 Water demand – supply (from KCC and other pumps) as per option-1

The summary of future water demand calculation on the basis of the assumption made in the Table 3.7 as per option-2 is presented in Table 3.10.

Table 3.10 Summary of water demand calculation of KCC area as per assumption ofoption -2

Item	Unit	Year			
		2007	2011	2021	2031
Total population	Nr.	932486	1036440	1338160	1716660
Coverage of KCC piped supplies					
Population coverage	%	60	70	75	85
Population take up from KCC pipe supplies	%	70	75	80	80
Net population served	%	42	52.5	60	68
Net population served	Nr.	391644	544131	802896	1167330
Domestic estimate					
Unit domestic demand	lpcd	65	75	90	100
Total net domestic demand	m^3/d	25457	40810	72260	116733
Non-domestic demand (%lpcd)	%	20	25	30	30
Total net demand	m^3/d	31821	54414	103230	166760
Overall wastages, losses	%	40	30	25	20
Wastages and losses	m^3/d	21214	36115	34410	41690
Total demand	m^3/d	53035	77733	137640	208450
Total unit demand	lpcd	135	143	171	178

The scenario of water demand, wastages and losses along with the population for the year 2007, 2011, 2021 and 2031 as per the option-2 is shown in the Figure 3.5. The scenaros between water demand and KCC water supply; water demand and total water supply (KCC supply and supply from other wells) are shown in Figure 3.6 and Figure 3.7 respectively.

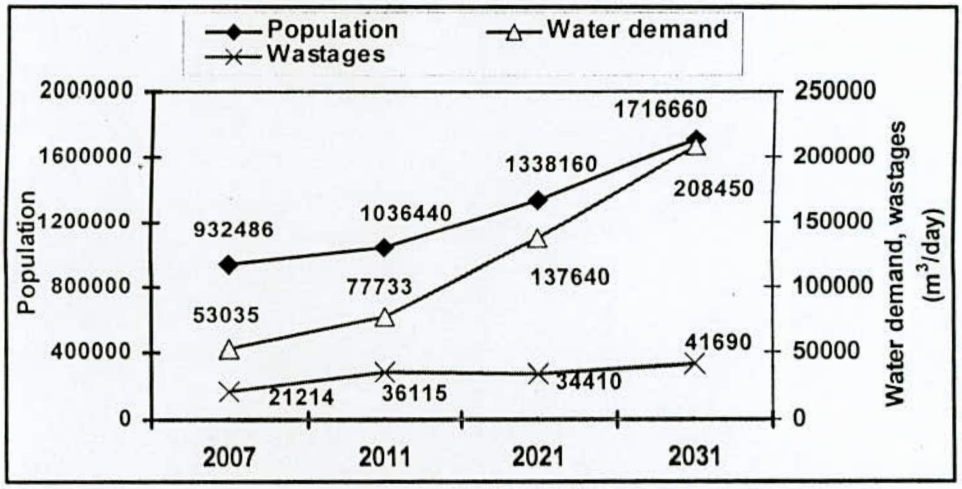


Figure 3.5 Population – Water demand and wastages curve as per option-2

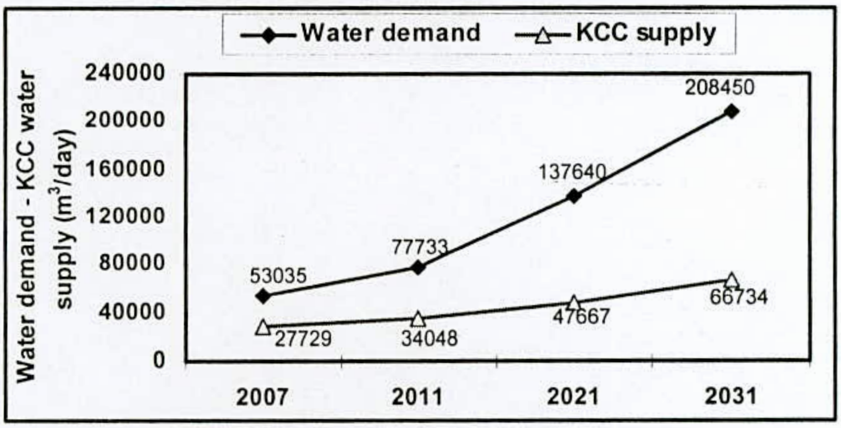


Figure 3.6 Water demand – KCC water supply as per option-2

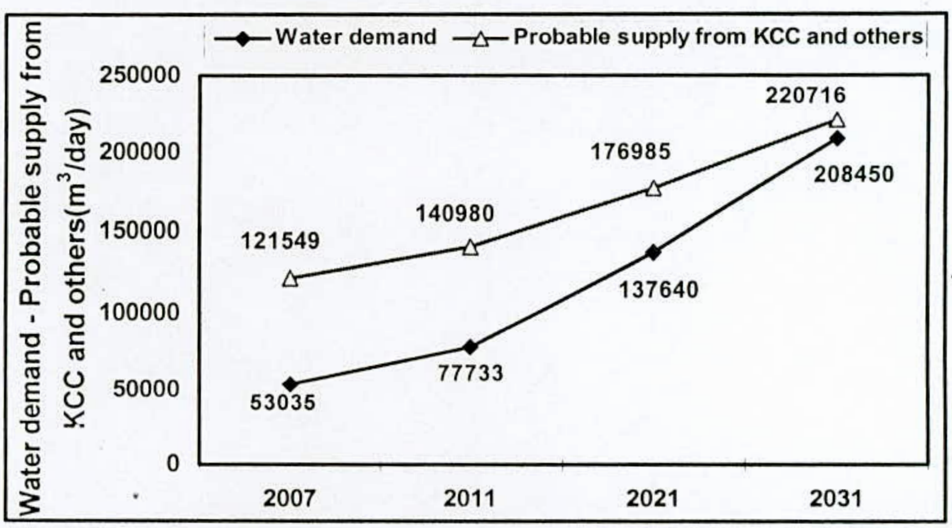


Figure 3.7 Water demand – supply (KCC and other pumps) as per option-2

The summary of future water demand calculation on the basis of the assumption made in the Table 3.8 as per option-3 is presented in Table 3.11.

The scenario of water demand, wastages and losses along with the population for the year 2007, 2011, 2021 and 2031 as per the option-3 is shown in the Figure 3.8. The scenaros between water demand and KCC water supply; water demand and total water supply (KCC supply and supply from other wells) are shown in Figure 3.9 and Figure 3.10 respectively.

Table 3.11 Summary of water demand calculation of KCC area as per assumption of option -3

Item	Unit	Year			
		2007	2011	2021	2031
Total population	Nr.	932486	1036440	1338160	1716660
Coverage of KCC piped lines supply					
Population coverage	%	60	75	85	90
Population take up from KCC pipe line supply	%	70	80	85	85
Net population served	%	42	60	72.25	76.5
Net population served	Nr.	391644	621864	966820	1313245
Domestic estimate					
Unit domestic demand	lpcd	65	75	90	100
Total net domestic demand	m^3/d	25457	46640	87013	131324
Non-domestic demand (% lpcd)	%	20	30	30	33
Total net demand	m^3/d	31821	66628	124305	196005
Overall wastages, losses	%	40	25	20	20
Wastages and losses	m^3/d	21214	22209	31076	49000
Total demand	m^3/d	53035	88838	155382	245000
Total unit demand	lpcd	135	143	161	186

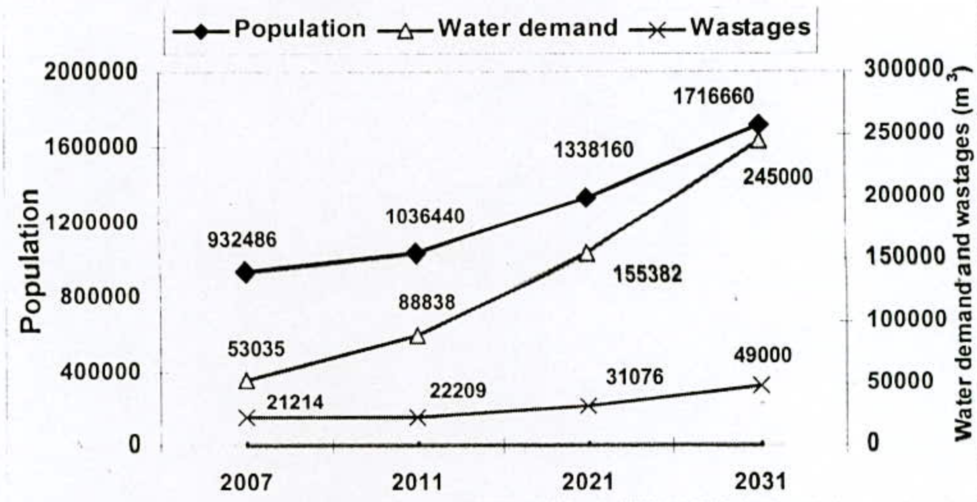


Figure 3.8 Population – Water demand and wastages curve as per option-3

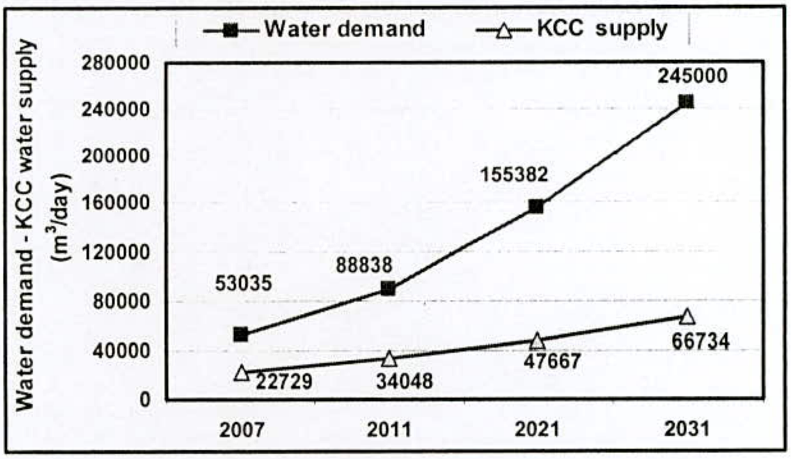


Figure 3.9 Water demand – KCC water supply as per option-3

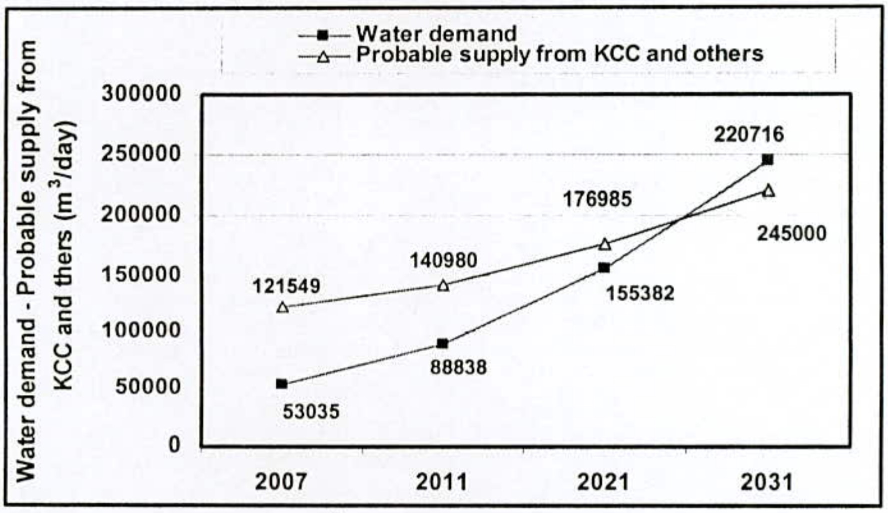


Figure 3.10 Water demand – supply (KCC and other wells) as per option-3·

The different scenarios of water demand and water supply from KCC and probable supply from other wells on the basis of assumptions made in three major options are presented in the Table 3.9, Table 3.10 and Table 3.11 and in the subsequent figures. The demand, water supply from KCC and from others wells are analysed. But the difference between the demand and KCC supply has been supplemented by supplying water from the private, public, industrial, institutions and other sources. As per Table 3.10 and associated Figure3.6 and Figure 3.7 it is observed that the gaps beteen demand and supply has increased from 2007 upto 2031 because the demand has increased as per the increase of population but KCC supply has not been increased accordingly. But it is interesting that the total demand is satisfied in 2031 due to the increased abstraction from other sectors than KCC. As per the option-3, the demand and supply scenarios have been presented in Table 3.11 and associated Figure 3.9 and Figure 3.10, it reveals that though the KCC supply has not been increased but the total supply curve run above the demand curve and meets with each other around the year 2025. It means that the water demand is satisfied with the supply but the dependencies on the water supply from private and public wells, institutional and industrial wells have been increased tremendously

The water demand presented in Table 3.11 as per the predicted option-3 seems more reasonablebecause the per capita water consumption, the population coverage and the wastages etc considered here is ideal and reasonable and the demand and supply are satisfied

3.5 Conclusion

Water is very much essential for all life either animal or plant. KCC is the official authority to supply water to the city people. Population forecasting and water demand calculation is important to take up any scheme related to water supply. This chapter deals with the population forecast and water demand analysis in KCC area.

At present, the area of Khulna City is about 45.65 km^2 with the population about 932000 having population density 20400 per km^2. The population of the city is forecast with the least square parabolic method using the population of the year 1981, 1991 and 2001 as per census reports. As per forecast, the population of Khulna City Coprporation area will be 932486 in 2007,1036440 in 2011; 1338160 in 2021 and 1716660 in 2031.

The water is used for different purposes as drinking, cooking, washing, bathing and gardening. The total water demand for a city depends on per capita water consumption of the people living in the city. Again the per capita consumption of water depends on the standard of the people living there, their professions, types and nature of industries and commercial activities exist there. The water demand is calculated for the years 2007, 2011, 2021 and 2031 on the basis of the population on those years. The total water demand estimation again depends on the consideration of the percentage of population coverage, wastages and losses and net domestic consumption rate. The estimations were done on the basis of three major options considered as to gradually increase the population coverage from 37% at present state to atleast 90%, reducing the wastages and losses from 60% to 20% and increasing the net domestic water consumption from 70 lpcd to 100 lpcd in the years up to 2031. In pursuance with these assumptions, the total water demand in KCC area were estimated as 56823 m^3/day, 88838 m^3/day, 155382 m^3/day and 245000 m^3/day for the year 2007, 2011, 2021 and 2031 respectively.

At present, KCC is supplying 26600 m^3 waters per day with the 35%-40% population coverage only. As per the estimate from the present state of KCC production, the water supply from KCC in 2007 will be 27729 m^3/day against 53035 m^3/day water demand. Similarly the probable water supply from KCC in 2011, 2021 and 2031 will be 34048 m^3/day, 47667 m^3/day and 66734 m^3/day against the water demand 88838 m^3/day, 155382 m^3/day and 245000 m^3/day respectively with the gradual increase of population coverage up to 90% at the year 2031.

It reveals from the study that there is the huge gap between the water demand in the city and water supply from KCC. But there are the other sources of water supply to the city people. There are a lot of wells in deep and shallow aquifers installed in KCC area either from public or private, industrial and institutions wells. It reveals from the analysis on the basis of three options considered that the demand of water and KCC supply gap has increased from 2007 towards up to the year 2031 as the supply from KCC has not been increased rather the demand has increased due to increase of population and better services apprehended. The gaps between the demand and KCC supply have been supplemented by the probable supply from others wells than KCC. It is also revealed that the probable total supply both from KCC and others will satisfy the demand around the year 2025.

But as Khulna City Corporation is the official authority to supply water to the city people, they should take full responsibility to supply water increasing their production capacity from either groundwater or surface water source. The authority should also discourage private abstraction from the groundwater source in KCC area because there is the excessive withdrawal and huge losses and wastages of water from their premises and ultimately the pressure is increasing on groundwater resources, the groundwater resource is not unlimited.

CHAPTER IV

ASSESSMENT OF WATER QUALITY AND HEALTH RISK OF KCC WATER SUPPLY

4.1 Introduction

The quantity and quality of water is closely associated. It is difficult to imagine any clear and sanitary environment without the quality water to maintain a clear and sanitary environment of a community. It is the most important consideration and main responsibility of a water supply authority to ensure potable water to a community. Potable water is one that is safe to drink, pleasant to taste and suitable for domestic uses.

Water is involved in the spread of communicable diseases in two ways. The well-known direct ingestion of infectious agent when drinking contaminated water. The second is due to the lack of sufficient water for personal hygiene purposes. Inadequate quantities of water for the maintenance of personal hygiene and environmental sanitation have been shown to be major contributing factors in the spread of epidemic diseases.

On a global basis, approximately three out of five persons in developing countries have no access to safe drinking water. Urban areas are better served, 75 percent of the population have some form of water supply through house connections or out door stand pipes. In rural areas in Bangladesh only 29 percent have access to safe drinking water (LGD/UNDP, 2002).

The quality of drinking-water as well as water safety is aconcern to consumers, water suppliers and authority alike. The most effective means of consistently ensuring the safety of a drinking water supply through a comprehensive health risk assessment as well as risk management approach is that encompasses all steps in water supply. This approach of health risk assessment and risk management for the ensuring potable water supply to a community is termed as water safety. There should be a comprehensive water safety plan for an authority to keep a consistent drinking- water supply, health risk assessment and risk management. The water safety plan may include-

- to develop a system of assessment to determine whether the drinking water supply is adequate in quality that meets the health base targets
- to identify the control measures in a drinking water system that will collectively control the identified risk and ensure that the health based target is met
- to prepare a management plan describing action to be taken during normal operation or incident condition and documenting the system assessment (including upgradation and improvement), monitoring and communication plans and supporting program.

The primary objective of water safety or its plan is to ensure good drinking-water supply to the community with minimization of contamination of source water, the reduction and remedial of contamination through treatment process and the prevention of contamination during storage, distribution and handling of drinking water.

Further more, preventive management is the preferred approach to drinking-water safety and should take account of the characteristics of the drinking water supply from the source to its use by consumers. A preventive integrated management approach with collaboration from all relevant agencies is the preferred approach to ensuring drinking water safety.

In this chapter, assessment of water quality of the supply water by KCC and its associated health risk are presented.

4.2 Drinking Water Standards

Access to safe drinking - water is essential to health, a basic human rights and a component of effective policy for health protection. Diseases related to contamination of drinking–water constitute a major burden on human health. Intervention to improve the quality of drinking–water provides significant benefit to health. The safe, potable drinking-water supply to the community is concerns to the authority and the suppliers.

In United States in 1913, the US Public Health Service (USPHS) adopted the first standards for drinking water supplied to the public. The USPHS revised and issued standards in 1925, 1942,1946 and 1962 until the standard setting function was transferred to USEPA in 1970. The USEPA as regulatory body published drinking Water Regulations and revised from time to time in phase to incorporate available health effect data. The European Community directives issued in 1980 on quality of water intended for human consumption applied to member countries.

The World Health Organization (WHO) had been in the forefront in developing water quality standards. The WHO standards for drinking water first published in 1958 were revised in 1963, 1968 and 1971. The WHO has published European standards, the latest condition of which was published in 1970. The WHO International standards 1971 and European standards 1970 were superceded by WHO 1984 guideline values for drinking water quality.

Bangladesh developed the first Water Quality Standards in 1976 based on the WHO 1971 International Drinking Water Standards. The Bangladesh standard Specification for Drinking Water (BDS 1240: 1989) was prepared and published by Bangladesh Standard and Testing Institution (BSTI) for control of quality of drinking water. The ministry of Environment and Forest, adopted comprehensive Water Quality Standards for Drinking Water in 1977 under Environment Conservation Act, 1995. The Bangladesh Drinking Water Standards, (ECR, 1997) with WHO Guideline values, 1996 are presented in the Table 4.1.

Basic Requirement for Drinking Water Standards

The drinking water needs some basic requirement to reach to the dwellers and the authority should investigate it before supply. The basic needs are :-

- Water to be completely free of pathogenic microorganisms that can cause disease.
- Water should contain no element or compound in concentrations that can cause acute or long-term adverse effect on human health.
- Water to be fairly clear and aesthetically attractive i.e, low turbidly and color.
- Water should not contain compounds that can cause on offensive taste and odor.
- It should not cause corrosion, scale formation, discoloration or staining.
- Water should not have a temperature unacceptable to the consumers.

Table. 4.1 Drinking water standards ((ECR, 1997) and WHOGV, 2004).

Water quality parameters	Unit	BDS	WHOGV, 2004
1. Aluminum	mg/L	0.2	0.2
2. Ammonia (NH_3)	mg/L	0.5	1.5
3. Arsenic	mg/L	0.05	0.01
4. Barium	mg/L	0.01	0.7
5. Benzene	mg/L	0.01	0.01
6. BOD_5 20^0C	mg/L	0.2	-
7. Boron	mg/L	1.0	0.3
8. Cadmium	mg/L	0.005	0.003
9. Calcium	mg/L	75	-
10. Chloride	mg/L	150-600*	250
11. Chlorinated alkenes			
Carbon tetrachloride	mg/L	0.01	.002
1.1 Dichloroethylene	mg/L	0.001	-
1.2 Dichloroethane	mg/L	0.03	0.03
Tetrachloroehylene	mg/L	0.03	-
Trichloroethylene	mg/L	0.09	-
12. Chlorinated phenols			
Pentachlorophenol	mg/L	0.03	-
2, 4, 6Trichlorophenol	mg/L	0.03	0.02
13. Chlorine (residual)	mg/L	0.2	0.6-1.0
14. Chloroform	mg/L	0.09	0.2
15. Chromium (hexavalent)	mg/L	0.05	-
16. Chromium (total)	mg/L	0.05	0.05
17. Chemical oxygen demand	mg/L	4	-
18. Coliform (faecal)	N/100ml	0	0
19. Coliform (total)	N/100ml	0	0
20. Colour	Hazen Unit	15	15
21. Copper	mg/L	1	1

22. Cyanide	mg/L	0.1	0.07
23. Detergents	mg/L	0.2	-
24. Dissolved oxygen	mg/L	6	-
25. Flouride	mg/L	1	1.5
26. Hardness (as $CaCO_3$)	mg/L	200-500	-
27. Iron	mg/L	0.3-1.0	0.3
28. Kjehldal nitrogen (total)	mg/L	1	-
29. Lead	mg/L	0.05	0.01
30. Magnesium	mg/L	30-35	-
31. Manganese	mg/L	0.1	0.1
32. Mercury	mg/L	0.001	0.001
33. Nickel	mg/L	0.1	0.02
34. Nitrate	mg/L	10	50
35. Nitrite	mg/L	<1	3
36. Odor	mg/L	Odorless	-
37. Oil and grease	mg/L	0.01	-
38. p^H	-	6.5-8.5	-
39. Phenolic compounds	mg/L	0.002	-
40. Phosphate	mg/L	6	-
41. Phosphorus	mg/L	0	-
42. Potassium	mg/L	12	-
43. Radioactive substances			
Total Alfa radiation	Bq/1	0.01	-
44. Selenium	mg/L	0.01	-
45. Silver	mg/L	0.02	0.01
46. Sodium	mg/L	200	-
47. Suspended solids	mg/L	10	200
48. Sulphide	mg/L	0	-
49. Sulphate	mg/L	400	250
50. Total dissolved solids	mg/L	1000	1000
51. Temperature	^0C	20-30	-
52. Tin	mg/L	2	-
53. Turbidity	JTU	10	5
54. Zinc	mg/L	5	3

4.3 Water Borne Diseases and Responsible Pathogen

The most important parameter of drinking water quality is the bacteriological quality that is the presence of pathogenic organism. The water borne diseases are caused by the ingestion of pathogens with drinking water. Improvement of drinking water quality is an effective preventive measure against transmission of water- borne diseases. Control of most water borne diseases is hinged upon availability of enough water for domestic and personal cleanliness. The water borne diseases can therefore also be described as water- washed diseases. The common water borne diseases and the pathogens responsible for these diseases with their routes of transmission are shown below in Table 4.2.

Table 4.2 Water borne diseases, pathogens, route of transmission (Ahmed and Rahman, 2003)

Diseases (Common name)	Pathogens (Type)	Routs of transmission
Dearrhoceal disease		
Cholera (Cholera)	Vibro cholera (Bacteria)	I, II, F→0, P→P
Shigellosis (Bactary and dysentery)	Shigella spp (Bacteria)	I, II, F →0
Amoebiosis (Amoebic dysentery)	Endamoeba histolytica (Protozoa)	I, II, F→0, P→P
Bacterial enteritis (Diarrhoea)	E-coli, salmonella Spp (Bacteria)	I, II, F→0, P→P,A→P
Gastroenteritis	Enteric viruses (Virus)	I, II, F→0, P→P
Poliomyelitis (Polio)	Polivirus (Virus)	DO
Viral diarrhoea (Diarrhoea)	Rotavirus,other viruses (virus)	DO
Gierdiasis (diarrhoea)	Giardia lambela (protozoa)	DO
Balantidiasis (Diarrhaoa)	Balanitidion coli (Bacteria)	I, II, F→0, P→P, A→P
Fevers :-		
Typhoid (Typhoid)	Bacillus Typhi Eberatheda Typhosa (Bacteria)	1, II, F→0, P→P
Para typhoid	Salmonilla paratyphi (Bacteria)	Do
Leptosperosis (Weel's disease)	Leptospira spp (Bacteria)	I, F→0, A→P
Hepatitis A (Jaundice)	Hepatitis A virus (Virus)	I, II, F→0, P→P.

I- Water borne; II: Water washed; F→0: Faecal-oral; P→P: Person to Person; A→P: Animal to-person

About 80% of all sicknesses and diseases can be attributed to inadequate water supply and sanitation. It is mentioned in an environmental report that diarrheal diseases kill 6 million children in developing countries every year and affects up to 18 million people. People with water born diseases occupy about half of all the hospital beds in the world. World Health Organization (WHO) estimates that about 25,000 people die from water-borne diseases every day (Asian Environment, 2003).

4.4 Assessment of Water quality oF KCC Water Supply

Water smples were collected from 23 wards in Khulna City Corporation and were tested for the various physical, chemical and bacteriological parameters. The water quality parameters were assessed by technology type in relation to Bangladesh Water Quality Standard (ECR,1997) and WHO guidelines value (WHOGV,2004).

To assess the water quality of supply water by KCC and to evaluate its suitability for drinking purpose, an extensive water sampling and laboratory analysis were undertaken. Proper quality assurances were maintained during laboratory testing and all the water quality parameters were tested according to standard procedure (APHA, 2000) and HACH recommended method. Water samples were tested for physical, chemical and bacteriological parameters as shown in Table 4.3.

Table 4.3 Quality parameters of KCC supply water tested in the laboratory

Type of test	Name of water quality parameters
Physical	Turbidity, Color, Temperature
Chemical	pH, Alkalinity, Total Hardness, EC, TDS, F^-, SO_4^{-2}, NO_3^-, Cl^-
Bacteriological	TC, TTC, E.coli

The physical, chemical and bacteriological parameters of KCC supply water were measured in the laboratory following the standard testing procedures. Turbidity was measured by standard turbidity meter (HACH) and Color was by spectrophotometer (HACH/DR 4000). pH of water was measured by pH meter (HACH) and electric conductivity (EC) by HACH conductivity meter. Alkalinity was measured by titrimetric method using H_2SO_4 and total hardness by EDTA method. TDS was measured by evaporating 100 ml water sample after filtration. Fluoride was measured by SPADNS method using HACH spectrophotometer, Sulphate by SulfaVer ®4. Nitrate was measured by cadmium reduction method and Chlorides by titration with AgNO3. TC and TTC was measured Membrane Filtration (MF) method and *E.coli* and TTC were measured simultaneously by MF method using m-coli blue reagent.

4.4.1 Water Sampling

Water samples were collected from 23 wards out of 31 Khulna City Corporation; there is no KCC water supply in wards from one to eight. The samples were collected in plastic bottles of 2 litres capacity for Physical and Chemical parameters tests. Before sampling, the bottles were washed thoroughly with the supply water at that point and marked properly mentioning date, time and location of sampling. For bacteriological test, the samplings were done in Sterilized Water Sampling Bags Containing Sodium Thiosulfate supplied by HACH. The samplings were done in the morning and most of the parameters were tested on the same day.

At first the water samples were collected from the production wells of KCC during the period July 5, 2006 to July 12, 2006 and tested the quality parameters of water giving emphasis on the bacteriological parameters but no TC, TTC and E.coli was found in any sample. Arsenic test was not performed at this time because such tests were conducted by LGED/BRGM in 2005 and no arsenic was found present in water from KCC production wells. Then it was decided to conduct the quality parameters test of KCC supply water collecting samples from the supply lines in different locations of the city.

According to the decision, the water samples were collected in three major seasons as rainy, winter and summer to observe the seasonal variation of water quality parameters. From each ward, one sample was collected from a pre-selected point and the details of the location of the sampling points are presented in the Table 4.5. The samplings were performed July 30, 2006 to September 05, 2006 in rainy season; from December 26, 2006 to February 06, 2007 in winter and from April 17, 2007 to June 26, 2007.

Table 4.4 Locations of the water samplings for physical, chemical and bacteriological tests.

Ward number	Locations of samples
Ward 09	Tap water from the house of Abdus Salam at Mujgunni main road
Ward 10	Tap water from the mosque of TNT Khulna Shilpa road
Ward 11	Water from Restaurant at Platinum Jubilee gate
Ward 12	Tap water from the house of Khalilur Rahman at Rotary School road
Ward 13	Water from KCC production well on Khalishpur School road
Ward 14	Tap water from the house of Rustam Sarder at Bayra central road
Ward 15	Shilpi Grossary shop at Paulpara road
Ward 16	Tap water from mosque at Bayra main road
Ward 17	Tap water from house of Musa Miah at Ibrahim road
Ward 18	Tap water from house of Sk. Aslam at Gabarchaka cross road
Ward 19	Tap water from house of M. Zaman at Bashupara road
Ward 20	Tap water from house of Ashraf Ali at Sheikpara baganbari road
Ward 21	Tap water from the house of Bashu Babu at Sir Iqbal road
Ward 22	Water from Alia madrasha KCC production wellat Khanjahan Ali road
Ward 23	Tap water from house of Babu Khan at Ahsan Ahmed road
Ward 24	Tap watr from the mosque at Hazi Meher Ali road
Ward 25	Tap water from house of Ahsanullah at Shohwardi college road
Ward 26	Tap water from the house of Salam Fakir at Nazir ghat cross road
Ward 27	Water from the house of Nasir chairman at Moulabipara road
Ward 28	Tap water from the house of Mofidul Islam at Tootpara main road
Ward 29	Tap water from house Mujibur Rahman at Arjan Ali lane at Hazi Mohsin road
Ward 30	Tap water from the Eatim Khana at Dilkhola road, Tootpara
Ward 31	Tap water from the mosque at Labanchara main road

4.5 Water Quality

4.5.1 Physical Water Quality of KCC Water Supply

The physical water quality, turbidity, color and temperature of the KCC supply water were tested for rainy, winter and summer seasons. The maximum, minimum and average test results of each parameter in different seasons are presented in the Table 4.6. It reveals from the results that turbidity in all seasons is within the allowable limit 10 NTU according to BDS. The color limit is exceeded by 22%, 26% and 39% in rainy, winter and summer seasons respectively as per BDS and WHOGV 15 Pt-Co unit.

Table 4.5 Test result of physical water quality parameters of KCC water supply

Season	Parameters	Unit	Max	Min	Average	BDS	WHO GV	Sample Size	Sample exceeding BDS (%)
Rainy	Turbidity	NTU	8.2	1.2	3.44	10	5		-
	Color	Pt-Co	23	9	13.39	15	15	23	5 (22%)
	Temp.	^0C	27.8	25.5	26.9	20-30	-		-
Winter	Turbidity	NTU	7.3	1.2	3.73	10	5		-
	Color	Pt-Co	24	11	14.1	15	15	23	6 (26%)
	Temp.	^0C	21.8	14.2	19.5	20-30	-		3 samples, < 20 ^0C
Summer	Turbidity	NTU	6.2	2.3	3.5	10	5		-
	Color	Pt-Co	30	10	14.78	15	15	23	9 (39%)
	Temp.	^0C	28.1	24.9	26.3	20-30	-		-

Color

Color in water is primarily due to the presence of colored organic substances (primarily humic substances), metals such as Fe, Mn or highly colored industrial wastes (from pulp, paper and textile industries). Drinking water should be colorless and transparent and maximum limit in drinking water should be below 15 Pt-Co unit according to BDS and WHOGV (Ahmed and Rahman, 2003; WHOGV, 2004). High color in drinking water is not acceptable to the consumers for aesthetic reason and indicates the pollution by organic substances. It reveals that in rainy season the maximum, and minimum values are 23 and 9 Pt-Co unit respectively and only 5 (22%) samples out of 23 exceed the BDS and WHOGV limit. In winter maximum, minimum values are 24, 11 Pt-Co unit respectively and only 6 (26%) samples exceed the BDS and WHOGV limit. While in summer the maximum, minimum values are 30, 10 Pt-Co unit respectively and 9 (22%) samples exceed the BDS and WHOGV limit. It indicates that the water in rainy season is more acceptable and aesthetically suitable for drinking purposes than in summer as per BDS and WHOGV. The distribution of color of the water in rainy, winter and summer season is shown in Figure 4.1.

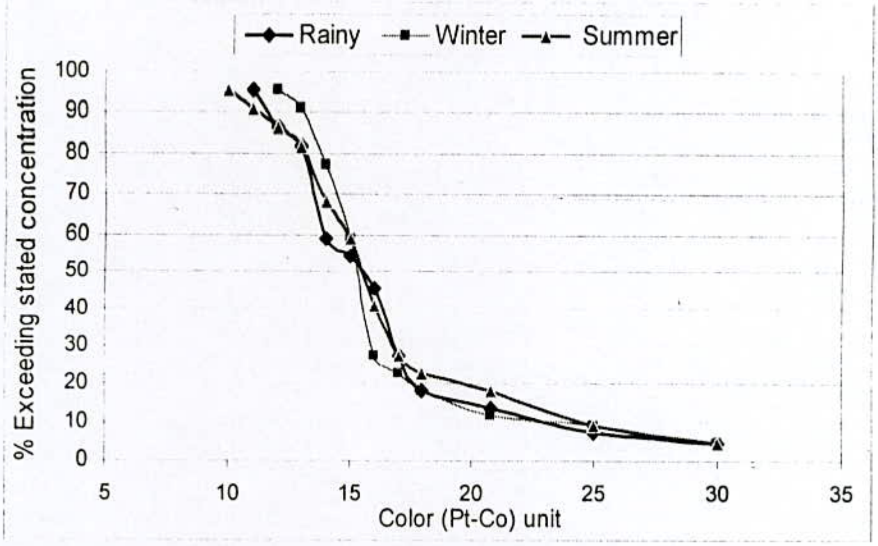


Figure 4.1 Color of KCC water supply in different seasons

Turbidity

Turbidity occurs in most surface waters due to the presence of suspended clay, silt, finely divided organic matters, plankton (algae) and microorganisms. Turbidity is an expression of certain light scattering and light absorbing properties of water sample and depend, in a complex manner, on such factors as the number, size, shape and refractive index of particulate matter present in water. Turbidity is expressed in Nephelometric Turbidity Unit (NTU) and in excess of 5 NTU as per BDS in water is objectionable to consumers.

The test results prevailed that in rainy season the maximum, minimum values are 8.2, 1.2 NTU respectively; in winter the maximum, minimum values are 7.3, 1.2 NTU respectively respectively. None of the turbidity value in any season exceeds the allowable limit of BDS and hence the water is aesthetically acceptable. The turbidity test results of the water samples in all three seasons are shown in Figure 4.2.

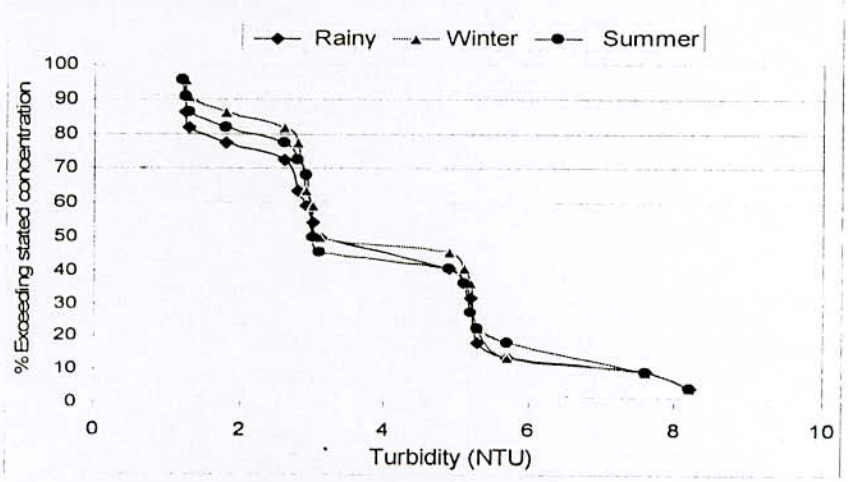


Figure 4.2 Turbidity of KCC water supply in different seasons

4. 5. 2 Chemical Water Quality Prameters of KCC Supply Water

Some important chemical parameters of water samples from KCC supply water in different seasons were tested. The summary of the test results is presented in the Table 4.8 and comparisons were made with the allowable value according to BDS and WHOGV. It reveals from the result that most of the results are within the limit of allowable limit according to BDS and WHOGV and only a few results exceed the tolerable range. Some of the water quality parameters are described below in details.

pH

The pH value of an aqeous system is a measure of the acid-base equilibrium achieved by various dissolved compoundsand an indicator of the acidic or alkaline condition of water and determines the strength of acidity or alkalinity in water. pH in water in specified range is important for coagulation, disinfection, water softening and corrosion control. The recommended range of pH for drinking water is 6.5 to 8.5 according to BDS and WHO guidelines value. It appears from the test results of pH in KCC supply water in all three seasons are within BDS and WHO guidelines limit. The distribution of pH in KCC supply water is shown in Figure 4.3.

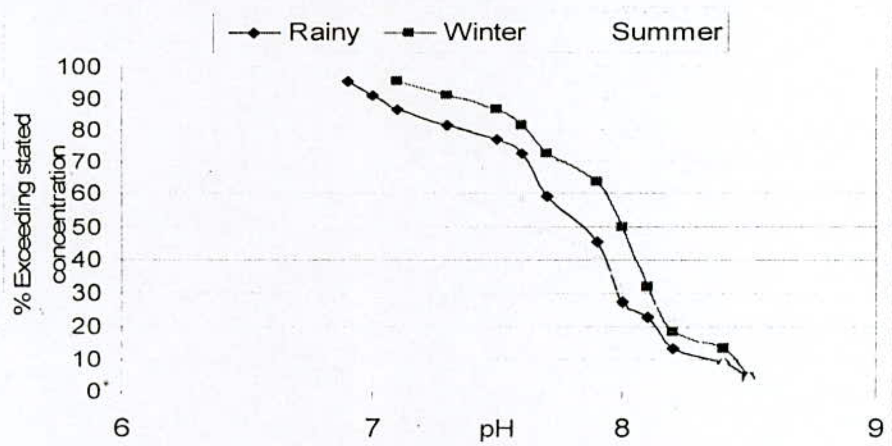


Figure 4.3 pH in KCC supply water in different seasons

Alkalinity

The alkalinity in water is a measure of its capacity to neutralize acids. The alkalinity is due primarily to salts of weak acid and strong bases. Such substances act as buffers to resist a drop in pH resulting from acid addition. Alkalinity is thus a measure of buffer capacity. Three major classes of materials as bicarbonate, carbonates and hydroxides cause most of the alkalinity in natural waters. Bicarbonates represent the most common form of alkalinity since they are formed, in large quantities, from the action of carbon dioxide upon basic materials in the soils. A few organic acids, such as humic acid, add to the alkalinity of natural waters. Excessive or insufficient alkalinity interferes with water treatment (Ahmed and Rahman, 2003). Since pH of water is less than 8.3, alkalinity of water is mainly due to HCO_3^- ions in water. The test results for alkalinity in all the samples in three seasons for making instant comparison are presented in the Figure 4.4.

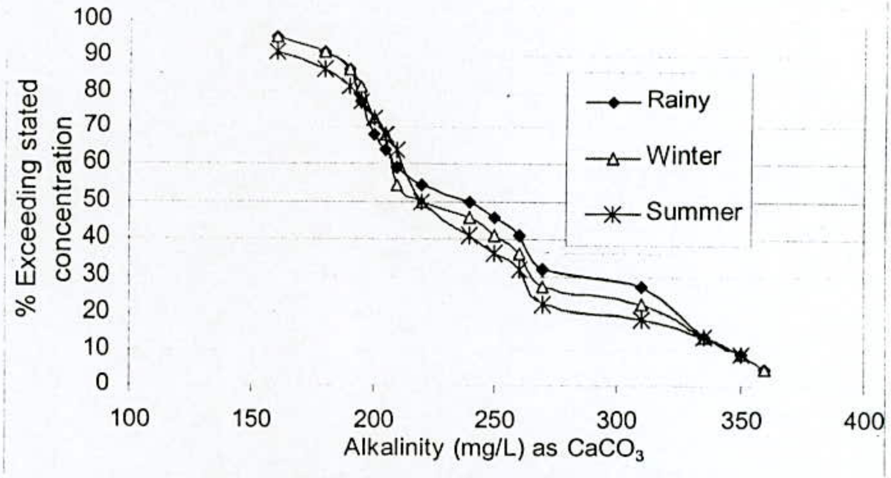


Figure 4.4 Alkalinity in KCC supply water in different seasons

Table 4.6 Test result of chemical water quality parameters of KCC water supply.

Seaso	Parameters	Unit	Max	Min	Ave	BDS	WHO GV	Sample Size	Sample exceeding BDS (%)
Rainy	pH	-	8.4	6.5	7.7	6.5-8.5		23	-
	Alkalinity as $CaCO_3$	mg/L	360	160	214.78	400	-	23	-
	Hardness as $CaCO_3$	mg/L	502	301	346.50	250-500	0	23	3(13%)
	Conductivity	µS/cm	1669	1000	1251	600-1000	-	23	20(86.95%)
	TDS	mg/L	1200	750	810	1000	1000	23	3(13%)
	Fluoride (F^-)	mg/L	0.40	0.20	0.26	1	1.5	23	-
	Sulphate (SO_4^{-2})	mg/L	1.7	1.3	1.62	400	250	23	-
	Nitrate (NO_3^-)	mg/L	1.2	0.65	0.80	10	50	23	-
	Chloride (Cl^-)	mg/L	340	140	187	150-600	250	23	9 % < 150
Winter	pH	-	8.5	6.7	7.9	6.5-8.5	-	23	-
	Alkalinity as $CaCO_3$	mg/L	354	140	192.80	400	-	23	-
	Hardness as $CaCO_3$	mg/L	550	420	483.5	250-500	-	23	5(21.74%)
	E. Conductivity	µS/cm	1638	1000	1190	600-000	-	23	13(56.52%)
	TDS	mg/L	1500	750	852.60	1000	1000	23	4(17.30%)
	Fluoride	mg/L	0.40	0.10	0.22	1	1.5	23	-
	Sulphate (SO_4^{-2})	mg/L	1.80	1.30	1.51	400	250	23	-
	Nitrate (NO_3^-)	mg/L	1.30	0.70	0.82	10	50	23	-
	Chlorides	mg/L	390	150	291	150-600	250	23	-

Summer	pH	-	8.5	6.5	7.4	6.5 - 8.5	-	23	-
	Alkalinity as $CaCO_3$	mg/L	280	120	201.5	400	-	23	-
	Total Hardness as $CaCO_3$	mg/L	550	302	410.5	250-500	-	23	6(26%)
	Conductivity	μS/cm	1702	950	1542	600-1000	-	23	15(65.27)
	TDS	mg/L	1350	730	903	1000	1000	23	3(13%)
	Fluoride (F)	mg/L	0.40	0.18	0.26	1.0	1.5	23	-
	Sulphate (SO_4^{-2})	mg/L	1.80	1.30	1.70	400	250	23	-
	Nitrate (NO_3^-)	mg/L	1.20	0.70	1.10	10	50	23	-
	Chloride (Cl^-)	mg/L	330	150	212.80	150 to 600	250	23	-

Total Hardness

Hardness is caused by multivalent metallic cation. Such cations are capable of reacting with soap to form precipitates and with certain anions present in water to form scale. The principal hardness causing cations are the divalent calcium and magnesium ions. The anions with which these cations usually associate to cause hardness are Sulfate, Chloride, Nitrate, Silicate and bicarbonate etc.

Hardness is classified in two ways: (a) With respect to the metallic ion and (b) With respect to the anions associated with the metallic ions. Calcium and magnesium cause by far the greatest portion of the hardness. Usually hardness is expressed as total hardness or calcium or magnesium hardness, where, total hardness is the algebraic sum of calcium and magnesium hardness. Again hardness may be classified as carbonate and non-carbonate hardness. The principal negative effects of hardness in domestic water are that it consumes too much soap, it clogs skin, discolors porcelain,vegetables and cooked foods. There is evidence that cardiovascular death rates are inversely correlated to hardness of water (Ahmed and Rahman, 2003).

The recommended value for hardness is 250 mg/L to 500 mg/L according to BDS. The maximum and minimum test result appears as 550 mg/L and 301 mg/L where 3 (13%) in rainy season; 5 (21.74%) in winter and 6(26%) in summer exceed the recommended limits of BDS out of total 23 samples in each season. Based on hardness, KCC water supply is classified as fair and medium to use. Since total hardness of water is much higher than the alkalinity in water, a significant portion of total hardness is non-carbonate hardness. The distribution of total hardness in three seasons is shown in Figure 4.5.

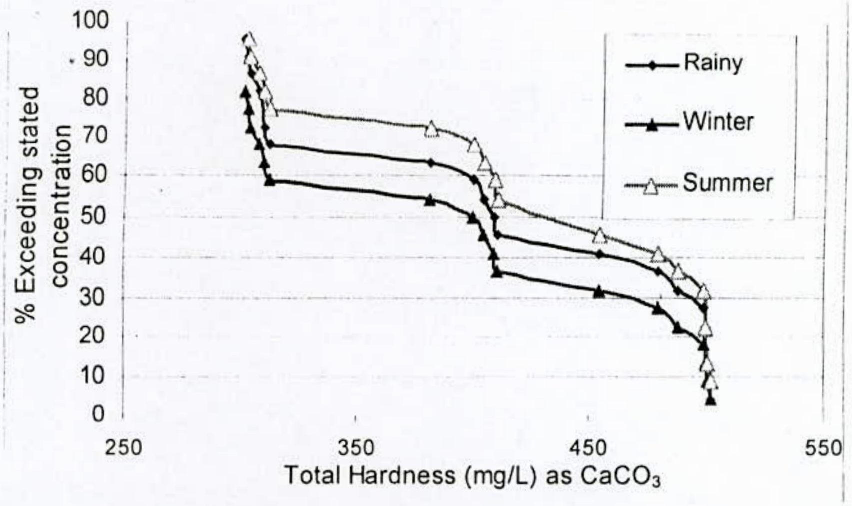


Figure 4.5 Total hardness in KCC supply water in different seasons

Electric Conductivity (EC)

The specific conductance (electric conductivity) is an indicator to the presence of inorganic salts and has a good correlation with the total dissolved solids (TDS) in water indicating the suitability for domestic use and has the presence of inorganic cation and anion. The recommended level of specific conductivity is 600 to 1000 μS/cm in drinking water according to BDS. The test results in three seasons appear that in rainy season the maximum value is 1669 μS/cm and minimum is 1000 μS/cm; in winter the maximum value is 1638 μS/cm and minimum is 1000 μS/cm, in summer the maximum value is 1702 μS/cm and minimum is 950 μS/cm. In rainy season the results exceed the recommended limit about 20(86.95%), in winter it exceed about 13(56.52%) and in summer the results exceed about 15(65.27%) out of 23 samples in each season. The distribution of EC in KCC supply water is shown in Figure 4.6.

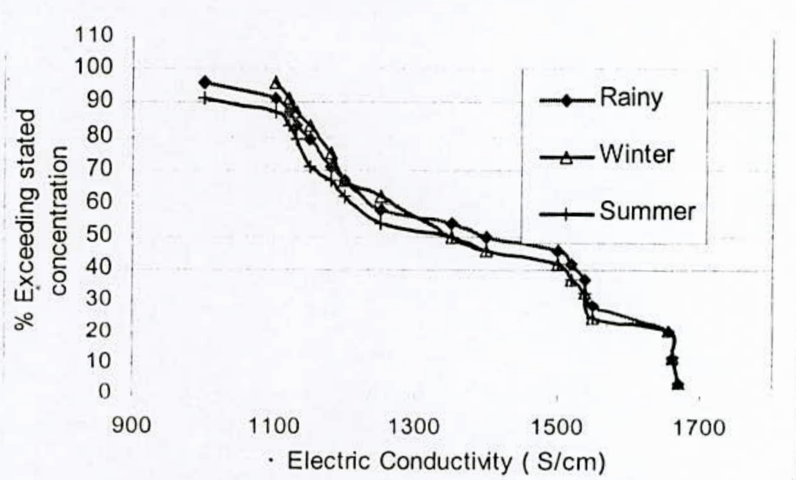


Figure 4.6 Electric Conductivity in KCC supply water in different seasons.

Total Dissolved Solids (TDS)

Total dissolved solids comprise inorganic salts and small amounts of organic matter. The amount of dissolved solids present in water is an important consideration in its suitability for domestic use. In general, waters with a total solids content of less than 500 mg/L are most desirable for such purposes; waters with a higher solids content s have a laxative. Depending on the TDS water is often classed as, TDS<300mg/L is excellent; 300to 600 mg/L is good; 600 to 900 mg/L is fair; 900 to 1200 mg/L is poor and .more than 1200 mg/L is unacceptable (Ahmed and Rahman, 2003).

The recommended limit of TDS in drinking water is 1000 mg/L according to both BDS and WHOGV. The samples collected from the supply water of KCC from 23 wards and and it appears that only 3(13%) samples in rainy season; 4 (17.39%) samples in winter and 3 (13%) samples in summer out of 23 each exceedmaximum limit. The TDS of water remains within 800 to 1200 mg/L indicates that huge amount of mineral salts are present in KCC water supply and water is classified as fair to unacceptable according to BDS. The distribution of TDS in KCC supply water is shown in Figure 4.7.

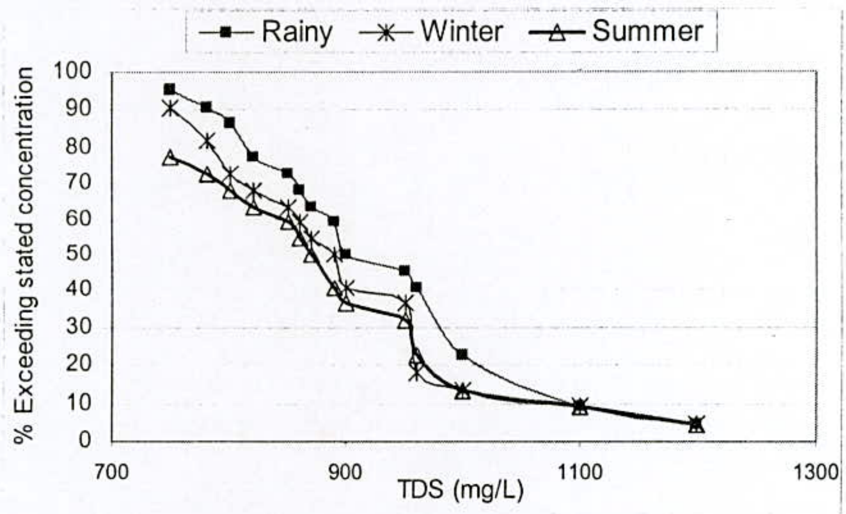


Figure 4.7 TDS in KCC water supply in different seasons.

Fluoride

Fluoride is a mineral substance and it exists in water in soluble form, excess fluorides in drinking water may have the health risk in tooth decaying and child diseases. The recommended range of fluorides in drinking water is 1.0 mg/Land 1.50 mg/L according to BDS and WHOGV respectively (Ahmed and Rahman, 2003). It appears from the test results that the Fluoride content in the samples in all three seasons are well below the allowable limit. The maximum, minimum values of Fluoride of water in rainy season is 0.40 mg/L, 0.20 mg/L ; the maximum, minimum values in winter are 0.40 mg/L, 0.10 mg/L, the maximum, minimum values in summer are 0.40 mg/L, 0.18 mg/L . The distribution of Fluoride in KCC supply water is shown in Figure 4.8.

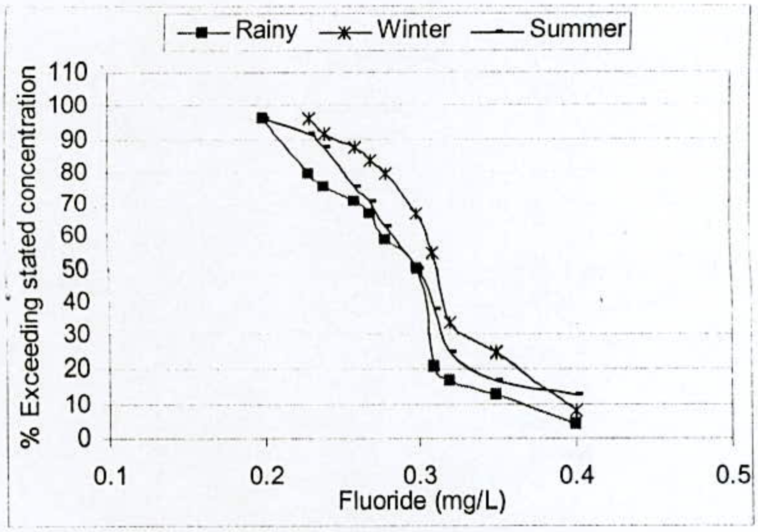


Figure 4.8 Fluoride in KCC water supply in different season

Sulphate

Excessive sulphates in drinking water may have the toxicity effect. The allowable limit of sulphate in drinking water is 400 mg/L and 250 mg/L according to the BDS and WHOGV respectively (Ahmed and Rahman, 2003; ERC, 1997). The test results of sulphates in KCC water vary from 1.30mg/L to 1.80mg/L in all three seasons and none of the result exceeds the BDS and WHOGV. The sulphates contain in KCC supply water is very low and the distribution of sulphate in KCC supply water is shown in Figure 4.9.

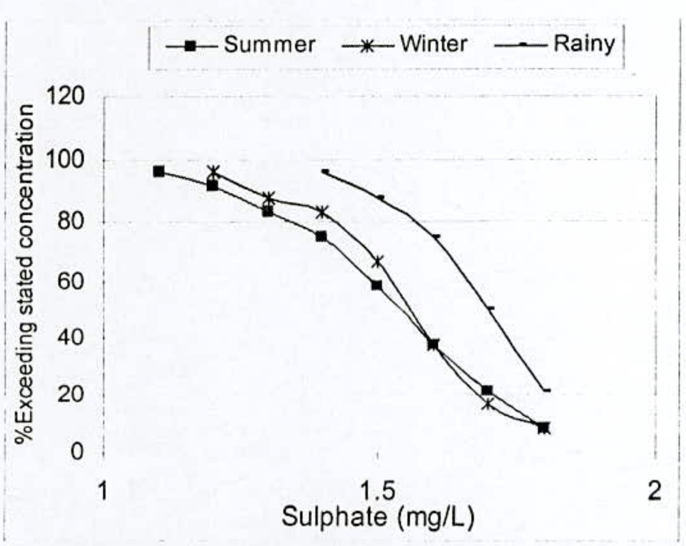


Figure 4.9 Sulphates in KCC supply water in different seasons

Nitrate

Nitrates are widely present in substantial quantities in soil, in most waters and in plants, including vegetables, fertilizer use, decayed vegetable, animal matter, domestic effluents, sewage sludge disposal to land, industrial discharges, leachates from refused dumps and atmospheric washout all contribute to these ions in water sources. Nitrate is toxic when present in excessive amounts in water and may cause "methamoglobinaemia" in infants and certain forms cancer may associate with very high concentrations. Nitrate aggravates to growth of algae in water tanks and reservoirs.

The recommended limit of the presence of nitrate in water is 10 mg/L and 50 mg/L according to BDS and WHOGV respectively. The test results of nitrates in KCC water vary from 0.70 mg/L to 1.30 mg/L in all three seasons and none of the test result exceeds the BDS and WHOGV limit 10mg/L. The distribution of nitrate in KCC supply water is shown in Figure 4.10.

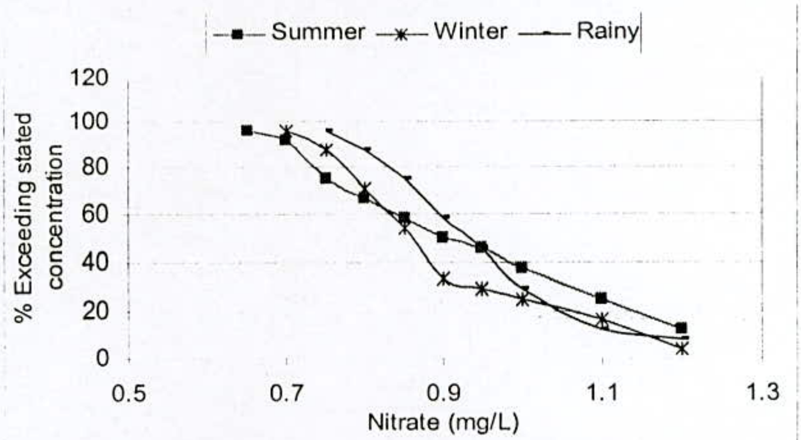


Figure 4.10 Nitrate in KCC suppy water in different seasons.

Chloride

Chloride remains in natural waters in different forms such as NaCl, KCl and $CaCl_2$ in widely varying concentrations. Rivers and ground waters usually have a considerable amount of chlorides though it is quietly low in upland and mountain supplies. Chlorides gain to natural waters in many ways. Ocean and seawater invasion to rivers and intrusion of seawater into fresh groundwater aquifers also contribute chlorides to natural waters. High chloride concentrations are corrosive to metals in water distribution system particularly water of low alkalinity. Higher chloride content in inland water usually indicates sewage pollution (Ahmed and Rahman, 2003). The recommended range of chlorides in drinking water quality is 150 mg/L to 600 mg/L as per BDS and 250 mg/L according to WHO Guidelines value. The test results of chlorides in all samples in KCC water remains with in 140 mg/L to 340 mg/L and even some results about 9%

falls below the lower limit of 150 mg/L.The test results of chlorides in KCC water are within the boundary limit of BDS and WHO guidelines as 150 mg/L to 600 mg/L except only one test of water from ward 25 in rainy season and one from ward 10 in winter have result 140mg/L is little less than the BDS and WHO guidelines. The distribution of chlorides in KCC supply water is shown in Figure 4.11

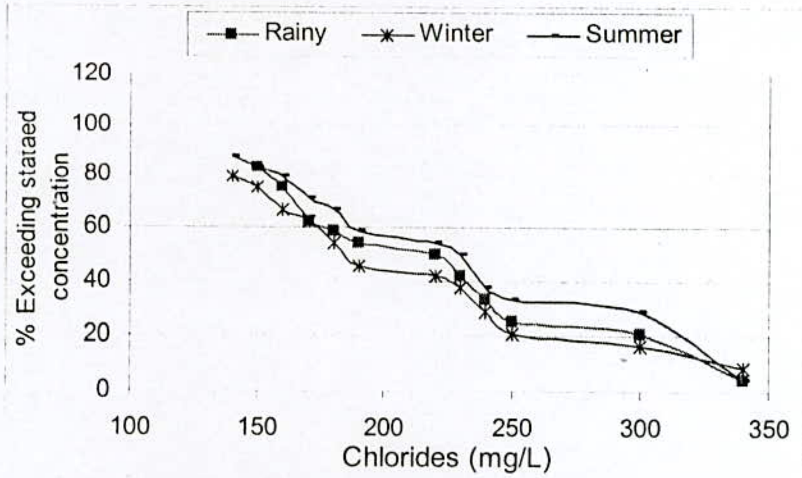


Figure 4.11 Chloride in KCC supply water in different seasons.

4.5.3 Bacteriological Water Quality Parameters of KCC Supply Water

The most common and wide spread danger associated with the natural surface water is that sewage and other wastes contaminate it as by human and animal excrements. Faecal pollution of water may introduce a variety of intestinal pathogens includes (i) bacteria causing typhoid fever (salmonella typhi), bacillary dysentery (shigella) and cholera (Vibrio cholerae), (ii) viruses causing hepatitis, poliomyelitis and gastro-enteritis and (iii) Protozoa causing amoebic dysentery (E.Histolytica) etc.

The principal risk associated with the drinking water is the spread of infectious water- borne diseases related to the faecal contamination. The drinking water must be free from any disease-producing organisms. Two major indicators –Total Coliform (TC) and Faecal Coliform (FC) that is Thermotolrance coliform (TTC) are used widely to characterize the microbiological quality of drinking water. Faecal pollution of water may introduce a variety of intestinal pathogens that is bacterial, viral or parasitic and both. BDS and WHOGV recommends that presence of both total coliform (TC) and faecal coliform (FC) in drinking water should be nil.

Total coliform is characterized by their ability to ferment lactose in culture at 35^0C to 37^0C, faecal coliform organism, which are exclusively of faecal origin, as characterized as coliform that are to ferment lactose at 44 ^{0}C to 44.5 ^{0}C.

The Coliform Groups

The coliform group is made up of bacteria with defined biochemical and growth characteristics that reused to identify bacteria that are more or less related to faecal contaminants. The total coliforms represent the whole group, and are bacteria that multiply at 37°C. The thermotolerant coliforms are bacteria that can grow at a higher temperature (44.2°C) and Escherichia coli is a thermotolerant species that is specifically of faecal origin(WHO,2005).

Total Coliforms

Coliform organisms, better referred to as total coliforms to avoid confusion with others in the group, are not an index of faecal pollution or of health risk, but can provide basic information on source water quality.

Total coliforms have long been utilized as a microbial measure of drinking water quality, largely because they are easy to detect and enumerate in water. They have traditionally been defined by reference to the method used for the group's enumeration and hence there have been many variations dependent on the method of culture. In general, definitions have been based around the following characteristics: Gram-negative, non-spore-forming rod-shaped bacteria capable of growth in the presence of bile salts or other surface-active agents with similar growth-inhibiting properties, oxidase-negative, fermenting lactose at 35-37°C with the production of acid, gas, and aldehyde within 24-48 hours. These definitions presume the use of cultural methods for identification and enumeration.

There has recently been a move towards a genotypic definition based on the recognition that in order to ferment lactose, organisms must possess - galactosidase activity. Using these approachs total coliforms are defined as members of a genus or species within the family Enterobacteriaceae capable of growth at 37°C and possessing -galactosidase. Traditionally, total coliforms were regarded as belonging to the genera Escherichia, Citrobacter, Enterobacter, and Klebsiella. However, regardless of the definition adopted, the group is heterogeneous. It includes many lactose-fermenting bacteria, such as Enterobacter cloacae and Citrobacter freundii, which can be found in both faeces and in the environment. It also includes members of genera such as Budvicia and Rahnella, which are never found in mammalian faeces.

Thermotolerant (faecal) Coliforms

The term 'faecal coliforms', although frequently employed, is not correct; the correct terminology for these organisms is 'thermotolerant coliforms'. Thermotolerant coliforms are defined as the group of total coliforms that are able to ferment lactose at 44-45°C. They comprise the genus Escherichia and, to a lesser extent, species of Klebsiella, Enterobacter and Citrobacter. Of these organisms, only E. coli is considered to be specifically of faecal origin, being always present in the faeces of humans, other mammals, and birds in large numbers and rarely, if ever, found in water or soil in temperate climates that has not been subject to faecal pollution although there is the possibility of re growth in hot environments (Fujioka et al., 1999).

Thermotolerant coliforms other than E. coli may originate from organically enriched water such as industrial effluents or from decaying plant materials and soils. Their presence in treated waters should not be ignored, as the basic assumptions that pathogens may be present and that treatment has been inadequate still hold good.

Escherichia Coli (E.Coli)

Escherichia coli is a taxonomically well-defined member of the family Enterobacteriaceae, and is characterized by possession of the enzymes - galactosidase and - glucuronidase. It grows at 44°C - 45°C on complex media, ferments lactose and mannitol with the production of acid and gas, and produces indole from tryptophan. However, some strains can grow at 37°C but not at 44°C - 45°C, and some do not produce gas. E. coli does not produce oxidase or hydrolyse urea. Complete identification of the organism is too complicated for routine use, but a number of tests have been developed for rapid and reliable identification with an acceptable degree of accuracy. E. coli is abundant in human and animal faeces, and in fresh faeces it may attain concentrations of 109 per gram It has been suggested that E. coli may be present or even multiply in tropical waters not subject to human faecal pollution (Fujioka et al., 1999).

E. coli is widely preferred as an index of faecal contamination. It is also widely used as an indicator of treatment effectiveness although, as with the other coliform indicators, it is more sensitive to disinfection than many pathogens (in particular viruses and protozoa).

In this thesis, the water collected from different wards of KCC supply were tested for TC, TTC (FC) and E.coli. The summary of test results for all these coliforms in KCC water in three seasons are presented in Table 4.9. It was observed that presence of TC, TTC and E.coli in most of the water samples indicating high risk of spreading water borne diseases by KCC water supply.

Table 4.7 Summary of bacteriological test results of KCC supply water in different seasons

Season	Parameters	Unit	Max	Min	Ave	BDS	WHO GV	Sample Size	xceeding BDS (%)
Rainy	TC	No/100 mL	182	0	46	0	0	23	95.65%
	TTC (FC)	No/100 mL	62	0	19.61	0	0		87%
	E.Coli	No/100 mL	28	0	5.52	0	0		69.56%
Winter	TC	No/100 mL	156	5	43.35	0	0	23	100%
	TTC (FC)	No/100 mL	62	0	15.13	0	0		87%
	E.Coli	No/100 mL	23	0	5.13	0	0		73.91%
Summer	TC	No/100 mL	116	0	42.48	0	0	23	95.56
	TTC (FC)	No/100 mL	46	5	16.91	0	0		100%
	E.Coli	No/100 mL	26	0	6.48	0	0		69.56%

The details of microbial test results of KCC supply water is presented in Table 4.10. The distribution of TC, TTC and E.coli in KCC supply water is shown in the Figure 4.12, Figure 4.13 and Figure 4.14 respectively for different season.

Total Coliform (TC)

Bacteriological tests were performed in KCC supply water from 23 wards. It reveals that TC is presents almost in every sample of water in all seasons. The maximum, minimum value of TC are 182 No/100mL, 8 No/100mL in rainy season; the maximum, minimum TC are 156 No/100mL, 7 No/100mL in winter and maximum, minimum value of TC in summer are 116 No/100mL, 0No/100mL respectively. It means the KCC supply waters are equally contaminated by TC in all seasons. The distribution of TC in KCC supply water in rainy, winter and summer is presented in Figure 4.12.

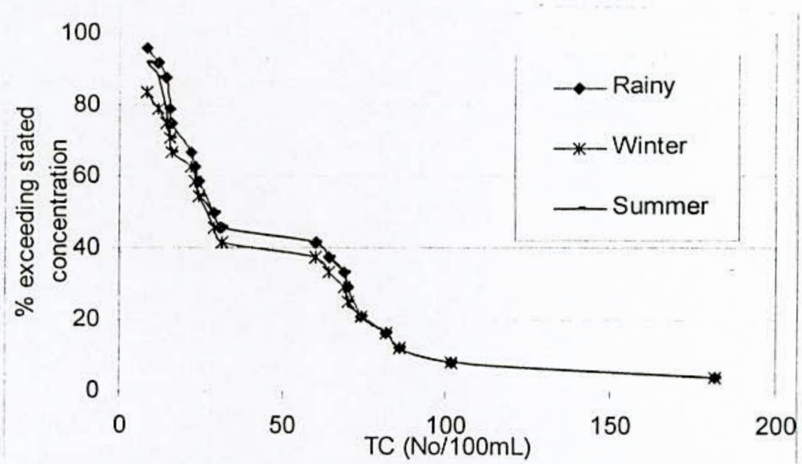


Figure 4.12 Summary of TC in KCC supply water in different seasons

Table 4.8 TC, TTC and E.coli in KCC supply water in different seasons

Ward No.	Rainy season			Winter season			Summer season		
	TC (No/100mL)	TTC (No/100mL)	E.coli (No/100mL)	TC (No/100mL)	TTC (No/100mL)	E.coli (No/100mL)	TC (No/100mL)	TTC (No/100mL)	E.coli (No/100mL)
W09	70	15	9	62	9	7	68	18	11
W10	31	9	6	29	10	6	51	11	5
W11	24	11	0	13	4	0	9	2	0
W12	82	24	12	76	16	11	49	15	9
W13	15	8	0	7	6	1	12	7	0
W14	16	12	7	18	7	4	28	9	4
W15	8	0	0	8	5	0	0	5	0
W16	69	69	12	30	20	7	34	46	16
W17	16	12	3	26	24	6	18	28	3
W18	24	18	8	20	16	7	24	45	13
W19	14	12	0	14	8	0	14	16	0
W20	70	14	2	78	0	3	70	7	4
W21	74	0	0	112	21	0	86	12	0
W22	29	20	0	36	21	1	29	9	0
W23	14	13	8	28	18	9	14	21	9
W24	64	27	0	28	0	0	68	6	0
W25	22	13	2	22	12	4	22	7	5
W26	12	0	0	12	9	0	12	9	0
W27	60	36	11	46	27	13	75	26	17
W28	23	0	0	23	0	0	23	6	0
W29	102	9	1	94	11	6	98	9	5
W30	86	47	18	82	42	11	76	38	22
W31	182	59	28	156	62	23	116	46	26

Thermotolerant Coliform (TTC)

It is found from the bacteriological test of KCC supply water that TTC is present in the supply in rainy, winter and summer seasons but quietely less than that of TC. The maximum, minimum value of TTC are 59 No/100mL, 0(nil)No/100mLin rainy season; 62 No/100mL, 0 No/100mL in winter and 116 No/100mL, 0 No/100mL in summer. It preveals from the results that TTC is higher in summer in comparison to rainy and winter. It means KCC water in summer is more contaminated than that of in rainy and winter seasons.The distribution of TTC in KCC supply water in rainy, winter and summer seasons is shown in Figure 4.13.

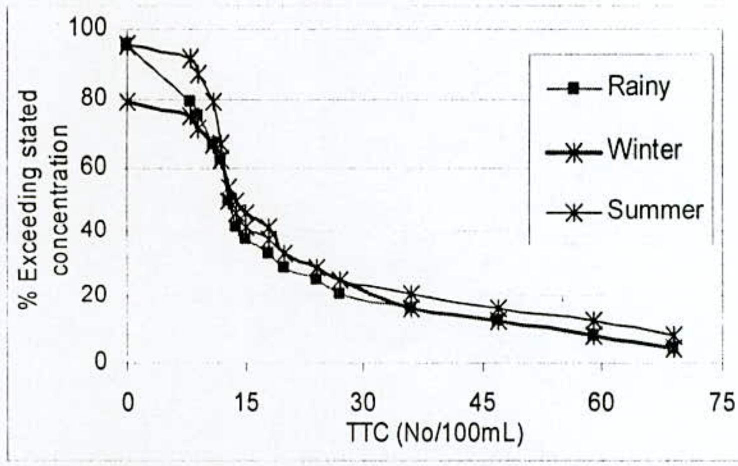


Figure 4.13 Summary of TTC in KCC supply water in different seasons

Escherichia Coli (E.coli)

Bacteriological tests in KCC supply water confirmed that the water is contaminated by TC, TTC and E.coli in substantial in number per 100 mL. Further to confirm the presence of E.coli and its degree the confirmatory test was conducted by M-coli blue reagent. The results confirmed that E.coli is present in the supply but not in all samples. 39.13%, 30.43% and 39.13% samples are free from E.coli respectively in rainy, winter and summer season. The maximum and average value of E.coli in KCC supply water is 28 No/100mL and 1 No/100mL in rainy, 23 No/100mL and 1 No/100mL in winter, 26 No/100mL and 4 No/100mL in summer respectively. It is also prevailed from the distribution pattern that percent concentration of E.coli in winter gradually increases from 8% and continues upto 95% than that of the E.coli in rainy and summer and percent concentration of E.coli in summer runs between winter and rainy season from 38% concentration. The distribution of E.coli in KCC supply water is presented in Figure 4.14.

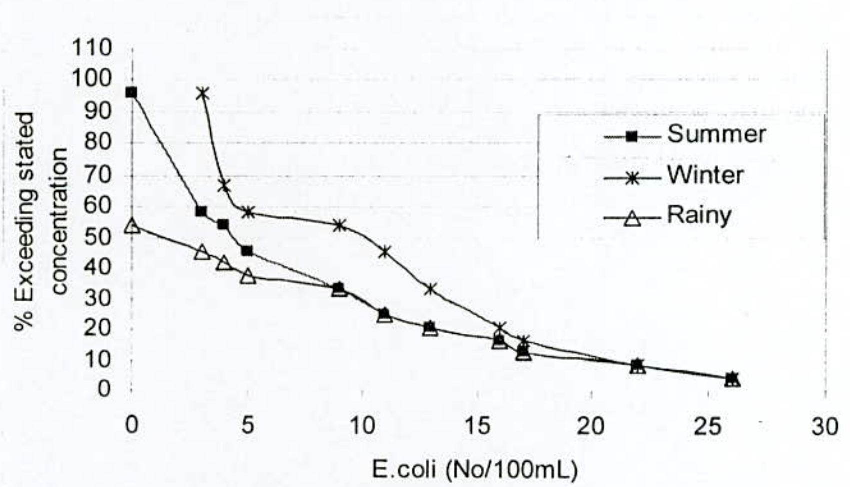


Figure 4.14 Summary of E.coli in KCC supply water in different seasons

The bacteriological tests were performed for KCC supply waters after sampling from 23 wards. The samples were collected in rainy, winter and summer to look into the seasonal variation . It is appeared from the tests that waters in all seasons are bacteriologically contaminated with very little variation from season to season. TTC (FC) presents in 82.61% samples with the result ranging from 8 to 69 No/100mL rainy season while the same is 87% samples in winter having range from 6 to 62 No/100mL and 100 % samples in summer ranging from 5 to 46 No/100mL.. E. coli also appeared in 61% samples with range from 1 to 28 No/100mL in rainy season, 69.37% samples in winter of result having range from 1 to 23 No/100mL and 60.87% in summer water ranging from 3 to 26 No/100mL. It reveals that the KCC water supply is microbially contaminated with very little seasonal variation in TTC and E. coli and not suitable for drinking. The water safety and water surveillance program from KCC should be undertaken immediately.

4.6 Health Risk Assessment

The most serious water contamination problem is the faecal pollution originated from indiscriminate defection and inadequate safe water supply. Inadequate provision of safe drinking water is directly or indirectly related to the communicable diseases, health risk, poor health and poverty. The low availability of safe water goes hand-in-hand with high child mortality rates. Hence, in water supply options analysis the financial, technical, health, environmental and social feasibility of each option are considered. In relation to health, technology option presenting the lowest disease burden would always be preferred and the technology is considerd also to measure the burdrn. Quantitative Health Risk Assessment (QHRA) is one of such technic to assess the severity of health risk in drinking water (APSU, 2005).

In water supply context, Quantitative Health Risk Assessment (QHRA) is a technique to estimate predicted disease burden based on input data about water quality such as TTC, E.coli, arsenic etc. QHRA is a predictive, modelling technique and a tool to estimate what disease burden may be from specified exposures. Again QHRA is not a descriptive, empirical technique and not a tool to measure disease burden in communities. Therefore, QHRA is a scientific model whose out put is only the prediction and estimation and its accuracy fully depends on the accuracy of input data and assumptions applied on the model (APSU, 2005).

In the framework for safe drinking water, assessment of risk is not a goal in its own right but is a part of an iterative cycle that uses the assessment of risk to derive management decisions that, when implemented, result in incremental improvements in water quality. Descriptions of a "reference level of risk" in relation to water are typically express in terms of specific health outcomes. The range of water related illness with differing severities, including acute, delayed and chronic effects and both morbidity and mortality. Effects may be as adverse as adverse birth outcomes, cholera, cancer, dysentery, infectious hepatitis, intestinal worms, skeletal fluorosis and typhoid. A reference level of risk enables the comparison of water-related diseases with one another and a consistent dealing with each other. The reference level of risk is measured with a unit matric called DALY- Disability Adjusted Life Year. The application of DALYs for setting a reference level of risk is a new and evolving approach, which combines assessment of morbidity and mortality and allows different diseases and illness to be compared (Murray and Lopez, 1996). The details about DALY, a new approach for assessing the disease burden, are given below.

DALY is a metric - a new evolving approach for setting a reference level of risk. The diverse hazards that may be present in water are associated with very diverse adverse health outcomes, Some outcomes are acute (diarrhoea, methaemoglobinaemia), and others are delayed (cancer by years, infectious hepatitis by weeks); some are potentially severe (cancer, adverse birth outcomes, typhoid), and others are typically mild (diarrhoea and dental fluorosis); some especially affect certain age ranges (skeletal fluorosis in older adults often arises from exposure in childhood; infection with hepatitis E virus [HEV] has a very high mortality rate among pregnant women), and some have very specific concern for certain vulnerable sub populations (cryptosporidiosis is mild and self-limiting for the population at large but has a high mortality rate among those who test positive for human immuno deficiency virus [HIV]). In addition, any one hazard may cause multiple effects (Gastroenteritis, Gullain-Barré syndrome, reactive arthritis and mortality associated with Campylobacter).

In order to be able to objectively compare water-related hazards and the different outcomes with which they are associated, a common metric- DALY can take account of differing probabilities, severities and duration of effects is needed. This metric should also be applicable regardless of the type of hazard, applying to microbial, chemical and radiological hazards. The metric, DALY, is used in the Guidelines for Drinking Water Quality. WHO has quite extensively used DALYs to evaluate public health priorities and to assess the disease burden associated with environmental exposures.

The basic principle of the DALY is to weight each health effect for its severity from 0 (normal good health) to 1 (death). This weight is multiplied by the duration of the effect that is the time in which disease is apparent (when the outcome is death, the "duration" is the remaining life expectancy) – and by the number of people affected by a particular outcome. It is then possible to sum the effects of all different outcomes due to a particular agent.

Thus, the DALY is the sum of years of life lost by premature mortality (YLL) and years of healthy life lost in states of less than full health, i.e., years lived with a disability (YLD), which are standardized by means of severity weights.

Thus, DALY = YLL + YLD

Key advantages of using DALYs are its "aggregation" of different effects and its combining of quality and quantity of life. In addition – and because the approaches has taken require explicit recognition of assumptions made – it is possible to discuss these and assess the impact of their variation. The use of an outcome metric also focuses attention on actual rather than potential hazards and thereby promotes and enables rational public health priority setting. Most of the difficulties in using DALYs relate to availability of data.

DALYs can also be used to compare the health impact of different agents in water. For example, ozone is a chemical disinfectant that produces bromate as a by-product. DALYs have been used to compare the risks from Cryptosporidium parvum and bromate and to assess the net health benefits of ozonation in drinking-water treatment.

Every disease has different severities such as cancers have different severities, manifested mainly by different mortality rates. A typical example is renal cell cancer, associated with exposure to bromate in drinking-water. The theoretical disease burden of renal cell cancer, taking into account an average case: fatality ratio of 0.6 and average age at onset of 65 years, is 11.4 DALYs per case (Havelaar et al., 2000). These data can be used to assess tolerable lifetime cancer risk and a tolerable annual loss of DALYs. Here, it is accounted for the lifelong exposure to carcinogens by dividing the tolerable risk over a life span of 70 years and multiplying by the disease burden per case: (10^{-5} cancer cases / 70 years of life) x 11.4 DALYs per case = 1.6×10^{-6} DALYs per person-year or a tolerable loss of 1.6 healthy life-years in a population of a million over a year (WHOGV, 2004).

4.6.1 Model Structure and Data

For estimating the disease burden associated with the KCC water supply, a predictive model, QHRA model was used. QHRA model is a well accepted model (Howard et al, 2007) and its used in health risk assessment recommended by WHO (WHOGV,2004). The model is primarily developed to assess the health risk burden with various water supply options and in arsenic mitigation of APSU. This model can be used to estimate health burden due to microbial contaminationas as well as excessive amount of arsenic present in water. The architecture of QHRA model is shown in figure 4.1 (RAMMO,2005).

The microbial data of KCC water supply expectedly TTC and E.coli that were ascertained by laboratory analysis and used as model input. Several previous reports on water quality of KCC stated that presence of arsenic in supply water is much lower or nil and hence arsenic data was not input in the model.

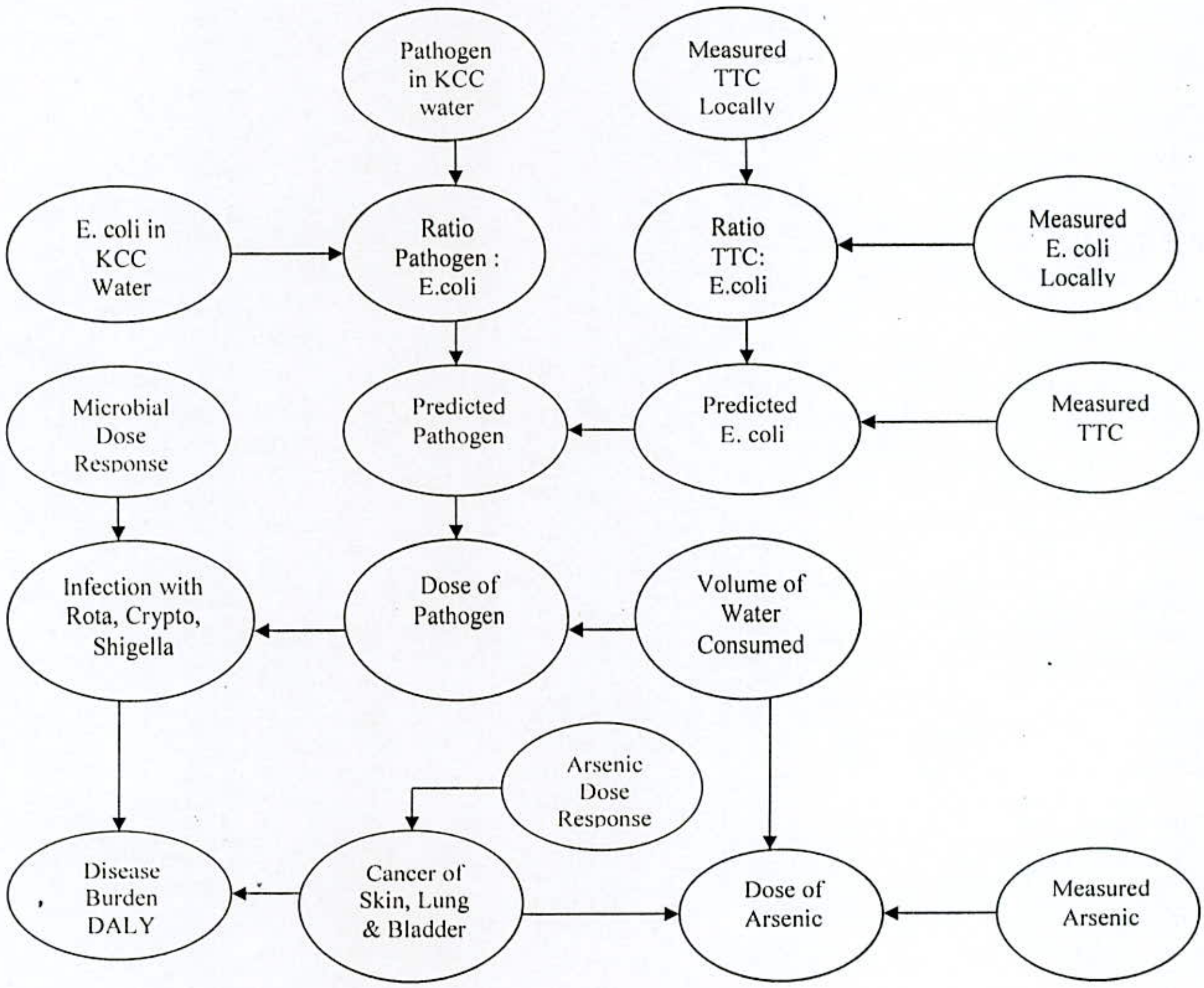


Figure 4.15 Overview of QHRA model

The bacteriological test results of KCC supplied water reveals the presence of Thermotolerant coliform (TTC) and E. coli in substantial numbers. These microbial indicators TTC and E. coli from test results are put into the QHRA model (Haward et al, 2006) and hence associted disease burdens are assessed for KCC water supply.

Assessment of Health Burden

In assessing health risk, two scenarios were explored; one is associated with TTC and another with E.coli in KCC water supply in different seasons

4.10.1(i) Health Risk for TTC in rainy season

The thermotolerant coliforms (TTC) obtained from the tests performed in KCC water in rainy season were input in to the QHRA model to find out the scenario of microbial burden, scenario of viral burden, scenario of bacterial burden and scenario of prozoa burden. The out put from the model appear in the figure 4.14 below that the scenario of microbial burden varies from 2.1 μDALY/Person-year (μDPY) at 5%ile to 3.7 μDPY at 95%ile and the 90% confident interval is 3.2 μDPY. It means that the maximum tolerable loss of 3.7 healthy life per million person over a year and minimum tolerable loss of 2.1 healthy life per million person over a year.

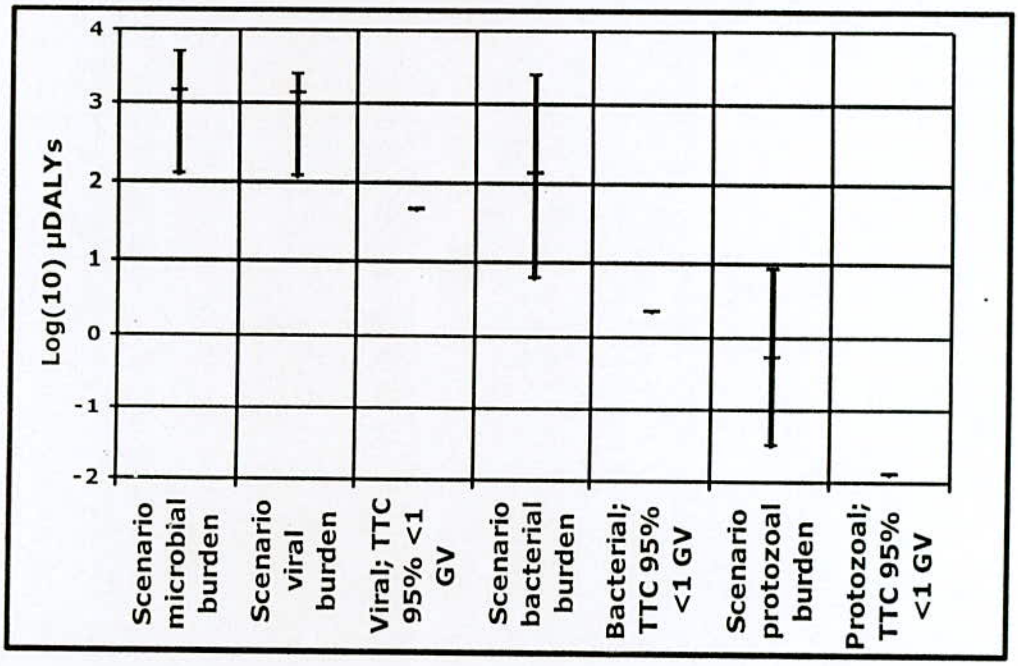


Figure 4.16 Disease burden due to TTC in KCC water in rainy season

The viral burden for TTC of 95% ile with <1GV (guididing value) it varies 2.1 μDPY to 3.4 μDPY that is tolerable loss of (2.1 to 3.4) healthy life per million over a year whereas the acceptable tolerance value is 1.7 μDPY. Hence the viral burden due to TTC in KCC water is beyond over the tolerable range.

The bacterial burden for TTC of 95%ile with <1GV (guididing value) is ranging from 0.8 μDPY to 3.4 μDPY whereas the minimum tolerable limit is 0.40 μDPY. Here it also appears that bacterial burden due to TTC in KCC water is beyond over the tolerable range.

The protozoal burden for TTC of 95%ile with <1 GV (guididing value) is ranging from –1.5 μDALYs to 0.9 μDPY whereas the minimum tolerable limit is –1.9 μDPY. Here it also appears that protozoall burden due to TTC in KCC water is beyond over the tolerable range.

4.6.1 (ii) Health Risk for E. coli in rainy season

The Escherichia coli (E. coli) obtained from the tests performed in KCC water in rainy season were input in to the QHRA model to find out the scenario of microbial burden, scenario of viral burden, scenario of bacterial burden and scenario of prozoa burden. The out put from the model appear in the figure 4.15 that the scenario of microbial burden due to presence of E. coli in water varies from 1.4 μDPY at 5%ile to 3.5 μDPY at 95%ile and the 90% confident interval is 2.7 μDPY. It means that the maximum tolerable loss of 3.7 healthy life per million person over a year and minimum tolerable loss of 1.4 healthy life per million person over a year.

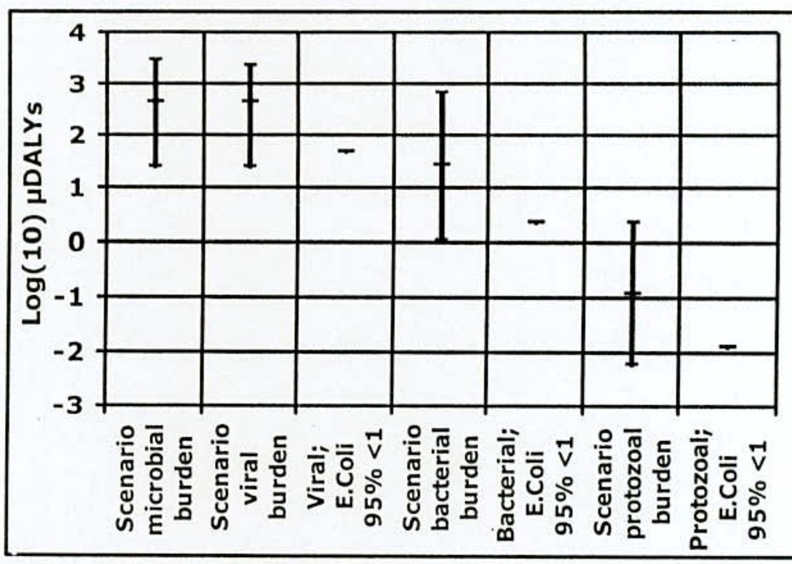


Figure 4.17 Disease burden due to E. coli in KCC water in rainy season

The viral burden for E.coli of 95% ile with < 1 GV (guididing value) it varies 1.4 μDPY to 3.4 μDPY that is tolerable loss of (1.4 to 3.4) healthy life per million person over a year whereas the acceptable tolerance value is 1.7 μDPY. Hence the viral burden due to E.coli is about 0.30 μDPY below the tolerable limit; here it is the good sign of KCC water.

The bacterial burden for E.coli of 95%ile with <1GV (guididing value) is ranging from 0 μDPY to 2.8 μDPY whereas the minimum tolerable limit is 0.40 μDPY. Here it also appears that bacterial burden due to E.coli in KCC water is far below the tolerable range indicating positve sign of KCC water.

The protozoal burden for E.coli of 95%ile with <1 GV (guididing value) is ranging from –2.2 μDPY to 0.4 μDPY whereas the minimum tolerable limit is –1.9 μDPY. Here it is also appeared that protozoall burden due to E.coli in KCC water below the minimum tolerable range is the good sign of KCC water.

4.6.1 (iii) Health Risk for TTC in winter

The thermotolerant coliforms (TTC) obtained from the tests performed in KCC water in winter season were input in to the QHRA model to find out the scenario of microbial burden, scenario of viral burden, scenario of bacterial burden and scenario of prozoa burden. The out put from the model appear in the figure 4.16 below that the scenario of microbial burden varies from 2.0 μDPY at 5%ile to 3.6 μDPY at 95%ile and the 90% confident interval is 3.1 μDPY. It means that the maximum tolerable loss of 3.6 healthy life per million person over a year and minimum tolerable loss of 2.0 healthy life per million person over a year.

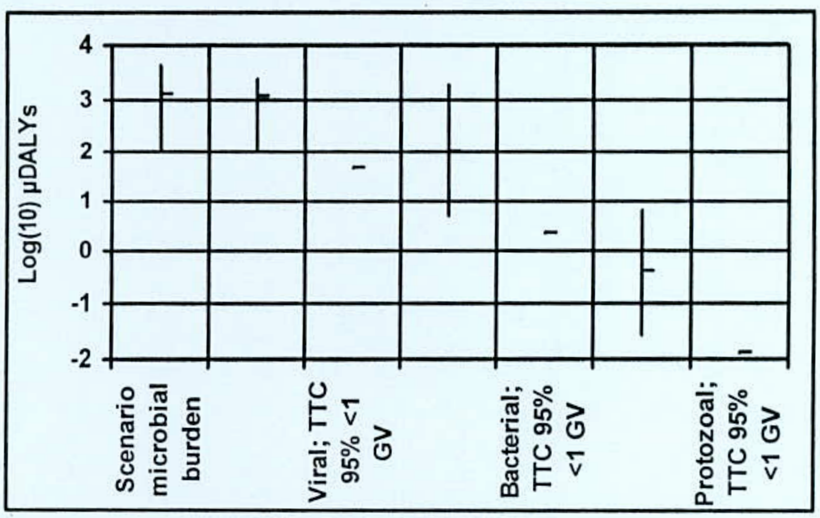


Figure 4.18 Disease burden due to TTC in KCC water in winter

The viral burden for TTC of 95% ile with <1GV (guididing value) it varies 2.0 μDPY to 3.4 μDPY that is tolerable loss of (2.0 to 3.4) healthy life per million person over a year whereas the acceptable tolerance value is 1.7 μDPY. Hence the viral burden due to TTC in KCC water is beyond over the tolerable range.

The bacterial burden for TTC of 95%ile with <1GV (guididing value) is ranging from 0.7 μDPY to 3.3 μDPY whereas the minimum tolerable limit is 0.40 μDPY. Here it also appears that bacterial burden due to TTC in KCC water is beyond over the tolerable range.

The protozoal burden for TTC of 95%ile with <1 GV (guididing value) is ranging from −1.6 μDPY to 0.8 μDPY whereas the minimum tolerable limit is −1.9μDPY. Here it also appears that protozoall burden due to TTC in KCC water is beyond over the tolerable range.

4.6.1 (iv) Health Risk for E. coli in Winter

The Escherichia coli (E. coli) obtained from the tests performed in KCC water in winter season were input in to the QHRA model to find out the scenario of microbial burden, scenario of viral burden, scenario of bacterial burden and scenario of prozoa burden. The out put from the model appear in the figure 4.17 that the scenario of microbial burden due to presence of E. coli in water varies from 1.9 μDPY at 5%ile to 3.5 μDPY at 95%ile and the 90% confident interval is 2.9 μDPY. It means that the maximum tolerable loss of 3.5 healthy life per million person over a year and minimum tolerable loss of 1.9 healthy life per million person over a year.

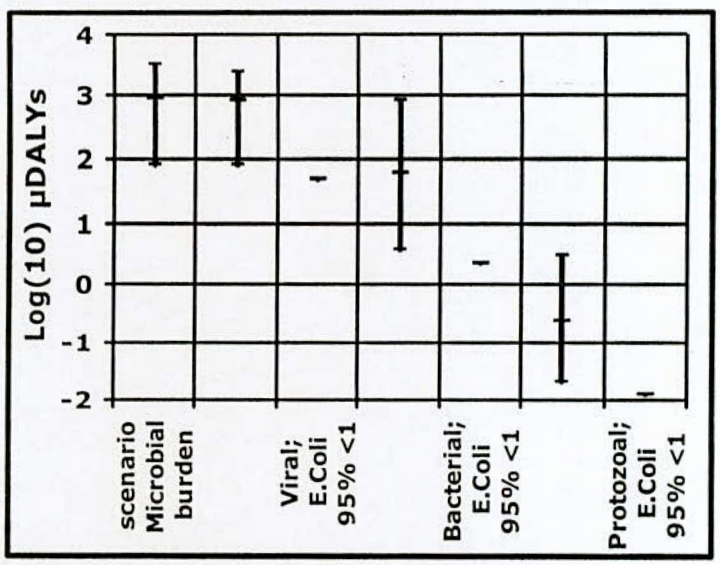


Figure 4.19 Disease burden due to E. coli in KCC water in winter

The viral burden for E.coli of 95% ile with < 1 GV (guididing value) it varies 1.9 μDPY to 3.5 μDPY that is tolerable loss of (1.9 to 3.5) healthy life per million person over a year whereas the acceptable tolerance value is 1.7 μDPY. Hence the viral burden due to E.coli is beyond above the minimum tolerable limit.

The bacterial burden for E.coli of 95%ile with <1GV (guididing value) is ranging from 0.6 μDPY to 2.9 μDPY whereas the minimum tolerable limit is 0.40 μDPY. Here it also appears that bacterial burdenin KCC water is beyond above the tolerable limit.

The protozoal burden for E.coli of 95%ile with <1 GV (guididing value) is ranging from –1.7 μDPY to 0.5 μDPY whereas the minimum tolerable limit is –1.9 μDPY. Here it is also appeared that protozoall burden due to E.coli in KCC water is above the minimum tolerable limit.

4.6.1(v) Health Risk for I TTC in Summer

The TTC obtained from the tests performed in KCC water in summer season were input in to the QHRA model to find out the scenario of microbial burden, scenario of viral burden, scenario of bacterial burden and scenario of prozoa burden. The out put from the model appear in the figure 4.18 below that the scenario of microbial burden varies from 2.0 μDPY at 5%ile to 3.6 μDPY at 95%ile and the 90% confident interval is 3.1 μDPY. It means that the maximum tolerable loss of 3.6 healthy life per million person over a year and minimum tolerable loss of 2.0 healthy life per million person over a year.

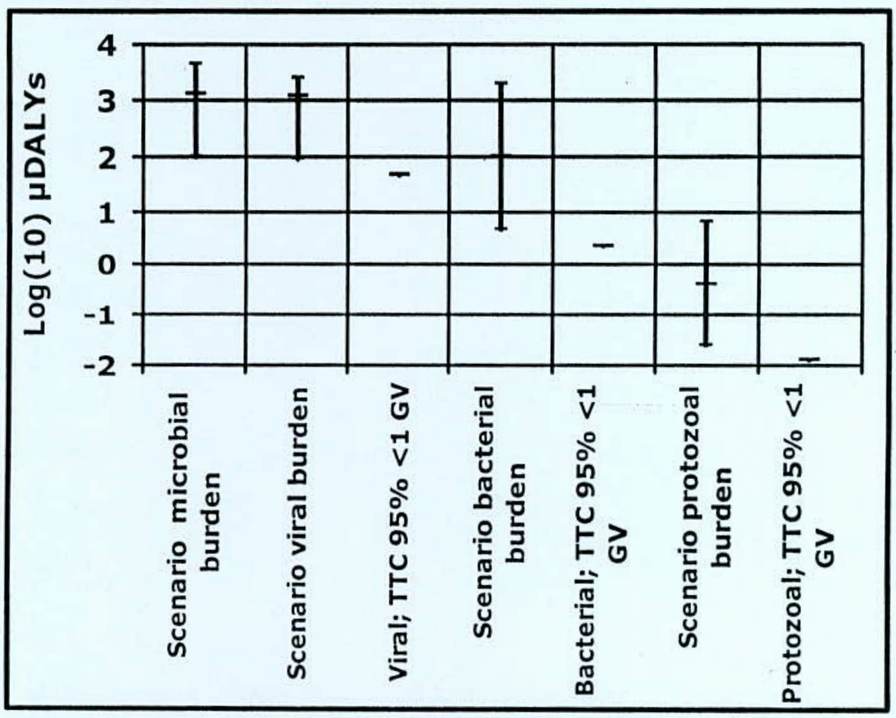


Figure 4.20 Disease burden due to TTC in KCC water in summer

The viral burden for TTC of 95% ile with <1GV (guididing value) it varies 2.0 μDPY to 3.4 μDPY that is tolerable loss of (2.0 to 3.4) healthy life per million person over a year whereas the acceptable tolerance value is 1.7 μDPY. Hence the viral burden due to TTC in KCC water is beyond over the tolerable range.

The bacterial burden for TTC of 95%ile with <1GV (guididing value) is ranging from 0.7 μDPY to 3.3 μDPY whereas the minimum tolerable limit is 0.40 μDPY. Here it also appears that bacterial burden due to TTC in KCC water is beyond over the tolerable range.

The protozoal burden for TTC of 95%ile with <1 GV (guididing value) is ranging from −1.6 μDPY to 0.8 μDPY whereas the minimum tolerable limit is −1.9 μDPY. Here it also appears that protozoall burden due to TTC in KCC water is beyond over the tolerable range.

4.6.1 (vi) Health Risk for E. coli in summer

The Escherichia coli (E. coli) obtained from the tests performed in KCC water in summer season were input in to the QHRA model to find out the scenario of microbial burden, scenario of viral burden, scenario of bacterial burden and scenario of prozoa burden. The out put from the model appear in the figure 4.19 that the scenario of microbial burden due to presence of E. coli in water varies from 1.7 μDPY at 5%ile to 3.5 μDPY at 95%ile and the 90% confident interval is 2.9 μDPY. It means that the maximum tolerable loss of 3.5 healthy life per million person over a year and minimum tolerable loss of 1.7 healthy life per million person over a year.

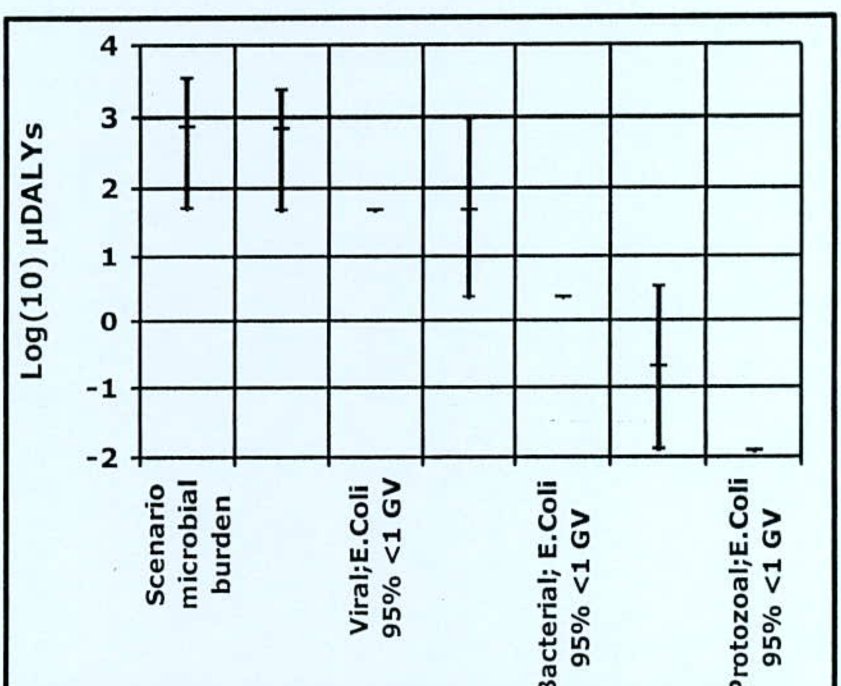


Figure 4.21 Disease burden due to E. coli in KCC water in summer

The viral burden for E.coli of 95% ile with < 1 GV (guididing value) it varies 1.7 μDPY to 3.4 μDPY that is tolerable loss of (1.7 to 3.4) healthy life per million person over a year whereas the acceptable tolerance value is 1.7 μDPY. Hence the viral burden due to E.coli in KCC water is beyond above the tolerable limit.

The bacterial burden for E.coli of 95%ile with <1GV (guididing value) is ranging from 0.40 μDPY to 3.00 μDPY whereas the minimum tolerable limit is 0.40 μDPY. Here it also appears that bacterial burden due to E.coli in KCC water is above the allowable limit.

The protozoa burden for E.coli of 95%ile with <1 GV (guididing value) is ranging from –1.9 μDPY to 0.5 μDPY whereas the minimum tolerable limit is –1.9 μDPY. Here it is also appeared that protozoa burden due to E.coli in KCC water is above the minimum tolerable range.

The disease burden due to the presence of microbial contaminants- TTC and E.coli in KCC supply water in different seasons were discussed elaborately with the figures. The summary of the disease burden associated with TTC and E.coli in 95%ile, 5%ile and median value to make comparison with the tolerable limit according to WHO is presented in the Table 4.9.

Table 4.9 Disease burden in Different percentile due to microbial contaminants

Season	Microbial contaminants	Disease burden in μDPY			WHOGV (μDPY)	Highest result from allow.value
		95%ile	5%ile	Median		
Rainy	Viral burden due to TTC	3.4	2.1	3.1	1.7	2 times
	Bacterial burden due to TTC	3.4	0.8	2.1	0.4	8.5 times
	Protozoa burden due to TTC	0.9	-1.5	-0.3	-1.9	-
	Viral burden due to E.coli	3.4	1.4	2.6	1.7	2 times
	Bacterial burden due to E.coli	2.8	00	1.4	0.4	7 times
	Protozoa burden due to E.coli	0.4	-2.2	-0.9	-1.9	-
Winter	Viral burden due to TTC	3.4	2.0	3.1	1.7	2 times
	Bacterial burden due to TTC	3.3	0.7	2.0	0.4	8.25 times
	Protozoa burden due to TTC	0.8	-1.6	-0.4	-1.9	-
	Viral burden due to E.coli	3.4	1.9	2.9	1.7	2 times
	Bacterial burden due to E.coli	2.9	0.6	1.8	0.4	7.25 times
	Protozoa burden due to E.coli	0.5	-1.7	-0.6	-1.9	-
Summer	Viral burden due to TTC	3.4	2.00	3.1	1.7	2 times
	Bacterial burden due to TTC	3.3	0.7	2.0	0.4	8.25 times
	Protozoa burden due to TTC	0.8	-1.6	0.4	-1.9	-
	Viral burden due to E.coli	3.4	1.7	2.8	1.7	2 times
	Bacterial burden due to E.coli	3.0	0.4	1.70	0.4	7.50times
	Protozoa burden due to E.coli	0.5	-1.9	-0.7	-1.9	-

4.7 Conclusion

In chemical quality parameters Hardness, pH, Fluorides, Chlorides, Sulphates, Nitrates, Conductivity and TDS were tested. Test results of all the parameters were within the limit of BDS and WHO guidelines value except total hardness, total dissolved solids and conductivity. The allowable limit for hardness in drinking water is 250 to 500 mg/L and in average 20% samples exceeded the limit marginally. Due to presence of excessive hardness in water it consumes excessive soap and difficult to produce lather or foam, it clogs skin, discolored vegetables and cooked foods etc. The test results in conductivity found excessive, about 69.58% samples exceeding the allowable limit 600 to 1000 μS/cm according to BDS. Conductivity indicates the presence of inorganic salts and has a good correlation with the total dissolved solids in water indicating the suitability for domestic use. Total dissolved solids exceed the BDS limit of 1000 mg/L by about 14% samples. Excessive TDS comprising common salts clims affect the taste, corrosion, it may exert adverse effects on aquatic animals and plants and amounts in specified quantities have the effects on the suitability for domestic use.

Bacteriological test results revealed excessive TTC (FC) and E.coli in all the seasons. TTC and E.coli value exceeded by 93% and 71% respectively of allowable limit 0 according to BDS and WHO guidelines value. Due to these exceesive values of TTC and E.Coli in KCC water it is associated with the disease burden to the usesrs. The quantitave health risk was assessed by QHRA model. Due to excessive presence of TTC the viral burden varies from 2.0 to 3.4 μDPY instead of allowable limit 1.70 μDPY; bacterial burden varies from 0.70 to 3.30 μDPY instead of allowable limit 0.70 μDPY and protozoa burden varies from –0.80 to 1.60V in lieu of –1.90 μDPY. And again due to presence of E.coli in KCC water, the viral burden varies from 1.70 to 3.40 μDPY instead of 1.70 μDPY; bacterial burden varies from 0.3 to 2.80 μDPY instead of limiting value 0.80 μDPY and protozoa burden varies from –1.80 to 0.50 μDPY instead of allowable limit –1.9 μDPY (APSU, 2005). It is also revealed that due to excessive TTC and E.coli there is the guge disease burden beyond the acceptable range according to WHOGV. According to the comparison it is revealed that due to microbial TTC and E.coli the disease burden in KCC supply water varies from 100% to 750% and from 100% to 650% respectively more than WHOGV for drinking water.

CHAPTER V

ANALYSIS OF DRAINAGE SYSTEM AND WASTEWATER LOADING

5.1 Introduction

Drainage system is an integral part of the city along with other major infrastructures. The drains should be in proper sections and slopes, adequate in number as per the requirement to carry out the domestic waste water and storm runoff of the city to the river, canal, ditches or any other places of safe distances. A proper drainage system is considered as an indicator for a healthy and environmentally polluted free city. The city dwellers must have some sorts of access in the drainage in their premises to drain out the wastewater. But survey of a large number of households in Khulna City shows that about 68 percent of the households have no planned drainage facilities in and round their premises while only 32 percent have some sort of drainage facilities (KDA, 2002).

Khulna City has the topography sloped towards southwest direction helps for natural drain out. But unplanned spatial activities and habitation are causing encroachment on retention areas and natural drainage paths with little or no care for natural drainage system. Inadequate drain sections, natural siltation, indefinite drainage outlets and even absence of outlets, lack of proper maintenance of the existing drainage system and over and above disposal of solid wastes into the drains and drainage paths are accounted for the prime causes of blockage in drainage system and water logging. In addition, seasonal as well as occasional tidal effects are also causing water logging, especially in the southern part of the city (KDA, 2002). This chapter presents an assessment of the existing drainage facilities in KCC area. An analysis of the adequacy of drainage section, the characteristics of the wasterater and associated wasteloading from KCC drainage network to the nearby rivers are also presented.

5.2 Existing Drainage Facilities in KCC Area

In the city, pucca, semi-pucca and kutcha drains exist and these drains are discharging the wastewater into the nearby rivers, khals, low-lying areas and beels. There is no underground storm water drainage system in Khulna City; concrete box culverts are being used for road crossing only.

The drainage system in Khulna City areas have been improved during last few years by Secondary Towns Integrated Flood Protection Project (STIFPP) implemented by LGED and BWDB funded by World Bank. Moreover, KCC has also constructed some drains in last few years from their own funds. So drainage facility has improved for a large extent but still have to be improved a lot and mainly with regard to maintenance and cleaning activities to keep it workable.

The drains and other accessory works executed by LGED and BWDB to provide drainage facilities in KCC areas are discussed below. The existing drainage network within KCC area is shown in Table 5.1.

Table 5.1 Existing drains in KCC area (KCC, 2006)

Area	Length of drain (Km)	Type of drains					
		Pucca drain (Km)	Pucca drain (%)	Semi-pucca drain (Km)	Semi - pucca drain (%)	Kutcha drain (Km)	Kutcha Drain (%)
KCC	528.12	291.23	55.14	71.79	13.60	165.10	31.26

The drains may be classified in different ways as their existing features and also according to the type of functions they are performing. As per the existing types of construction features they are – Pucca, Semi-Pucca and Kutcha. According to the nature of functions they are performing, drains are classified as:-

- Primary or main drain
- Secondary or carrier drain
- Tertiary drain

Primary or main Drain

The drain that connects its one end at the main outlet and the other end or at the several intermittent points are connected by the secondary drains which carry the wastewater from tertiary drain and it carries and ultimately disposes to the out let either in river, canal or ditches. This is called the main drain as it carries the wastewater collecting from secondary or carrier and tertiary drain which carries to the outlet.

Secondary or Carrier Drain

The drains, which are not directly connected with the outlets or even with the sources of main wastewaters, it connects the main or primary drain with the tertiary drain. It carries the wastewater from the tertiary drain to the main drain for dispose of to the outlet. As it carries the wastewater from the tertiary to the main drain it is called Carrier drain.

Tertiary Drain

These are the drains which are directly connected with the secondary drain and carry the wastewaters from the main sources to the main drain through carrier drain for dispose of to the outlet.

There are total about 528.12 Kms drains within the Khulna City Corporation area. Every year, some new drains are added with the list and their natures are also changing (KCC,2006; KDA, 2002). The length of different types of drains in Khulna City is furnished in Table 5.2 and also in Figure 5.1. The drainage network map of KCC area is presented in Figure 5.2.

- Length of Primary or Main drain = 175.43 km
- Length of Secondary or Carrier drain = 150.45 km
- Length of Tertiary drain = 202.24 km

Table 5.2 Drains in KCC Area (KCC, 2006; KDA, 2002).

Area	Length of drain (Km)	Different types of drain					
		Primary drain (Km)	Primary drain in % of total	Secondary drain (Km)	Secondary drain in % of total	Tertiary drain (Km)	Tertiary drain in % of total
KCC	528.12	175.43	33.22	150.45	28.49	202.24	38.29

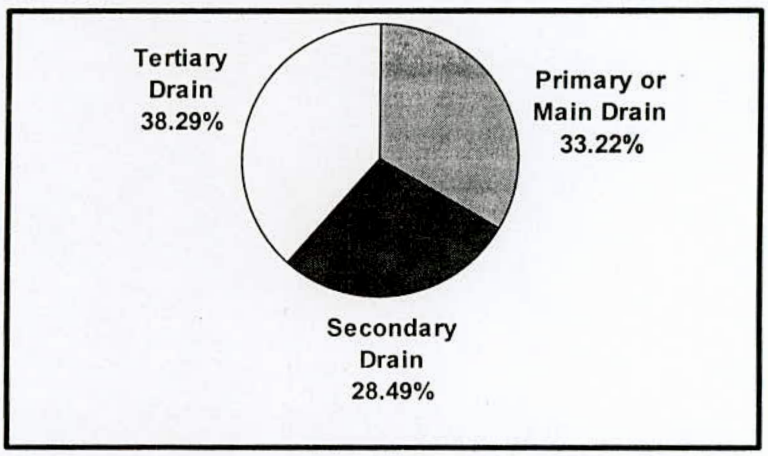


Figure 5.1 Drains types in KCC area.

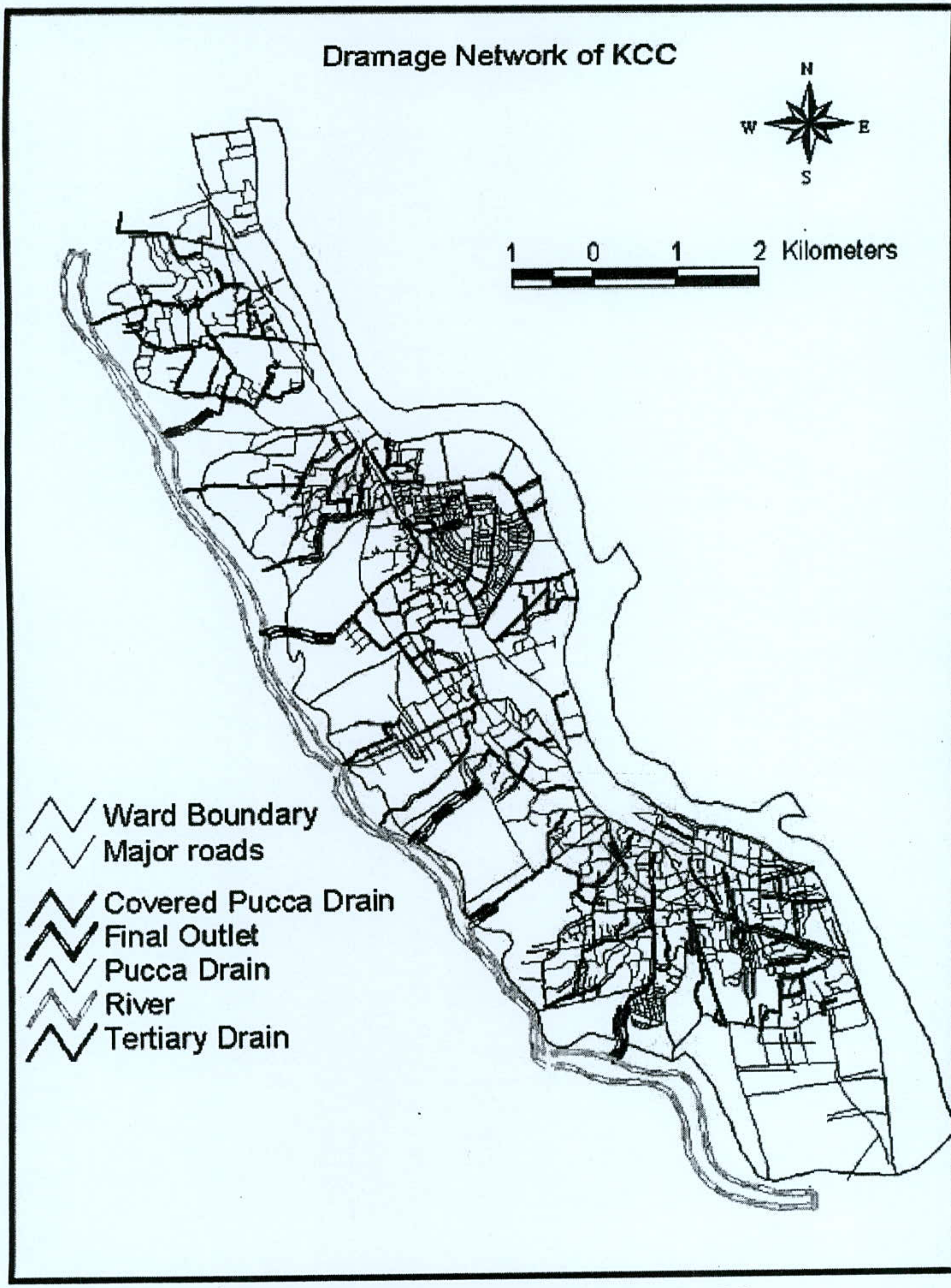


Figure-5.2 Drainage network map of KCC

5.2.1 Drainage Density in Khulna City Area

The drainage density is the drain in a particular specified area at Kilometers in length per Square Kilometers of area. The drainage density in each ward of KCC area is presented in the Table 5.3. Figure 5.3 shows the drainage density in each ward in KCC area.

Table 5.3 Drainage Density in Khulna City Area

Ward No.	Ward Area (m^2)	Primary or Main Drain (m)	Secondary or Carrier Drain (m)	Tertiary Drain (m)	Total Drain (m)	Drainage Density (Km/Km^2)
1	2110031	3459.10	2852.22	3833.38	10144.70	4.81
2	2165625	2728.40	2440.70	3280.30	8449.40	3.90
3	3475553	5419.87	4259.62	5724.33	15404.42	4.43
4	1060294	2492.70	2130.00	3862.72	8485.42	8.00
5	707691.1	5583.76	4183.70	4622.89	14390.35	20.33
6	1757244	5664.09	4923.62	6617.34	17205.05	9.79
7	692051	3596.00	3212.30	4317.33	11125.63	16.08
8	693834.4	2877.97	2230.7	2998.09	8106.78	11.68
9	5314189	5906.34	5660.80	6564.11	18231.25	3.43
10	701307.5	6309.24	4790.00	7281.76	18381.00	26.21
11	378303.3	3244.60	3015.98	4022.28	10282.86	27.18
12	674318.3	6254.61	5332.80	7867.28	19254.69	28.55
13	1071801	2222.64	2520.32	2815.31	7558.27	7.05
14	2787309	9839.63	8159.59	10966.5	28915.72	10.39
15	1550086	3498.66	3419.02	4591.96	11509.64	7.43
16	2414410	7118.50	6262.50	8916.80	22297.80	9.23
17	2490915	11642.84	9763.80	13122.55	34529.19	13.86
18	1127736	4345.03	3622.12	4868.13	12835.28	11.38
19	494341.6	4524.47	3728.30	5110.84	13263.61	26.83
20	491635.9	6212.14	5640.00	7811.36	19163.50	28.68
21	1392927	5209.29	4108.72	5722.12	15040.13	24.51
22	613728.4	5036.88	5018.31	6013.41	18168.6	26.10
23	**506452**	**5561.42**	**4004.20**	**7597.64**	**16068.60**	**33.88**
24	1549301	12632.54	10060.32	13521.07	36213.93	23.37
25	734007.4	6479.04	5913.17	7747.30	20139.51	27.43
26	659994.9	5457.59	4833.00	6495.55	16826.14	25.49
27	975523.3	7815.96	6998.50	9405.98	24220.44	24.89
28	524050.50	5526.87	4978.00	6717.31	17322.18	33.05
29	716047.7	6368.98	6008.15	8074.95	20452.08	28.56
30	1267483	6772.61	6359.20	8546.76	21678.57	17.10
31	**3660072**	**3884.51**	**3118.80**	**4191.67**	**11195.98**	**3.06**
Grand Total	**44786263.5**	**175426.27**	**150448.42**	**202245.31**	**528120.00**	**Av. 11.56**

The highest drainage density of the drain is 33.88 km/km^2 in ward 23 which is in the heart of the city and the lowest density is 3.06 km/km^2 in ward 31, the southwestern part of the city along the Rupsha river and the average drainage density of the city is 11.56 km/km^2.

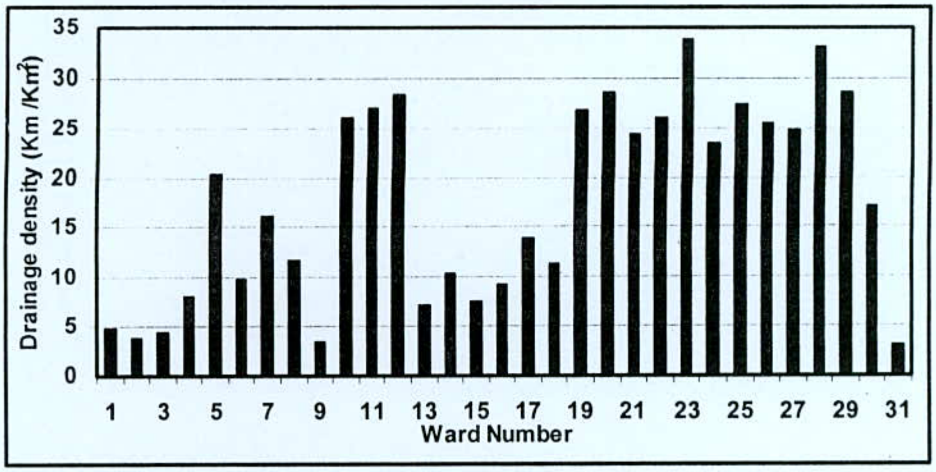


Figure 5.3 Drainage density in different wards in KCC area

5.2.2 Drains Improved by Project in KCC Area

Drains constructed by LGED

LGED has constructed and rehabilitated some drains in KCC area through STIFPP project with some others associated structures to improve the over all drainage condition in Khulna City area during the period 1996-2000. LGED has constructed about 80.59 kms primary drains (main drain), about 16.74 kms secondary drains (carrier drain) and about 38.00 kms tertiary drains and rehabilitated about 34.94 kms drains of different types. LGED have also constructed some Kutcha drains of about 1.38 kms. They have also constructed some structures that facilitated the drainage as well as solid waste management facilities. Among those are dust bin 451 nos, Development of garbage pit 231 m, Sock well 366 nos, RCC slab on drains 14619.67 m^2, Public toilets 63 nos, Solid waste collection pit 60 nos, culvert 210 nos and 4 bridges of 111.5m total span. The different types of drains constructed by LGED are shown in Table 5.4.

Table 5.4 Drains constructed by LGED (LGED,2000)

Area	Total Length (Km)	Drains constructed by LGED		
		Primary or Main drain (Km)	Secondary or Carrier drain (Km)	Tertiary drain (Km)
KCC	135.32	80.59	16.74	38.00

Drains and Flood Control Structures Constructed by BWDB

BWDB was involved in the Secondary Town Integrated Flood Protection Project (STIFPP) for construction of flood protection embankment, bank protection work, regulators and drains. It has facilitated a great extent in the KCC area in flood control and drainage arena in Khulna city.

BWDB has constructed six regulators and eight sluice gates which are facilitating to drain out storm water from KCC area that improved the over all drainage condition. The 10 vents sluice gate located at Alutala performs major drainage function of the Khulna City. Out of these, 4 regulators drain out storm water into the Rupsha River and the other 2 regulators drain out into the Khudir Khal, the upstream of Gollamari (Mayur) River. The road between Rupsha Bus Stand and Shipyard along Labon Chara Khal is a town protection embankment, which protects the eastern areas of KCC from river flooding. The embankment and sluice gates also control KCC areas from flooding of Solmari River on the south and southwestern edges of Khulna City area (KDA, 2002). The details flood protection structures constrcted by BWDB in KCC area are presented in Table 5.5 and Table 5.6.

Table 5.5 Flood protection works from BWDB (KDA, 2002)

Sl. No.	Name of Works	Quantity
1.	Retired Embankment	2.53 km
2.	Regulator :	
	a. R1 : 1-1.50 x 1.80 M b. R2 : 1-1.50 x 1.80 M c. R3 : 2-1.50 x 1.50 M d. R4 : 3-1.50 x 1.80 M e. R5 : 4-1.50 x 1.80 M f. R6 : 2-1.50 x 1.80 M	1 No at Rupsha River 1 No - do – 1 No - do – 1 No - do – 1 No at Khudir Khal 1 No at Khudir Khal
3.	Rehabilitation of existing regulator	3 Nos
4.	River Bank Protection areas	2.89 Km
	a. Ansar Flour Mills area b. Daulatpur College Stretch c. Roosevelt Jetty Street area d. Hospital Stretch at Jail Khana ghat	270 m 405 m 850 m 1215 m
5.	Temporary Bank protection by permeable spur.	400 m

Table 5.6 Flood control structures by BWDB (KDA, 2002)

Sl. No.	Name of Structure	Size	Operation and Maintenance.	Sl No.	Name of Struc-ture	Size	Operation and Maintenance
Sluice Gates :							
01.	S -1	1-0.90 x 1.20 M	KCC	05.	S -1	3-1.50 x 1.80M	O and M Division-II
02.	S -2	1-0.90 x 1.20 M	- do -	06.	S - 2	2-1.50 x 1.80M	BWDB, Khulna
03.	S -3	1-1.20 x 1.30 M	- do -	07.	S - 3	0-1.50 x 1.80 M	- do -
04.	S -4	Culvert, KCC	- do -	08.	S - 4	1-1.50 x 1.80M	do -
	Clossure						
09.	Alutala Closure	10 vent 1.50* 1.80M	- do -	10.	Kazibacha Closure		- do -

5.3 Drainage Pattern in KCC Area

The topographical features, existing internal network of khals and the river system in and around the KCC area show the following five drainage zones. The natural topographical features as it slopes down from northeast to southwest (KDA ,2002). The contour map of Kgulna City Corporation area is shown in Figure 5.4.

a. Long and Narrow Strip of Flat Highland Along Both Sides of the Bhairab and Rupsha River (Right Bank)

There is a long and narrow strip of flat highland along the Bhairab and Rupsha River and stretching along northwest to southeast direction; this strip consists of KCC core and urbanizing area.

The ground elevation of this narrow strip decreases sharply towards west and south direction and gradually turns into a flood plain and swampy lands/beels comprising flat and low-lying areas, criss-crossed by numerous tidal rivers and channels.

The drainage water is discharged into the Bhairab and the Rupsha River through BWDB sluices/ regulators lying on the embankment cum road. The drainage and flood protection works of this area are the responsibility of the LGED and BWDB and are covered by the STIFPP and BWDB Flood and Bank Protection Projects.

b. Strip on the Eastern Side of the Bhairab and Rupsha River (Left Bank)

These areas are drained through natural drains, borrow-pits and ground profiles sloping towards adjacent low-lying areas/ flood plain and ultimately into the outfall river / khals, viz., Bhairab, Rupsha, Atharbanki, Atai, Majudkhali, etc.

c. South and South-Eastern Area on the Left Bank of Rupsha, Kazibacha River

These areas are drained through numerous tidal creeks; low-lying areas/beels and flat land situated in the flood plain of the major rivers, which ultimately drained into the adjacent Rupsha, Kazibacha and Atharbanki rivers.

e. Western Part of the KCC Area Along Left Bank of Gallamari River and Khudir Khal

The western part of KCC between Daulatpur and Kazibacha River is drained by the upstream of Gallamari river or Khudir khal and downstream of Gallamari River and ultimately through a regulator (10 vent 1.50m x 1.80m) at Alutala which discharges into the Kazibacha and Rupsha river. A small part of the catchment area adjoining Khulna 'varsity area on the right side of the Gallamari river used to drain by two BWDB sluices, but now drains towards west and into the lower Sholmari river are hindring (polder no. 28/1, 28/2 of BWDB) due to occurrence of siltation problem in the Gallamari river and Khudir khal.

e. Northwestern Part of KCC and Structure Plan Area

This catchment may be subdivided into two areas, both of which are falling into the Khulna Jessore Drainage Rehabilitation Project comprising polder no. 25 (west), 25 (Beel Dakatia), 27/1, 27/2, 28/1 and 28/2, undertaken by the BWDB which have a lot of influence on the drainage activities in Khulna City.

- North and northwestern part of structure plan area between Daulatpur, Phultala and Avoynagar. The storm water run-off from these areas is discharged into the Dakatia Beel, Koyra Beel and Daira Beel (polder-25) through numerous khals comprising a complex system of khals and low-lying areas and ultimately the run-off is discharged into the upper Sholmari river through a 7-vent regulator at Salua which finally discharges into its outfall Kazibacha river.
- Middle and southwestern part of the structure areas are between upper and lower Sholmari river on the west side (left bank of Sholmari river) and Gallamari river/ Khudir khal on the east (right bank of Gollamari and Khudir Khal).
- The upper part of this catchment is lying in the polder 28/1, a small part of which adjacent to the upper Sholmari river is drained into this river through a number of BWDB sluices, but major part is drained through the main Joykhali khal which receives runoff through a complex network of khals in the basin and leads the run-off to the Ramada regulator (9-vent 1.8 x 2.1) which finally discharges into the lower Sholmari khal.

The Sholmari, Kazibacha, Rupsha, Bhairab, Majudkhali, Atharbanki rivers are all tidal rivers. Therefore, discharge of the sluices and regulators in the structural plan area will depend on favourable tides, otherwise, the drainage water could not be drained smoothly; consequently water-logging and drainage congestion will occur. Another important cause of drainage congestion is siltation problem in these rivers, which creates retention of runoff in the basin and decrease in drainage capacity of rivers. The Khulna-Jessore Drainage Rehabilitation Project upon completion will be able to eradicate this siltation and low capacity of the internal network of khals and rivers. Since most of the structural plan area is lying in the Khulna-Jessore Drainage Rehabilitation Project area, therefore, efficiency of the drainage system in the structural plan area will depend on successful implementation of the said project. In future drainage system of most of the structure plan areas will be westwards and towards the project area of Khulna-Jessore Drainage Rehabilitation Project.

5.4 Drainage Problem in Khulna City Corporation Area

The problems those come forward to the people of the city every day life and have to face for which the drainages or the systems are accounted for may be identified as the drainage problems. The drainage problems may be counted as - it creates obstacle to the easy movement particular for the children and women, it increases the transport cost, it spreads bad smells, pollutes the over all environment, it creates unhygienic condition for the inhabitants etc.

Inundation and water logging is the physical out come of the drainage problem and in some areas it is acute and exigent in low-lying areas mainly in rainy season. The inundated areas associated with serious drainage congestion in Khulna city areas are mentioned below:

- Natun Bazar
- Tutpara
- Bagmara
- Boyra
- Maheshwar pasha
- Rayer Mohal (Khan-A-Sabur Road).
- Nodal Point of Khan Jahan Ali road and KDA Avenue (Nearby and surrounding Royal Hotel)
- Rupsha
- East bania khamar
- Shipyard Areas
- Municipal Tank road
- Pabla Daulatpur area

The causes of drainage congestion is related with the causes of water logging in the city, in addition the congestion has aggravated more due to lack of maintenance of drains, siltation of drain bed ultimately reduces the effective depth of flow, obstraction of flow due to the hard materials inside the drain and over all encroachment of drainage paths by strictures and other installations from service providers.

To mitigate the drainage problem there should be an organized and planned drainage system in the KCC area as well as adjacent to the KCC area which it may improve drainage system. But there is no planned drainage system in KCC area. The drainage scheme may be extended and undertaken phase wise in an organized way along with the progress of urbanization. But this also depends on some factors, such as population growth, rate of urbanization, extent of flood damage in the area, affordability of KCC and viability of the project etc.

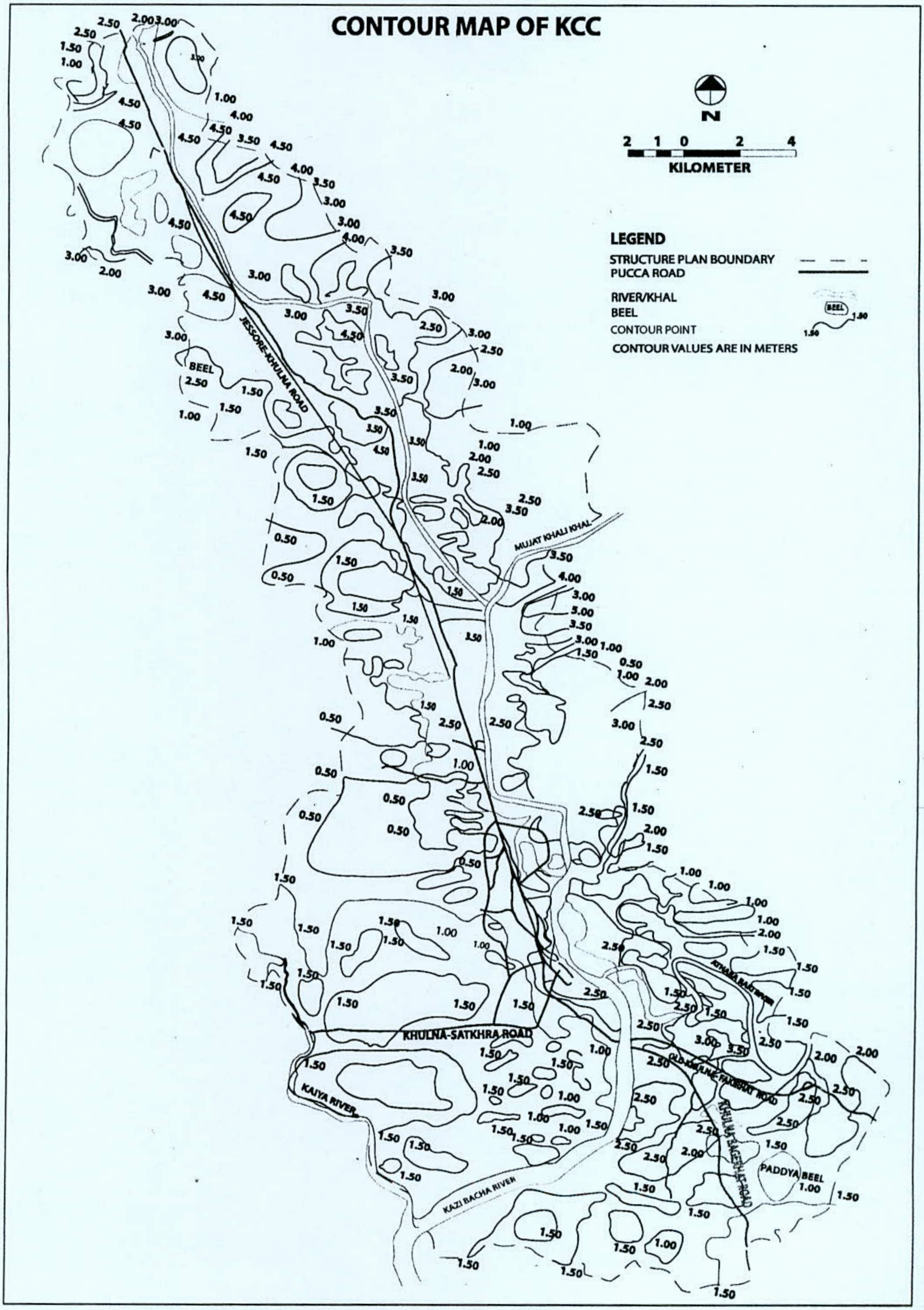


Figure-5.4 Contur Map of KCC

5.4.1 Causes of Drainage Problems

The main purposes of the drainage system is to carry out the wastewater as well as the storm water to it out fall either in river or canal or to a particular ditches so that it can not be accumulated for congestion in the town areas. But it happens and there are certain reasons behind it. The main reason is the insufficient of the drainage in Km/km^2 area - in addition there are some more reasons for these drainage problems as identified listed below:

The reasons for drainage problems have been identified as follows :

- Due to lack of proper cleaning and maintenance of existing drains,
- Due to blockage in the existing drains with hard materials,
- Due to absence of integrated network within the drainage system comprising primary, secondary and tertiary drains,
- Due to haphazard expansion of the regional settlements which obstructs the natural drainage system,
- Due to uncontrolled and haphazard disposal of solid waste into the drainage system,
- Due to siltation in the drainage channels with consequent reduction of discharge capacity.
- Due to unauthorized and improper encroachment of the drainage paths.

5.5 Adequacy Analysis of Drainage Sections in KCC Area

The types and classifications of drains in Khulna City Corporation areas were discussed in the previous sections. It has also been mentiond that major contribution in this sector has come from the project, STIFPP, implemented by LGED. The city corporation also undertakes some drainage schemes every year to maintain and rehabilitation from its annual development program. But LGED undertook the drainage schemes through STIFPP in a comprehensive engineering manner. It took three different types of drains such as Primary or Main drain, Secondary or Carrier drain and Tertiary drain. The wastewaters from the city are disposed of to the nearby rivers, canal and ditches through this drainage network. The drainage section is very much important as it is sufficient or not to carry out the wastewater and rainfall run off without overflowing the drain sides and making obstruction to people as well as thetraffic movements. An analysis was undertaken to check the adequacy of some drainage sections in the following paragraphs.

5.5.1 Rainfall in Khulna City Area

Rainfall and run-off data is essential prior to check the cross section of the drain of an area. During rainfall a certain portion of the rainwater is lost to the atmosphere and certain portion which infiltrates into the soil is lost to the ground water reservoir and certain portion find its way into the numerous small and large depressions. The remaining water flows overland towards the stream channel and is called the surface run-off. The urban storm design is primarily concerned with this surface run-off because the primary objective of the urban drainage system design is to drain out this storm water either through open surface drains or through under ground sewers. Rainfall occurs at irregular intervals and intensities, frequency and duration vary within a catchment. Due to this random nature of occurance of rain events, the drainage system is designed based on the past rainfall records. In Khulna city area, rainfall records from 1954 to 2001 have been procured from Meteriological Department, Khulna for this analysis.

Though the monthly rainfall record is available but it is not possible to get the required rainfall intensities from these data. So the maximum rainfall in the year for a day (24 hours duration) is divided by 2 and has been considered its intensity as mm/hr given in the Table 5.7. Three charts for the duration of 10 years (1992 to 2001), 20 years (1982 to 2001) and 30 years with maximum rainfall (1972 to 2001) along with the trend lines are prepared from these intensities shown in the Figure 5.5, Figure 5.6 and Figure 5.7 respectively. From the data of these three figures, 70% exceeding probabilities of each graph is estimated as 62 mm/hr, 70 mm/hr and 58 mm/hr respectively. Then the maximum value 70 mm/hr of these three from the Figure 5.5 from 20 years intensities seems most reasonable and has been considered as intensity of rainfall for checking the adequacy of drain sections.

Table 5.7 Maximum rainfall and its intensities in KCC area from 1954 to 2001.

Year	Rainfall in mm per 24 hrs	Duration of rainfall In 2 hours	Duration of rainfall In 4 hours	Duration of rainfall In 6 hours	Duration of rainfall In hours
		Intensity, mm/hr	Intensity, mm/hr	Intensity, mm/hr	Intensity, mm/hr
1954	117	58.50	29.25	19.50	14.63
1955	182	91.00	45.50	30.33	22.75
1956	211	105.50	52.75	35.17	26.38
1957	89	44.50	22.25	14.83	11.13
1958	78	39.00	19.50	13.00	9.75
1959	204	102.00	51.00	34.00	25.50
1960	116	58.00	29.00	19.33	14.50
1961	205	102.50	51.25	34.17	25.63
1962	254	127.00	63.50	42.33	31.75
1963	231	115.50	57.75	38.50	28.88
1964	153	76.50	38.25	25.50	19.13
1965	133	66.50	33.25	22.17	16.63
1966	79	39.50	19.75	13.17	9.88
1967	85	42.50	21.25	14.17	10.63
1969	107	53.50	26.75	17.83	13.38
1970	96	48.00	24.00	16.00	12.00
1971	107	53.50	26.75	17.83	13.38
1972	90	45.00	22.50	15.00	11.25
1973	127	63.50	31.75	21.17	15.88
1975	66	33.00	16.50	11.00	8.25
1976	116	58.00	29.00	19.33	14.50
1977	175	87.50	43.75	29.17	21.88

1978	125	62.50	31.25	20.83	15.63
1979	290	145.00	72.50	48.33	36.25
1980	106	53.00	26.50	17.67	13.25
1981	88	44.00	22.00	14.67	11.00
1982	185	92.50	46.25	30.83	23.13
1983	166	83.00	41.50	27.67	20.75
1984	197	98.50	49.25	32.83	24.63
1985	204	102.00	51.00	34.00	25.50
1986	140	70.00	35.00	23.33	17.50
1987	247	123.50	61.75	41.17	30.88
1988	152	76.00	38.00	25.33	19.00
1989	159	79.50	39.75	26.50	19.88
1990	161	80.50	40.25	26.83	20.13
1991	164	82.00	41.00	27.33	20.50
1992	220	110.00	55.00	36.67	27.50
1993	173	86.50	43.25	28.83	21.63
1994	86	43.00	21.50	14.33	10.75
1995	245	122.50	61.25	40.83	30.63
1996	149	74.50	37.25	24.83	18.63
1997	224	112.00	56.00	37.33	28.00
1998	108	54.00	27.00	18.00	13.50
1999	210	105.00	52.50	35.00	26.25
2000	95	47.50	23.75	15.83	11.88
2001	281	140.50	70.25	46.83	35.13

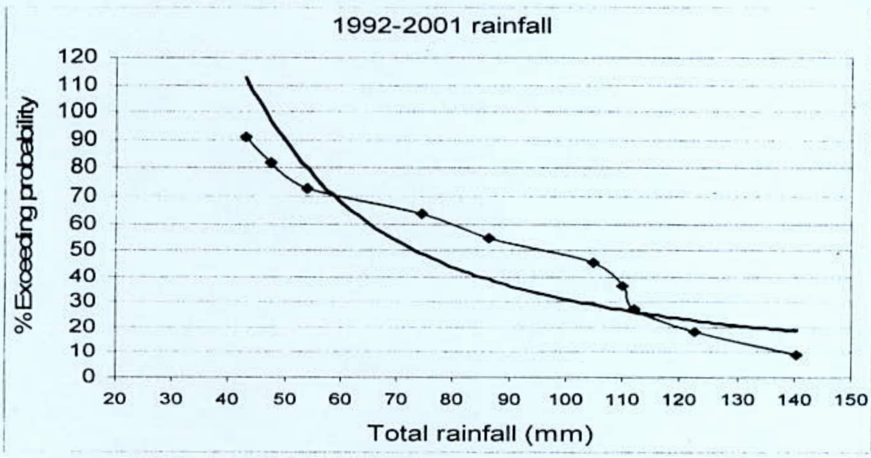


Figure 5.5 Inensity curve from 10 years rainfall data

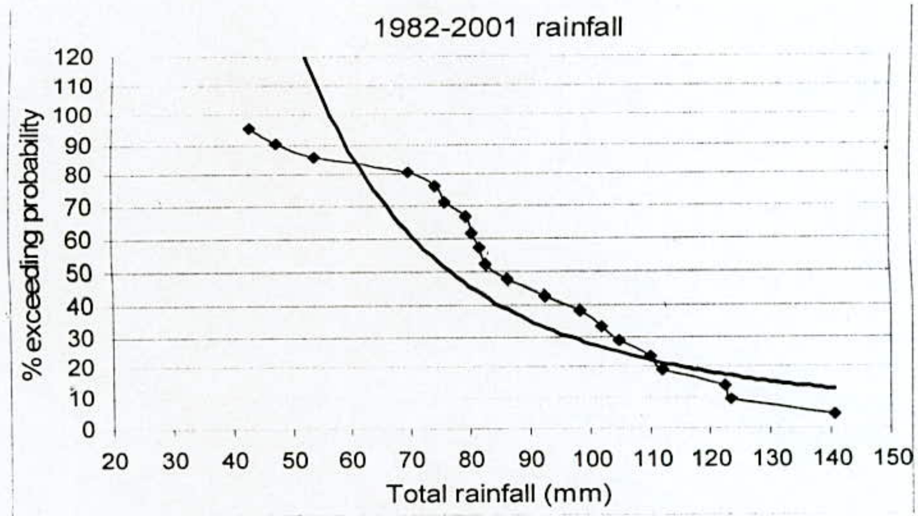


Figure 5.6 Inensity curve from 20 years rainfall data

5.5.2 Adequqcy of Cross Sections of KCC drains

In checking the adequacy of cross section of KCC drain, the comparison has been made between the discharging capacity as required from the hydrological consideration as derived from the rational formula and the discharging capacity of the existing drains. That is the comparison between two Q's as Q_1 from rational formula and Q_2 from velocity-cross sectional formula. To satisfy the adequacy of drain cross-section, the relationship should be $Q_2 > Q_1$.

The rational formula, $Q_1 = FCIA$ (Ahmed and Rahman, 2003)

Where, Q = Peak discharge in m^3/sec

F = A factor of proportionality = 0.278 when A in km^2 and I in mm/hr

C = Co-efficient of run-off which depends on the type of area and on soil condition

= 0.52 (Utilizing composite formula as resident area 50%, Asphalt 30% and lawns and other soil surface area 20%)

I = Rainfall intensity in mm/hr

A = Area of catchment, km^2

And

Area-Velocity formula, $Q_2 = AV$,

Where, Q = Peak discharge in m^3/sec

A = Cross-section of drain in m^2

V = Velocity in m/sec

$V = 1/n * R^{2/3} * S^{1/2}$ (Manning's equation) Here, n= 0.015 for concrete.

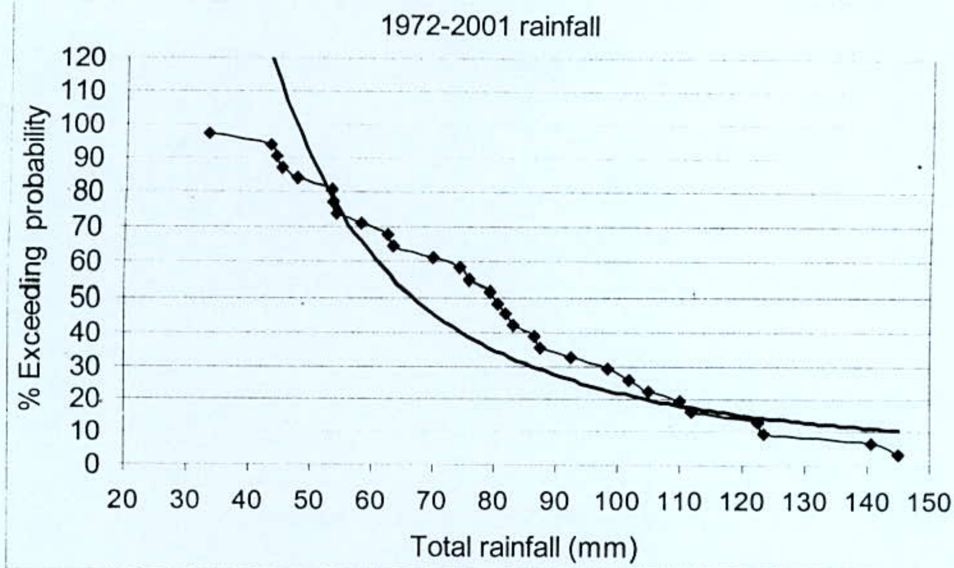


Figure 5.7 Inensity curve from 30 years rainfall data

It has been mentioned earlier that there are about 528.12 kms drains of different categories in KCC area. In checking the adequacy of the discharges capacity, the sections of the drains were taken from the scattered list of STIFPP, LGED and some drain's sections were measured in the fields. About 25 drains were selected randomly over the whole KCC area and the cross sections were checked and compared. It is found that the sections are sufficient with substantial factor of safety may be seen in the Table 5.8 below. In Khulna city the topography is sloped towards south and southwest and even some ares are depressed, the road sections are lowered there according to the topographical features, some secondary drains and tertiary drains passed through there have not been constructed according to the design slopes and maintained the normal natural gradient. Some of these places occurred water-logging and overflowed the roads even due to excessive rainfall. More over during the high tide in the nearby rivers the water inflows to the drains and some low areas become inundated. So if the excessive rainfall occurs during this high tide of the rivers the water can not be drained out properly to the rivers, then some tertiary and secondary drains are inundated at that time the drain sections seem insufficient. The entire main drains and most of the secondary drains except under this abnormal situation have the sufficient discharging capacities.

Table 5.8 List of drains those discharging capacities were checked.

Sl No.	Name of drain	Length of road (km)	Width of catchment (km)	Area A km^2	Q1=FCIA m3/sec	Width of drain (m)	Depth of drain (m)	(Hydra. radius)$^{2/3}$ $=R^{2/3}$	Area, A (m2)	Q_2 = A*1/n* $R^{2/3}S^{1/2}$	Adequacy $Q_2>Q_1$	Factor of safety
1	Dakbanglow to Natun bazar to Bhairab river	2.25	1.20	2.70	7.51	2.50	2.00	0.84	5.00	11.18	$Q_2>Q_1$	1.49
2	APC school to Ropsha ferry ghat	2.25	1.20	2.70	7.51	2.25	2.50	0.93	5.63	13.99	$Q_2>Q_1$	1.86
3	Shaheed Hadith park to Custom	2	1	2.00	5.61	2.20	2.20	0.81	4.84	9.26	$Q_2>Q_1$	1.65
4	Satmatha near Royal hotell to Bagmara khal via	2	1	2.00	5.61	2.20	2.00	0.79	4.40	9.32	$Q_2>Q_1$	1.66
5	Shib bari to Sonadanga Khal	1.5	1	1.50	4.20	2.20	1.80	0.77	3.95	8.13	$Q_2>Q_1$	1.94
6	Alamnagar Housing area to Charerhat ghat at	2	1	2.00	5.61	2.20	2.00	0.79	4.40	9.32	$Q_2>Q_1$	1.66
7	Khulna polytechnic to Charer hat to Bhairab river	2	1	2.00	5.61	2.20	2.00	0.79	4.40	9.32	$Q_2>Q_1$	1.66
8	Newsprint mill gate to Marwari ghat at Bhairab river	1.5	1.2	1.80	5.04	2.10	2.00	0.78	4.20	8.74	$Q_2>Q_1$	1.73
9	Khalishpur Govt. staff quarter to Patkerbazar to Mayur river	1.5	1.2	1.80	5.04	2.10	2.00	0.78	4.20	8.74	$Q_2>Q_1$	1.73
10	Baniakhamar more to Mayur river via Nirala R/A	1.5	1	1.50	4.20	1.80	1.80	0.71	3.24	6.74	$Q_2 > Q_1$	1.60
12	Daulatpur bus stand to bill pabla at Mayur river via Pabla	1.5	1	1.50	4.20	2.00	1.80	0.74	3.60	7.81	$Q_2 > Q_1$	1.86
13	PSC more to Bastohara colony at Mayur river	1.5	1.2	1.80	5.04	2.00	1.80	0.74	3.60	7.81	$Q_2>Q_1$	1.56
14	Chitrali cinema hall to Bermashill at Bhairab river	1.5	1	1.80	4.20	2.10	1.80	0.75	3.78	7.56	$Q_2>Q_1$	1.48

Run-off co-efficient, C=0.52, Rainfall intensity, I=70mm/hr, Roughness co-efficient, n= 0.015, Slope, S = 0.0016

Table 5.8 List of drains those discharging capacities were checked.

Sl No.	Name of drain	Length of road (km)	Width of catchment (km)	Area A km^2	Q_1=FCIA m3/sec	Width of drain (m)	Depth of drain (m)	(Hydra. radius)$^{2/3}$ $=R^{2/3}$	Area, A (m2)	$Q_2 = A*1/n*R^{2/3}S^{1/2}$	Adequacy $Q_2>Q_1$	Factor of safety
15	Sangita cinema hall to Nabinbagh via KDA cross	1.8	1	1.80	5.04	2.20	1.80	0.74	3.96	7.45	$Q_2>Q_1$	1.48
16	Ray para to baghmara khal via [illegible]	1.8	1	1.80	5.04	2.20	1.80	0.77	3.96	8.10	$Q_2>Q_1$	1.61
17	Power house more to Gallamari khal via moilapota	2	1	2.00	5.61	2.00	2.00	0.76	4.00	8.10	$Q_2>Q_1$	1.44
18	Mohsin School to Mayur river near the house of Siraj gazi	1.8	1	2.00	5.04	2.00	2.00	0.76	4.00	8.10	$Q_2>Q_1$	1.61
19	Maniktala food godown to Bill dacotia	2	1	2.00	5.61	2.00	2.00	0.76	4.00	8.10	$Q_2>Q_1$	1.44
20	Moheshwar pasha to Aronghata via maddyadanga	2	1	2.00	5.61	2.00	2.00	0.76	4.00	8.10	$Q_2>Q_1$	1.44
21	Darogerdighi to Kartikerpool at bill dacotia	2	1	2.00	5.61	2.00	2.00	0.76	3.60	8.10	$Q_2>Q_1$	1.44
22	Mailapota more to Gallamari khal at Bagmara	1.8	1	1.80	5.04	2.10	1.80	0.74	3.78	7.46	$Q_2>Q_1$	1.48
23	Sheikhpara to Sonadanga via gabarchaka	1.8	1	1.80	5.04	2.10	2.00	0.79	4.20	9.27	$Q_2>Q_1$	1.78
24	Choto Boyra to gallamari near Sonadanga	1.5	1.2	1.80	5.04	2.10	2.00	0.79	4.20	8.85	$Q_2>Q_1$	1.76
25	Dakbanglow to Bhairab river via barobazar	1.2	1	1.20	3.36	1.80	1.80	0.71	3.24	6.13	$Q_2>Q_1$	1.82

Run-off co-efficient, C=0.52, Rainfall intensity, I=70mm/hr, Roughness co-efficient, n= 0.015, Slope, S = 0.0016

5.6 Wastewater Quality Analysis

Khulna is the third largest city of the country of about 45.65 km^2, having about 0.9 million populations living here and a lot of people are visiting every day. There are 528.12 km drains here to dispose of accumulating wastewater from bath rooms, toilets and urinals, kitchen and hotels, clinics, diagnostics centers and hospitals, industries, rainwater etc. The wastewater contains several quality parameters harmful for the human health and over all environments when it crosses the tolerable limit as suggested by WHOGV and BDS. Here initiatives have been taken to investigate several parameters in different seasons to compare the limit with the standards. The drains are then numbered as per their outlets to facilitate the collection of samples and to investigate quality parameters. The drains as per their outlet locations in ward wise are shown in Table 5.9 and as per the seasonal flow conditions are shown in Table 5.10

Table 5.9 Wardwise outlet locations of Drains in KCC Area

Ward No.	Total Drain Length (m)	Main Outlet	Outlet Location
1	10144.70	-	-
2	8449.40	4	River (Bhairab)
3	15404.42	1	River (Bhairab)
4	8485.42	2	Khals
5	14390.35	-	-
6	17205.05	2	Khals
7	11125.63	1	River (Bhairab)
8	8106.78	-	-
9	18231.25	2	Lake/Pond
10	18381.00	-	-
11	10282.86	-	-
12	19254.69	-	-
13	7558.27	2	River (Bhairab)
14	28915.72	-	-
15	11509.64	3	River (Bhairab
16	22297.80	3	Khals
17	34529.19	2	Khals
18	12835.28	4	Khals
19	13263.61	-	-
20	19163.50	-	-
21	15040.13	9	River (Bhairab
22	18168.6	5	River (Bhairab
23	16068.60	-	-
24	36213.93	1	Khal
25	20139.51	-	-
26	16826.14	-	-
27	24220.44	2	Khals
28	17322.18	1	Khal
29	20452.08	-	-
30	21678.57	2	River-Rupsha
31	11195.98	3	River-Rupsha
Total	**528120.00**	49	

Table 5.10 Situation of outlets of drains in different seasons.

Sl No.	Location of Drainage Outlet	Situation of Drainage outlet in different season			
		Summer	Rainy	Winter	Spring
1	Cable Factory Ghat	√	√	√	√
2	I.D. Hospital Ghat	×	√	×	×
3	Shasan Ghat	×	√	√	×
4	Nagar Ghat	√	√	√	√
5	Jamuna Ghat	×	√	×	×
6	Hardbord Ghat	×	√	√	×
7	Charerhat Ghat	√	√	√	√
8	Khalishpur College Ghat	×	√	√	√
9	Port Road	×	√	×	×
10	6No. Ghat	×	√	√	√
11	BIWTA Steamer Ghat	√	√	√	√
12	Dab Ghat	×	√	√	×
13	Kalibari kheya Ghat	×	√	×	×
14	Panshi Ghat	√	√	√	√
15	Panshi Ghat	√	√	√	×
16	Hospital Ghat	×	√	√	√
17	Hospital Road Ghat	√	√	×	×
18	Jailkhana Ghat	×	√	√	×
19	Circuit HouseRd	×	√	×	×
20	1No.Custom Ghat	×	√	√	√
21	Rupsha Beribadh Road	√	√	√	√
22	N.Bazar Ap.Rd	×	√	×	×
23	Belayet Hossain Rd	×	√	√	√
24	Rupsha Feri Ghat	√	√	√	√
25	Rupsha Feri Ghat	√	√	√	×
26	Ispahany Match Factory	×	√	√	√
27	Labanchara	×	√	×	×
28	Mohammadia Para	√	√	√	√
29	South Labanchara	×	√	×	×
30	Hazi Ali Rd	×	√	√	√
31	Ziaur Rahaman Sarak	×	√	×	×
32	Graveyard	×	√	×	×
33	Nirala Residential Area	√	√	√	×
34	Gallamari	√	√	√	√
35	UPHCC (Arambag Road)	×	√	×	×
36	Hazi Tamizuddin Rd	×	√	×	×
37	G. Moktadir School Rd	×	√	√	√
38	Madrasa Road	×	√	×	×
39	Khulna Hospital (500 Bed)	√	√	√	√
40	Islamia College Road	×	√	√	×
41	Mollic Bari Road	×	√	×	×
42	Mirerghat Road	×	√	×	√
43	Mujgunni Main Road	√	√	√	√
44	Mujgunni Housing Main Rd	×	√	×	×
45	Karigarpara	√	√	√	√
46	L.G.E.D. Road	×	√	√	√
47	Deana Yatimkhana Rd	×	√	×	×
48	Deana Para Main Rd	×	√	×	×
49	Moheshwarpasha	√	√	√	√

√ means wastewater flow exist and × means no flow

5.6.1 Wastewater Sampling and Analysis

Wasterwater was sampled from the drain near the outlets in four seasons. The wastewater was collected in a clean plastic bottle one litre capacity and capped well. After sampling, these were labeled properly mentioning the location of the sample, collecting date and number. The sampling was done in the morning and the samples were tested in the laboratory on the same day. Wastewater was analysed for Color, SS, COD, Nitrate, Phosphate, pH, Alkalinity, DO, Cl^-, SO_4^{-2}, TDS, VS and FS. All the tests were done according to standard procedure (AWWA, 2004) and also as per HACH procedure.

5.6.2 Characterization of Wastewater

Wastewater samples were collected at most of the outlet stations of KCC drains in four seasons and tested in KUET laboratory. The summary of test results of some wastewater parameters are presented in the Table 5.11.

pH

The test result of pH for wastewater showed 12.5 to 10.2 in summer; 11.2 to 7.9 in rainy; 10.2 to 9.6 in winter and 10.1 to 6.9 in spring. The allowable limit of pH in wastewater dischare to surface or inland water bodies is from 6.0 t 9.0 according to ECR, 1997. It reveals from the tests that about 70% results are within the range of allowable limit but all the results in summer exceed the allowable range.

COD

The test result showed that COD presents in wastewater ranges from 1040 mg/L to 640 mg/L in summer; 560 mg/L to 350 mg/L in rainy; 820 mg/L to 530 mg/L in winter and 850 mg/L to 620 mg/L in spring. The maximum COD was found 1040 mg/L in summer and minimum 350 mg/L in rainy season. The allowable limit for COD in wastewater is 400 mg/L according to ECR, 1997. It reveals that though the minimum result is within the acceptable limit but most of the test results about 90% exceed the allowable limit in KCC drains.

Chlorides

It is revealed that the Chlorides present in wastewater vary from 910 mg/L to 505 mg/L in summer; 810 mg/L to 556 mg/L in rainy; 670 mg/L to 540 mg/L in winter and 740mg/L to 540 mg/L in spring. The maximum chloride is found 910 mg/L in summer and minimum 490 mg/L also in summer. The allowable limit of Chlorides in wastewater according to ECR, 1997 is 600 mg/L. It is also revealed that the lowest values in all seasons are within the allowable limit but about 60% results in all seasons exceed the highest limit.

Table 5.11 Summary of results of wastewater in KCC drains.

Season	Quality Parameters	Unit	Max	Min	Allowable limit to surface or inland water bodies
Summer	pH	-	12.5	10.2	6.0-9.0
	COD	mg/L	1040	620	400.00
	Chlorides (Cl^-)	mg/L	910.00	505.00	600.00
	Sulphides (as S)	μg/L	310.00	179.00	2.00
	NO_3 - N	mg/L	1.90	0.70	250.00
	PO_4-P	mg/L	7.14	5.80	35.00
	Suspended Solid	mg/L	3460.00	2750.00	100.00
	Dissolved Oxygen	mg/L	1.47	0.89	4.50-8.00
Rainy	pH	-	11.2	7.9	6.0-9.0
	COD	mg/L	560.00	350.00	400.00
	Chloride (Cl^-)	mg/L	810.00	556	600.00
	Sulphide (as S)	μg/L	315.00	175.00	2.00
	NO_3 - N	mg/L	3.30	0.74	250.00
	PO_4-P	mg/L	7.50	1.48	35.00
	Suspended Solid	mg/L	3650.00	2640.00	100.00
	Dissolved Oxygen	mg/L	1.50	0.70	4.50-8.00
Winter	pH	-	10.2	7.9	6.0-9.0
	COD	mg/L	820.00	530.00	400.00
	Chlorides (Cl^-)	mg/L	670.00	540.00	600.00
	Sulphide (as S)	μg/L	300.00	186.00	2.00
	NO_3 - N	mg/L	1.32	0.76	250.00
	PO_4-P	mg/L	8.30	5.00	35.00
	Suspended Solid	mg/L	3520.00	2756.00	100.00
	Dissolved Oxygen	mg/L	1.42	0.60	4.50-8.00
Spring	pH	-	10.1	6.9	6.0-9.0
	COD	mg/L	850.00	620.00	400.00
	Chlorides (Cl^-)	mg/L	740.00	540.00	600.00
	Sulphide (as S)	μg/L	450.00	230.00	2.00
	NO_3 - N	mg/L	1.10	0.80	250.00
	PO_4-P	mg/L	6.60	3.50	35.00
	Suspended Solid	mg/L	3410.00	2760.00	100.00
	Dissolved Oxygen	mg/L	1.20	0.75	4.50-8.00

Sulphide

The results showed that Sulphide present in drains in different seasons ranges from 310 μg/L to 179 μg/L in summer; 315 μg/L to 175 μg/L in rainy; 300 μg/L to 186 μg/L in winter and 450 μg/L to 230 μg/L in spring. The maximum value of sulphide is found 450 μg/L in spring and minimum 175 μg/L in rainy season. The allowable limit for sulphide in waste disposal is 2.00 μg/L according to ECR, 1997. It is revealed that Sulphides present in KCC drains in all seasons are excessive and all results are above the allowable limit.

Nitrogen-Nitrate (NO_3-N)

The NO_3-N presents in wastewater ranges from 1.9 mg/L to 0.70 mg/L in summer; 3.30 mg/L to 0.74 mg/L in rainy; 1.32 mg/L to 0.76 mg/L in winter and 1.10 mg/L to 0.80 mg/L in spring. The maximum NO_3-N is found 3.30 mg/L in rainy season and minimum 0.70 mg/L in summer. The allowable limit for NO_3-N in waste disposal is 250 mg/L according to ECR, 1997. It is revealed that all test results in all seasons are within the allowable limit.

Ortho-phosphate (PO_4 - P)

The test results prevail that Ortho-phosphate present in wastewater ranges from 7.14 mg/L to 5.80 mg/L in summer; 7.50 mg/L to 1.48 mg/L in rainy; 8.30 mg/L to 5.00 mg/L in winter and 6.60 mg/L to 3.50 mg/L in spring. The maximum Ortho-phosphate found 8.30 mg/L in winter and minimum 1.48 mg/L in rainy season. The allowable limit for Ortho-phosphate in waste disposal is 35 mg/L according to ECR, 1997. Hence all the results for Ortho-phosphate in wastewater in KCC drains are within the allowable limit.

Dissolved Oxygen (DO)

The test results for DO vary ranging from 1.47 mg/L to 0.89 mg/L in summer; 1.50 mg/L to 0.70 mg/L in rainy; 1.42 mg/L to 0.60 mg/L in winter and 1.20 mg/L to 0.75 mg/L in spring. The maximum DO was found 1.50 mg/L in rainy season and minimum 0.60 mg/L in winter. The allowable limit for Ortho-phosphate in waste disposal is 4.5 to 8.00 mg/L according to ECR, 1997. Hence all the results for Dissolved Oxygen in wastewater in KCC drains are within the allowable limit.

Suspended Solid (SS)

The amount of Suspended Solid (SS) presence as prevailed from tests are ranging from 3460 mg/L to 2750 mg/L in summer; 3420 mg/L to 2350 mg/L in rainy; 3520 mg/L to 2756 mg/L in winter and 3410 mg/L to 2760 mg/L in spring. The maximum Suspended Solid (SS) was found 3520 mg/L in winter and minimum 2350 mg/L in rainy season. The allowable limit for Suspended Solid in waste disposal is 100.00 mg/L according to ECR, 1997. Hence all the results for Suspended Solid in wastewater in KCC drains are far beyond the allowable limit.

The detail of the wastewater quality parameters is shown in the Appendix F.

5.6.3 Measurement of Wastewater Flow Rate

The float technique was used to measure the flow velocity in KCC drains. The effective depth and width of the drain is physically measured to calculate the cross section of the drain. The flow rate was estimated by-

Q = VA,

Where, Q = Flow rate in m^3/day

V = Velocity in m/day

A = Cross sectional area in m2 (D*W, D = Effective depth, W = Width of drain)

The flow rates were calculated on the basis of single observation for each season for each drain at outlet section in summer, rainy, winter and spring and are presented in the Figure 5.8, Figure 5.9, Figure 5.10 and Figure 5.11 respectively. There may be the more accurate flow rates if the observations were possible to make several times for each drain in a season. But was not possible due to constraint of time and other logistics.

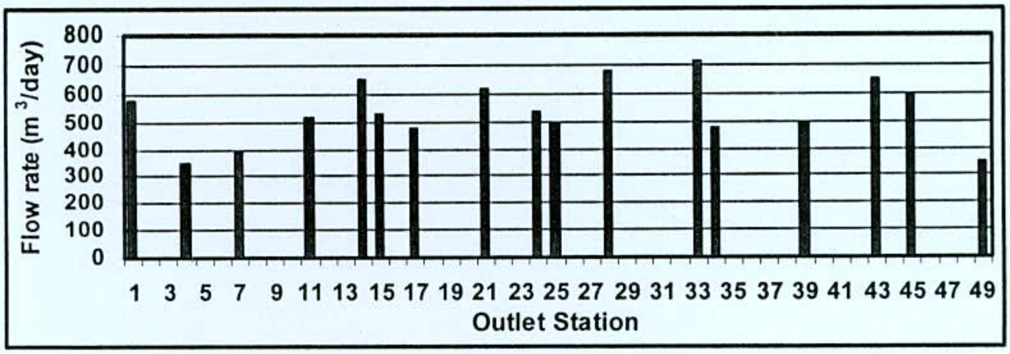


Figure 5.8 Wastewater flow rate in KCC drain outlets in Summer season

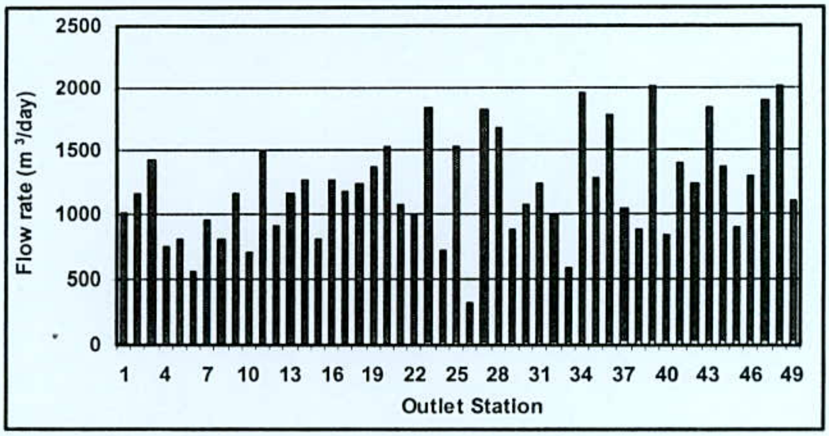


Figure 5.9 Wastewater flow rate in KCC drain outlets in rainy season

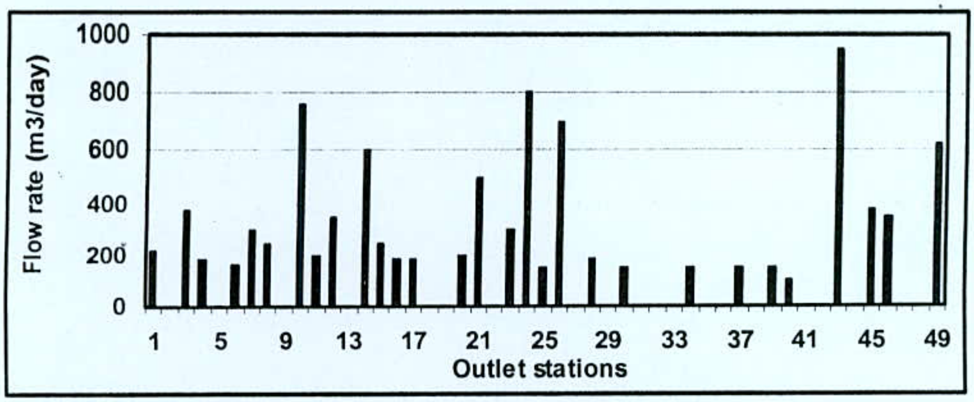


Figure 5.10 Wastewater flow rate in KCC drain outlets in winter season

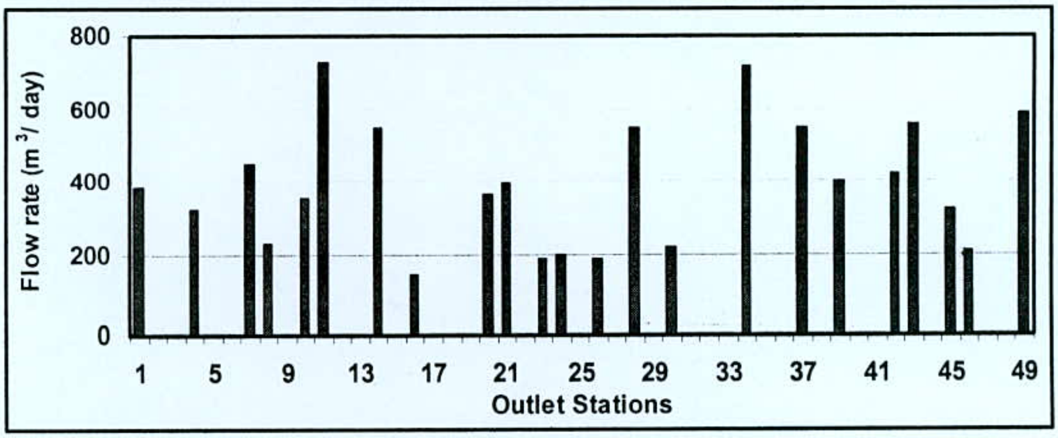


Figure 5.11 Wastewater flow rate in KCC drain outlets in spring season

5.7 Summary and Conclusion

Khulna is the third largest city of the country having population of about 0.9 millions with the area of about 45.65 km^2. The average population density is about 19700 in per square kilometer. There are about 528.12 kms drains of different types over the city. Among those 55.14% are pucca; 13.60% are semi-pucca and 31.26% are kutcha. Though the average drainage density of all types over the city is about 11.56 km/km^2 but the difference between one ward to another is substantially high. The maximum density is 33.88 km/km^2 in ward 23 whereas the density in ward 31 is only 3.06 km/km^2. It is revealed from one report that around 68% households of the city have no planned drainage facilities and only 32% have some sorts of facilities in and around their premises.

Khulna city is situated on the banks of two rivers the Bhairab and the Rupsha and the city is mainly stretched along these rivers in east west direction. Except these two banks sides the town is naturally sloped towards south and southwest direction. So the normal drainage flows occur toward these directions and most of the drains were constructed considering the slopes towards south and southwest direction. The sizes of the pucca drains constructed are adequate to drain out the rainfall and storm waters. But very few occasions in rainy seasons some low lying areas are found inundated and some secondary and tertiary drains are overflowed. But this is not fully accounted for the size of the drains. There are some other reasons as the areas are low and the roads are construcded maintaining the topographical features, due to blockage and improper encroachment of drainage paths, due to reduction of drainage depth and due to major lack of maintenance. More over, from the last few years it has been found that the water enters to the drains during the high tide of the rivers and inundated some low areas. So if the rain occurs during this high tide waters cannot drain out to the rivers and some drains in low areas are overflowed and these are also the major reasons for water logging of Khulna city.

There are about 49 major outlets of the drains and mainly in the river Bhairab, Rupsha, Mayur, Gallamari some canals and ditches. The flow through these drains is different in seasons and the waste loads are also varied substantially. The waste loading and the wastewater quality of some parameters were tested and comparisons have been made for different seasons. The flow rate is maximum in rainy season as 3062 m^3/day and all the drains are found active. But in other seasons as summer, winter and spring some drains are blocked and are inactive and the flow rate is very little.

In wastewater test, COD was found maximum in summer ranging from 530 mg/L to 1040 mg/L exceeding 400 mg/L allowable limit in all seasons. The nitrate was also found maximum in summer ranges from 0.70 mg/L to 1.90 mg/L less than the allowable limit 250 mg/L. The phosphate revealed maximum in winter ranging from 1.48 mg/L to 8.30 mg/L is far below the allowable limit 35 mg/L. Chlorides maximum in summer and ranges from 505 mg/L to 910 mg/L exceeding about 45% than the allowable limit 600 mg/L. Sulphide ranges from 175 mg/L to 450 mg/L exceeding far above the allowable limit 2 mg/L in all seasons. DO was found ranges from 0.60 mg/L to 1.50 mg/L in all seasons which are far behind the allowable limit 4.50 to 8.00 mg/L and suspended solids in all seasons ranges from 2640 mg/L to 3650 mg/L also exceeded the allowable limit 100 mg/L.

CHAPTER VI

SOCIAL ASSESSMENT

6.1 Introduction

A detail questionnaire survey was conducted to explore the people perception on water supply, drainage and others in KCC area. Questionnaires were distributed among different categories of people to analyze and assess the standard and level of certain services deserve the city dwellers such as potable drinking water, proper drainage system, drainage maintenance and over all healthy and hygienic environment. A three pages questionnaire was distributed among the households in 31 KCC wards on random basis in such a way that each questionnaire can represent a few number of households of that area may have the same nature of social status and facilities. In this context a total of 385 questionnaires were distributed that represents 9095 households which is about 7.71% of total households of the city. The format of questionnaire for the social assessment is presented in Annex-G. The social assessment survey was conducted during the period of study for this thesis and the responses from the questinnaire were analyzed and presented hereafter either in tabular or graphical format.

For the assessment of people's perceptions, the questionnaires were distributed among the respondents of two broad classes as resident area (RA) and slum area (SA) in 31 wards of KCC. The assessment is based on the analysis of information and data from questionnaires survey. The assessment is relied on qualitative rather than quantitative methods and attempts to include from a wide section of communities living in KCC area. The social survey was designed to cover the following:

- Personal profile of the respondents likes sex, education level and age etc.
- Information regarding drinking water sources and its quality, water use pattern performances of water related services etc.
- Drainages facilities, maintenance performances of drainages and other drainage related issues and
- General health and environmental issues

6.2 Characterization of Respondent

In order to assess the perceptions of the city people on the services of water supply and drainages and other related facilities, questionnaires were distributed among different categories of city dwellers such as different sexes, ages and educational level as follows.

6.2 .1 Different Sexes of Respondents

The survey was conducted through 385 questionnaires among those 229 were in resident area and 156 in slum area where 247 were male and 138 were female. In resident area among 229 respondents 137 were male and 92 were female and in slum area 92 were male and 46 were female. The male and female respondents were 247 and 138 in numbers those were 64.15 % and 35.85 % respectively is shown in Table 6.1.

Table 6.1 Male and Female Respondents in social survey

Number of respondents in Resident Area		Number of respondents in slum Area		Total	
Male Number (%)	Female Number (%)	Male Number (%)	Female Number (%)	Male Number (%)	Female Number (%)
137 (59.82 %)	92 (40.18 %)	110 (70.51 %)	46 (29.49 %)	247 (64.15 %)	138 (35.85 %)

6.2.2 Educational Level of Respondents

Education level is an important factor for a community development but to get the actual people perception for the social assessment people of different education level is required. In social assessment survey, questionnaires were distributed among the people having different level of education even within the illiterate persons. The Figure 6.1 below shows the percentages of people having different level of education. Among 385 respondents, there are 1% postgraduate, 9% graduate, 13% HSC level, 18% SSC level, 20% junior school level, 25% primary school level, 5% can put the signature only and 9% are illiterate.

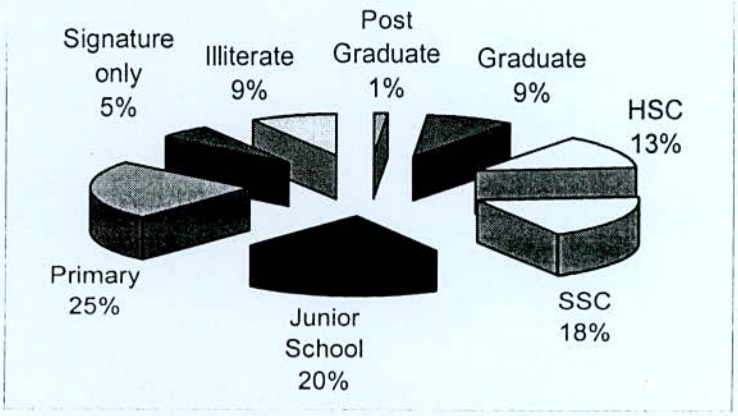


Figure 6.1 Educational level of the respondents

6.2.3 Age Level of Respondents

The questionnaires were designed in such a way that the fact might come out from the answers of the respondents, and hence to get it properly the respondents of different sections of city dwellers of various education background and the sexes were emphasized. Similarly the importances were also given to the peoples of different ages who might have the conception on society, have consciousness about the services of city administration etc. The total number of respondents was classified in six different age groups based on - such as from age below 20 years, 21-30 years, 31-40 years, 41-50 years, 51-60 years and 60 years above. The distribution of the respondents based on age groups is shown in the Figure 6.2.

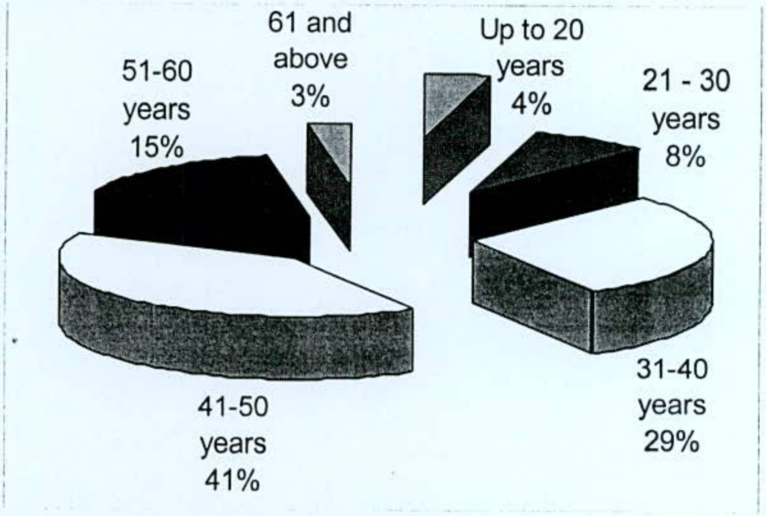


Figure 6.2 Distribution of respondents based on age group

6.3 Information Regarding Water Supply

It is revealed from the field survey that at present there is no water supply from KCC in ward number 1,2,3,4,5,6,7 and 8 though in some places there are the old pipelines and few years back there were the water supply. The remaining 23 wards have water supply from KCC but not everywhere through out the ward.

From the questionnaires analysis, it reveals that 29% to 100% of the respondents depend on KCC water supply. The individual respondent perceptions regarding dependency on KCC water supply varies from 20 % to 100% in context to the area in each ward in slum area. But the combine perception of respondents from both resident and slum area regarding water supply in the different wards is shown in the Figure 6.3

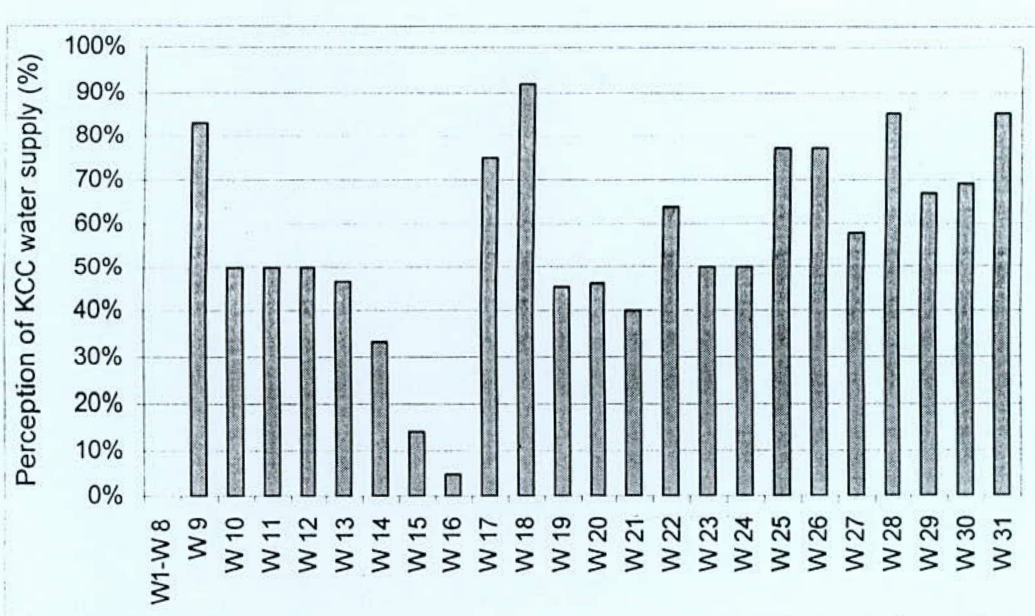


Figure 6.3 Perception of the respondants about KCC water supply in each ward

Figure 6.3 presnts the combine water supply scenario both for resident area and slum area. It reveals that the combine water supply in KCC as per respondants perceptions varies from 4.9% to 93.12% from ward to ward. The respondants perception is that on average 42% peoples are availing KCC water water supply facilities.

6.3.1 Sources of Drinking Water

It is revealed from the questionnaires survey that majority of the people use Tube Wells (TW) either shallow or deep as the souerce of drinking water (91.94%), very few percent of population drink river water (0.52%) and only 7.54% percentages of people use KCC supply as drinking purposes. There is no well in KCC area as per the respondents and none drink pond water. The people perception on drinking water source is shown in Table 6.2.

Table 6.2 Perception of respondents on sources of water for drinking

Sources of Drinking Water	Percentages of Population Drink
TW (STW, DTW)	91.94%
Rivers	0.52%
Ponds	0%
Wells	0%
KCC	7.54%

The peoples were asked whether the KCC supply water becomes red within 30 minutes or not and it is revealed that 79.31% of the respondants mentioned "No" and 20.69% mentioned "Yes".

Regarding the consumption of detergent or soap in washing, 34.82% respondents opined that huge detergent are required and 65.18% opined that consumption of detergent is not so high when using KCC supply water, 68.12 % respondents mentioned that that KCC supply water is saline in taste and 31.88% said it is sweet. Regarding the sufficiency of KCC supply, 58.62% opined that KCC supply is sufficient and 41.38% said that supply is insufficient. All these perceptions of the respondents on KCC water are shown in Table 6.3.

Table 6.3 Perceptions of the respondents on certain quaries on KCC water

Consumption of detergent or soap in KCC water is huge or not		Taste of KCC water for drinking is saline or sweet		KCC water supply is sufficient or not	
Yes	No	Saline	Sweet	Yes	No
34.82 %	65.18%	68.12 %	31.88 %	58.62 %	41.38 %

The perceptions of the respondants regarding the KCC water supply system, frequency of supply and availability of KCC supply water is presented in the Table 6.4.

Table 6.4 People's perceptions on supply system, frequency and availabilityof water supply

KCC water supply system			Frequency of supply			Supply is available		
Regular	Irregular	Intermittent	Whol e day	Once/ day	Twice/ day	Morning	Evening	Night
48.27%	50.23%	1.50%	0%	17.24 %	82.76 %	100%	72%	0%

6.3.2 Sources of Water for Other Purposes

It has been revealed from the survey that only 7.54% of city dwellers depends on KCC supply as their source of drinking water. For other domestic uses like washing, bathing and cooking peoples use KCC supply, Tube wells (STW and DTW), ponds and rivers and rainwater. The perceptions of the respondents regarding sources of water for these purposes are shown in Figure 6.4. The percentages of water of different sources as per multifarious use has been studied by Khulna University (Rahman and Murtaza,2002) has been cited here as a reference in this context in Table 6.5.

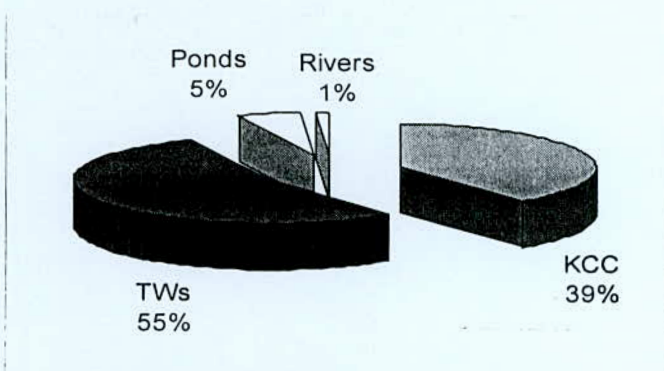


Figure 6.4 Perception of the respondants of sources of water for other domestic purposes

Table 6.5 Sources of water for other purposes in percentages (Rahman and Murtaza, 2002)

Nature of use of water	Percentages of different sources of water					Total Percentage
	KCC Piped water	Hand Tube Wells (DTW)	Hand Tube Wells (STW)	Pond	River	
Drinking	4.2	48.6	47.2	00	00	100
Cooking	32.9	21.6	40.5	4.6	0.50	100
Washing	39.5	17.7	37.4	10.7	0.70	100
Bathing	39.3	11.9	35.5	12.4	0.80	100

6.3.3 Distances of Water Sources

In the city the people had to carry water for drinking, washing, cooking and bathingr from TWs, ponds and rivers either in and around their premises or from outside.The distances of sources from where the people collect waters have been classified in six categories and are shown in in Figure 6.5.

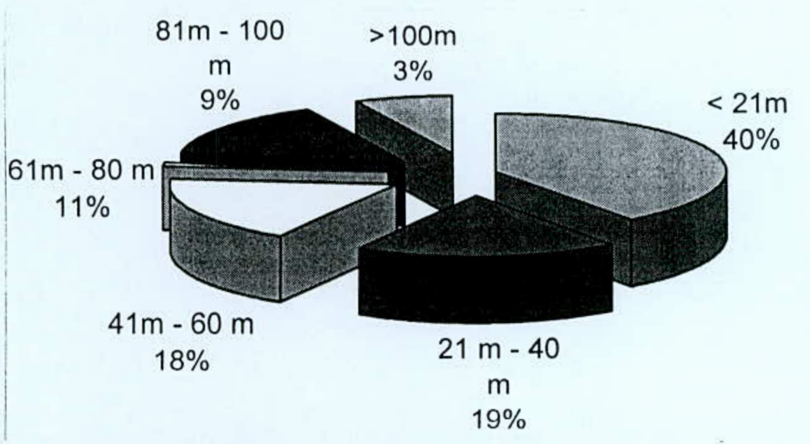


Figure 6.5 Distances of water sources to collect water

The people were asked on the quantity of supply from KCC whether the supply satisfies the demand of the city dwellers or not, the perceptions of the respondents are summarized in the Table 6.6. The majority of the respondants (51.73%)) mentioned that KCC water supply do not meet their demand.

Table 6.6 Perception on quantity of KCC water supply

KCC supply satisfy the demand	
Yes	No
48,27%	51.73%

6.4 Information Regarding the Drainage in Khulna City Area

Questionnaires were distributed among the city people of Khulna City area to assess and analyze the perceptions of the respondents regarding the drainage system in KCC area. The perceptions of the respondents on different issues of drains are illustrated below either in tabular or graphical forms.

6.4.1 Drain Types

There are mainly two types of drains pucca and kutcha. The pucca drains are lined and defined and some drains are with covered, the kutcha drains are not defined and and have no cover. The perception of the respondents on types of drains and the covers is summarized in Table 6.7

Table. 6.7 Perceptions regarding the types of drains and drain-covers.

Pucca drains	Kutcha drains	Pucca drains with cover	Pucca drains without cover
74.93%	25.07 %	7.95 %	92.05 %

6.4.2 Liquid Waste Generation from Households

The liquid waste is generated from the households and is ultimately dispose to the rivers. The respondent's perception on the approximate volume of waste generation per person per day from the household is presented in the Table 6.8. Majorty of the respondants (27.27%) mentioned to generate liquid waste of about 4.5 lpcd.

Table 6.8 Liquid waste generations from the households

Liquid generation from the households per person per day						
3.0 Litres	3.5 Litres	4.0 Litres	4.5 Litres	5.0 Litres	5.5 Litres	6.0 Litres
7.27%	20.00%	22.08%	27.27%	12.73%	5.95%	4.70%

6.4.3 Solid Waste Disposal Sites and Distances from the Settlements

There is no waste treatment plant in Khulna City area. The waste is generated from the houses and is first disposed of to the nearby dustbin or dumping places and then it is carried by KCC trucks for the final dispose of to the safe distances. The respondent's perceptions on the distances of the first disposal site are presented in the Table 6.9.

Table 6.9 Distances of waste disposal sites from settlements

Distances of disposal sites from settlements in metres				
Up to 15	16 – 20	21 – 25	26 - 30	31 and above
23.64%	35.58%	29.09%	9.87%	1.82%

6.4.4 Cleanning and Maintenance of Drains

The cleaning and maintenance performance of KCC drain is vey poor. The maintenance responsibility has been bestowed on the commissioner in their own ward. The perception of the respondents is that the laborers are engaged by the ward commissioners in their own area for maintaining the drain and they do other jobs as desired by commissioner. They opined that if the labourers are under the control of KCC administration there should be the better service. They also opined that the maintenance responsibility may be given to NGOs that may improve the performances of maintenance. All the respondents have strongly approach that city administration should take necessary measures in this regard to make and keep the drain as well as the whole environment clean, healthy and hygienic.

6.5 Information Regarding Health and Environment

6.5.1 Water-borne Disease

The respondants were asked about some water-borne diseases such as Cholera, Diarrhoea, Typhoid, and Dysentery etc whether they suffer from the diseases or not. The perception of the respondants is presented in the Table 6.10. The majority of the respondants opined that most of them suffer from Typhoid (38.31%), diarrhea (29.22%).

Table. 6.10 Perception of the respondent on the types of diseases from people suffered

Cholera	Diarrhoea	Typhod	Dysentery and others
9.74 %	29.22%	38.31%	22.73%

6.5.2 Occupational Health Issues

Respondent's perception on occupational health issues as came out from the survey is shown in the Table 6.11.

Table 6.11 Perception of respondents on occupational health issues

Working area			Living area		
Spaciuous	Congested	Suffocating	Spaciuous	Congested	Suffocating
37.66%	47.53%	14.81%	31.43%	44.93%	23.64%

6.5.3 Visible/Perceived Impacts on the Environment

Respondent's perception on the visible/perceived impacts on the environment on surface water, ground water or land etc has been furnished in the Table 6.12.

Table 6.12 Perception on visible/perceived impacts on environment

Impact on surface water impairment			Effect on ground water		Impact on land	
Domestic issue	Aquatic weeds	Recreation	Tw water	Others	Wastes of land	Conversion in to marshy land
79.18%	18.67%	2.15%	62.67%	37.33%	87.33%	12.67%

6.6 Conclusion

The City Corpoaration is supplying water only in 23 Wards bot not everywhere and in 8 wards from Ward 1 to Ward 8 there have no KCC water supply. The KCC supply is meeting only 7.54 % of drinking water demand in KCC area. The remaining demand of drinking water is met from the Tube Wells (91.94%) either deep or shallow and rivers (0.52%). The demand of waters for other purposes as bathing, washing and cooking are met from different sources of water such as 55% from TW, 39% from KCC, 5% from ponds and 1% from rivers. The people have to carry the water from TW outside their premises at an average distances about 50m as there is no TW everywhere close to their residences.The city people is not satisfied with the present KCC supply water in regard to the quantity and quality. The supply is not available full time to them even there is no assurance that the water will be available in a particular time. Naturally the people become interested to install more tube wells in the city to satisfy their demand.

There are different types of drains in KCC area as pucca and Kutcha, drains with covered and without cover. According to the people perception there are 84.93% drains are pucca and 15.07% drains are Kutcha and on the pucca drains 7.95% have cover and 92.05% have not. The ward commissioners look after the maintenance activities of drains in their respective ward engaging maintenance labourers,occasionally the labourers are found at site but the performance is very poor, the monitoring and supervision from the authority for cleanning is also insufficient. The overall maintenance situation is very miserable. So the wastes accumulate in the drains and the wastes are overflowed sometimes. This makes the environment unhealthy, inhygienic and polluting the environment.

The over all environments in Khulna City Corporation area are not rich. The perception of the respondents is very much negative in respect to the health services in city area. There are different types of diseases are found as Cholera, Diarrhoea, typhoid, dysentery and others,these diseases may break out due to the water and the pollution from the drains. Adequate supply of water and proper maintenance of drains are essential for a healthy environmental city.

CHAPTER VII

SUGGESTIONS AND GUIDELINES FOR SUSTAINABLE WATER SUPPLY IN KCC AREA

7.1 Introduction

Khulna is the third largest metropolitan city as well as one of the divisional headquarters of the country. Considering the importance of resources and geographical location it was established as Municipality in 1884 with an area of only 12 Km^2 and a very few thousands of population (NRPL, 2004). The urbanization was started from then and went one step ahead when the Khulna railway station was established in 1885. But Khulna received a fresh impetus to grow demographically after the partition of the then India creating Pakistan in 1947 as huge populations migrated from India and settled here. Again a new urbanization was started after the establishment of Khulna as divisional headquarter in 1960. A lot of offices, institutions, industries, commerce and trade centers etc were established here. Considering the importance as Municipality in divisional head quarter Khulna Municipality was upgraded as Khulna City Corporation in 1984 with the expansion of its area as well as the number of wards. Now, the area of Khulna City Corporation is about 45.65 Km^2 comprising of 31 wards with the population of about 0.80 millions.

The Khulna City Corporation as inherited from Khulna Municipality and the formal basis of KCC organization lies in the Khulna City Corporation Ordinance of 1984 (MSP, 2001). The City Corporations or Municipalities are basically the organizations to provide services to meet the basic needs of its dwellers. From the inception of the establishment as the corporation its field of activities has expanded a lot in accordance with the demand of the modern age of urbanization such as roads, drainages, solid waste management, water supply, sanitation and housing developments, etc. Supply of adequate water is one of the basic demands of the city dwellers to the city management. Proper appraising, planning, management capabilities and in time efficient implementation or execution etc are the preconditions for an efficient and good organization. The implementation of improvements and the establishment of a sustainable water supply system, its existing organization and suggestive modification etc are the fundamental concerns of this chapter of the thesis.

In different occasions the informal discussions were made with CE, XEN (Implementation), XEN (WWD), Water supervisor, Assistant water supervisor and others of KCC and information were collected. During discussion the limitations and over all pictures were known. But it was not discussed on the suggestions and recommendations made here.

7.2 Present Water Supply and Drainage Scenario in KCC Area

7.2.1 Water supply Scenario

Khulna City Corporation is responsible to provide water to the city populace for drinking and other purposes. But KCC has not yet able to cover all wards under its water supply network. At present, 23 wards are under it water supply network and 8 wards (ward-1 to ward-8) have not yet got the water supply access from City Corporation. Though the population of the city has increased and the area of it has been expanded, the water supply network has not been increased accordingly even recently the total supply has decreased substantially. Some wards where KCC was supplying water through its own networks in few years back, now those lines have been abandoned due to lack of due repair and maintenance and even some production wells those were active in a few years back are now out of order for the same. The water supply capacity of City Corporation has not been improved as per requirement and even reduced substantially.

All these necessary activities were not possible to address in time properly due to the limitation of both financial and human resources and lack of due evaluation of necessity from the authority concern. The important obligation lies with the fact that the city corporation authority some times becomes very much concern with the quantity of supply but not so much about the quality. The KCC should take proper measures for the quality also because quality is associated with the health risk of the users. The city corporation has no sufficient arrangement to routine checking of the quality of the supply water, has limitations for equipments and technical personnel.

At present KCC is providing about 26700 m^3 water per day to the city through it network, whereas the demand is about 71000m^3/day. It means KCC is supplying only 37.60% of the total demand of water of the people. There are huge gaps between the supply of water from KCC and demand of the people. At present, the supply and demand ratio is 1:2.60 and day by day the difference is increasing because the demand is increasing along with the increased population on the other hand the supply is decreasing. Other than KCC, water is abstracting by private and public tube wells, by institutional and industrial wells. These wells are contributing to meet the remaining 62.40% water demand of the city abstracting from ground water resource. Huge pressure is creating on groundwater resource due to the abstraction by all these wells. KCC should find out the alternative source to reduce the pressure on groundwater resource. Surface water may be the best alternative source and in this case possibility to install surface water treatment plant may be investigated.

The water quality investigation was conducted for the KCC supply water sampling from 23 wards only in three seasons. Most of the physical and chemical water quality parameters are acceptable according to BDS and WHOGV with the minor seasonal variations. Bacteriological parameters reveals that the water is microbial contaminated, TC, TTC and E.coli are present in water substantially. To assess the health risk for these contaminants present in water, the Quantitative Health Risk Assessment (QHRA) model is used. This model has been recognized by WHO. It is observed that due to the presence of both TTC and E.coli, there is the huge disease burden to the users of KCC supply water.

Due to the presence of TTC in KCC water, the lower and upper value of viral burden are 2.033 μDPY ($2.033*10^{-6}$ DALY) and 3.4 μDPY where the allowable limit is 1.70 μDPY; the lower and upper value for bacterial burden are 0.73 μDPY and 3.33 μDPY where the allowable limit is 0.40 μDPY and the lower and upper value for protozoa burden are -1.56 μDPY and 0.83 μDPY where the allowable limit is -1.90 μDPY.

Similarly, due to the presence of E.coli in KCC supply water, the lower and upper value of viral burden are 1.67 μDPY and 3.43μDPY where the allowable limit is 1.70 μDPY; the lower and upper value for bacterial burden are 0.33 μDPY and 2.20 μDPY where the allowable limit is 0.40 μDPY and the lower and upper value for protozoa burden are -1.93 μDPY and 0.47 μDPY where the allowable limit is -1.90 μDPY. It is concluded that high health risk is associated with KCC supply water due to presence of microbial contaminants-TTC and E.coli. To avoid the health risk and to supply adequate quantity of water, KCC should have long term Water Safety Plan and Surveillance activities to be undertaken immediately.

The responsibility for operation and maintenance of the KCC water supply system is vested on the Water Works Department. But the WWD has some limitations which reserves to be addressed but has not able to draw the attention of the City Corporation administration. A review of the present water supply and operation and maintenance (O and M) system within the Water Works Department (WWD) reveals the following main deficiencies(MSP, 2001):

- There is no organized O and M program for preventive maintenance (PM).
- Repair and breakdown maintenance work is not done in due time and some times the initiative is taken only after failure of an operational facility.
- No periodic maintenance work is carried out, normal WWD activities are currently limited to routine operation, making new house connections according to the demand of households and conducting some emergency repairs when breakdown occur.
- No 'as-build' plan of the existing transmission/distribution network is available.
- No routine leak detection surveillance is carried out.
- No skill human resources and equipments for routine checking the quality of water and no surveillance team to look after quality.

7.2.2 Drainage Scenario

The main purposes of the drainage system is to carry out the wastewater as well as the storm water and finally discharge to river or canal so that it can not be accumulated for congestion in the town areas. In KCC area, there are about 528.12 kms drains in the city, out of which 68.74% are pucca and 31.26% are kutcha. The average density of the drain in KCC area is about 11.56 kms/km^2. The major problem associated with the drain is that the drains are not maintenance regularly. The water logging and overflows through drains etc in the city area are the outcomes of the lack of maintenance of drains. The environment is becoming unhygienic and polluted due to this drains which are not cleaned and maintenance regularly.

To mitigate the drainage problem there should be an organized and planned drainage system in the KCC area that may improve drainage activities in the area as a whole. The drainage scheme may be extended and undertaken phase wise in an organized and planned way along with the progress of urbanization. But this also depends on some factors, such as population growth, rate of urbanization, extent of flood damage in the area, affordability of KCC etc.

To implement the recommendation properly cited above for the improvements and establishment of a sustainable water supply and drainage system the organization should also be restructured and rearranged as discussed below.

7.3 Existing Organization of Khulna City Corporation

The existing organization of Khulna City Corporation comprises of six departments operating under City Mayor. The departments are Secretariat, Accounts Department, Revenue Department, Public Works, Public Health and Water Works Department (WWD). The Water Works Department has a total human strength of about 161 persons, which comprises non-technical administrative staff and technical staff with supporting field personnel. An Executive Engineer (Mechanical), Water supply, is responsible officer for the Water Works Department and reports directly to the Chief Executive Officer (CEO) of the Corporation. The existing organization of Khulna City Corporation is shown in Figure 7.1.

The Secretariat Department has general administrative functions covering many multidisciplinary tasks and provides assistance to other departments. Public works are responsible for construction, reconstruction and day to day maintenances of all civil works except water supply; Public Health Department is responsible for health services, environmental, sanitation and conservancy activities through their personnel posted in ward levels, The Revenue Department is responsible for property assessment, tax assessment and tax collection while the Accounts Department carry out all types of general accounting.

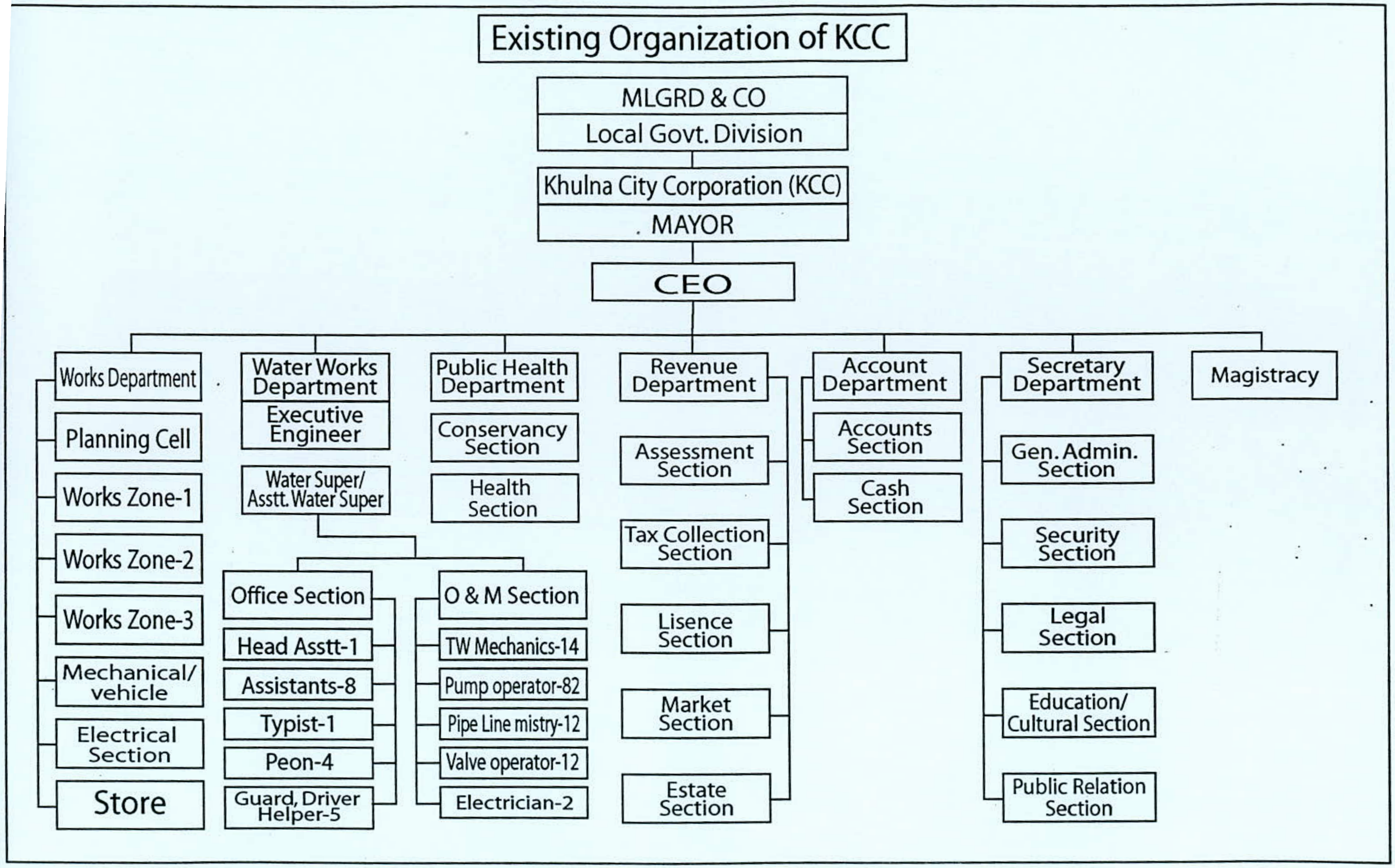


Figure 7.1 Existing organization of KCC

7.3.1 Suggestion for Restructuring the Organization

The existing organizational structure shown in Figure 7.1 is required to reorganize and restructure to provide due services to the city dwellers properly. Several options may be placed for considering restructuring the WWD as follows:

Option -1 : Strengthening the existing WWD as a semi autonomous water supply department
Option- 2 : Creating a new autonomous water authority (WA) for Khulna City Corporation
Option- 3 : Privatization of KCC water supply services.

Option- 1 : Strengthening of KCC Water Supply Department

This option mainly involves the strengthening of KCC Water Works Department to perform the related activities in time by its own set up as: Planning, Designing, Operation and Maintenance, quality control billing and collection of revenues. The modified organization of the KCC water Supply Department in this context is shown in Figure 7.2. The Water Works Department (WWD) is referred to as the Water Supply Department (WSD).

To implement this option as the line of establishing WSD, some actions from KCC to be under taken formally as:

(i) To improve the integration among administrative and technical functionaries within other departments of KCC itself.

(ii) To stimulate decentralization within City Corporation by transferring tasks and responsibilities together with the administrative and financial support and

(iii) To improve over all financial structure, administrative system, evaluation and formulate the annual budget, assessment and preparation of bills and revenue collection procedures.

Water Supply Department will establish a mechanism for routine quality checking of water, implement water safety plan and coordination among the different sections to take decision for immediate action, it will facilitate and expedite the tax collection without disrupting the existing operational staff, it will be in the line of the central Government decentralization policy. But it may take time to implement because support from line ministry will require and have the chances to be influenced by local politics among the existing sections.

Option- 2 : Creating a New Autonomous Water Authority (WA) for KCC

This would involve a transfer of water supply activities from KCC to a Water Authority (WA) with transfer of development tasks of planning, designing, construction, operation and maintenance (O and M). The typical organization of a new Water Authority, which would replace the existing Water Works Department, is shown in Figure 7.3 prepared in the light of Chittagong WASA.

The formalities to be met and action to be undertaken to implement the Water Authority (WA) in KCC as follows:

- To set up a Water Authority (WA) and transfer all water supply activities to them
- To reorganize the staff responsibilities and position

The Water Authority (WA) will act as semi-autonomous unit in KCC to facilitate the water supply activities according to the decentralize policy of government, it will facilitate and beneficial the experiences and organization plan of WASA and will ease the transfer and reorganize the responsibilities duties of personnel. But disruptions may occur to existing water supply operations and may take time to make coordination with other departments.

Option- 3 : Privatization of KCC Water Supply Services

Khulna City Corporation water supply system could be completely privatized in the manner like some other banks and industrial enterprises have been previously privatized in Bangladesh. Partial privatization may be exercised for customer services and billing may be enacted under options-1 and option-2 but there may be some problems to exercise the activities in a short span of time and require the motivation to the consumers as well as the office personnel.

A major benefit would be that administrative and managerial capabilities and efficiencies would increase resulting in improved service to the consumers. A major disadvantage would be that unless several water supply companies are established a monopoly may prevail in activities and services may deprive the consumers from due services. Without the stimulations of competition, a private water company may exert excessive control leading to increase costs for water supply and limited incentive to provide a satisfactory customer services. Thus the general public, particularly the poorer and illiterate under privileged communities may suffer getting in time services, payment of bills, in taking new connections etc.

7.3.2 Recommended options

The proposed three options are summarized and shown in the Table 7.1, it is also evaluated and compared with each other to recommend the best one to be easy for the KCC to implement a sustainable water supply system including quality assurance for drinking purposes. Privatization cannot be evaluated comprehensively for lack of detailed studies because the absence of examples and results of such types organizational activities.

Option-1 that is the strengthening of the existing WWD as a semi-autonomous water supply department and option-2 that is creating a new autonomous water authority (WA) for Khulna City Corporation is mere equally positive and recommendable. However, option-2, the creation of Water Authority (WA) for Khulna City Corporation area (like WASA in Khulna) is time consuming because it would need the approval from the highest level of government even need the parliamentary legislation.

Therefore, option-1, the strengthening of KCC Water Supply Department into a self-managed and self-supportive department by effecting the required reorganization (Administrative, Financial and Technical) is the best alternative for Khulna Water Supply.

Table 7.1 Comparison among different options for reorganization of KCC Organogram

Sl. No.	Options	Criteria				Overall results
		Decentralization	Integration	Consumers cervices	Disruption	
01	Strengthening KCC water supply department	Medium	Good	Good	Minor	Positive
02	Creation of Khulna Water Authority	Maximum	Good	Good	Substantial	Positive
03	Privatization of KCC water supply	High	Good	High	Major	Likely positive

7.3.3 Organizational Advantages

The recommended reorganization of KCC water supply has some organizational advantages as, the water supply department remains a part of the KCC but would operate as a separate entity on an economically viable, it would be more acceptable and beneficial to the consumers because it would be controlled through the elected authority but on an improved financial basis.KCC will be running its own water supply system supervised by the water supply committee and consumers will feel that they have full control of the service and it will be fully accountable to the consumers because their representatives, Water Supply Committee, would control it.

7.4 Conclusion and Recommendations

7.4.1 Conclusion

In regard to KCC water supply and related problems, the existing water supply system and the manpower associated in water works department in KCC were discussed elaborately. It is revealed from the discussion that KCC is providing water to the city people abstracting by the production wells. This important department is headed by an Executive Engineer (Mechanical) and works with the support of one water supervisor and one assistant supervisor as the technical staff. They are engaged mainly to provide the line connections, supervising the production of existing wells but have no so skilled technical personnel to identify the reasons and rectification of quantity of production, water level and very rare to look after the quality of water either in production wells, water tanks or in the consumers' houses and their tanks.

It is wise to modify the KCC organizational structure having the provision to investigate the resources, regular monitoring and supervision of the wells production capacity and regular basis to check the quality of the supplied water. A surveillance team to move around and intensive monitoring system to be developed to prepare a comprehensive report regularly on quality assurance and submit it to the water committee with recommendation for necessary actions. There should be a high level KCC Water Committee to sit on regular basis and take necessary measures on water on the basis of the investigation reports both in context of resources and quality. In regard to the water supply and drainages, a comprehensive package recommendation is provided here to take necessary actions from KCC authority.

7.4.2 Recommendations

The summary of this chapter is to improve the water supply and drainages facilities and to mitigate the problems and bottlenecks associated with these services, some recommendations are placed to afford KCC as tools to prepare a sustainable water safety plan and surveillance activities and to develop a mechanisms to construct and maintenance drains properly.

(i) There should be a technical team to investigate the ground water reserves in KCC area and to evaluate how long the abstraction from ground water resource can be continued and recommend for the necessary actions. The team should also investigate the possibility of surface water use for drinking purposes. There should also be a high level committee comprising with both technical and management personnel to evaluate the recommendation of technical team and take necessary measures for immediate action.

(ii) The KCC water supply network should divide at least three regions instead of supplying from a single network. The connections of the supply lines, reservoirs tanks and production wells should be rearranged according to the regions on the basis of populations. It will ease the detection of problems related to water supply and to take necessary measures to solve the problems. The supply of water to all other regions will not be hampered due to the problems of one region.

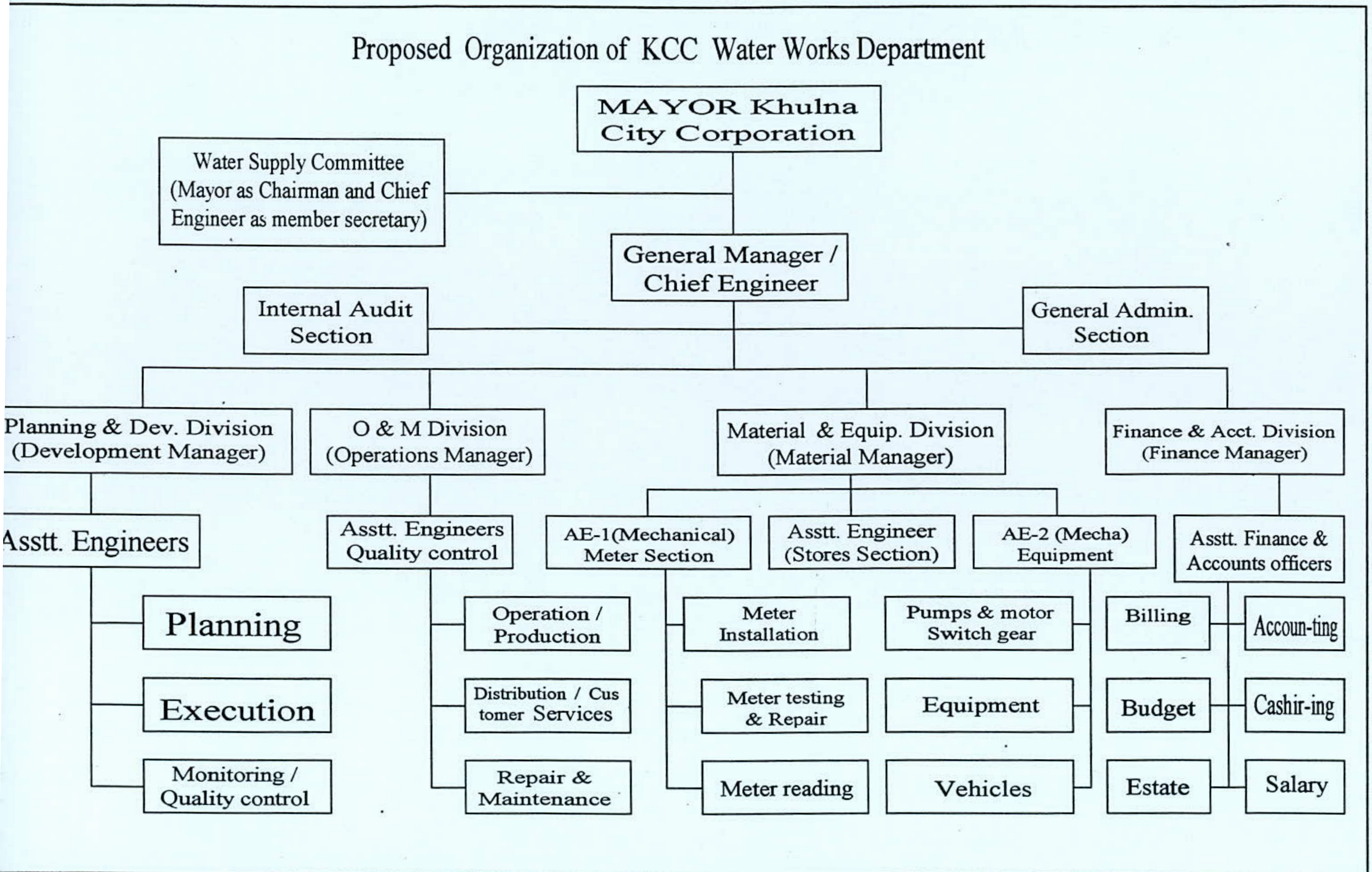
(iii) KCC should undertake a crash program either from their own fund or from the donors to install new pipe lines in the wards where there is no water supply, replace the old lines in other wards and install production wells as per the requirement of population on the basis of the three regions.

(iv) KCC should reorganize and restructure the water works department with sufficient staff, to form a surveillance team to investigate the physical quantity and quality parameters of waters, leak detection, investigate the discharging rate and yielding capacity of production wells.

(v) KCC should establish a laboratory with sufficient equipments, chemicals and other materials, technical skilled man power to investigate the quality of water, evaluate the risk assessment on health for the water quality parameters, particularly some important essential parameters such as TTC and E.coli etc those have the direct effect on human health.

(vi) KCC should have a sustainable plan in short and long term perspective to construct and rehabilitate the drains and to emphasize on routine cleaning and maintenance of existing drains. KCC should also look in to the possibilities to hand over the responsibility of drain maintenance activities to NGO or any other private organization.

(vii) The management of KCC should also address the importance and necessity of water supply in context of both quantity and quality, construction of drains and its proper maintenance in time and allocate the required funds accordingly.



igure 7.2 Proposed organization of KCC Water Works Department.

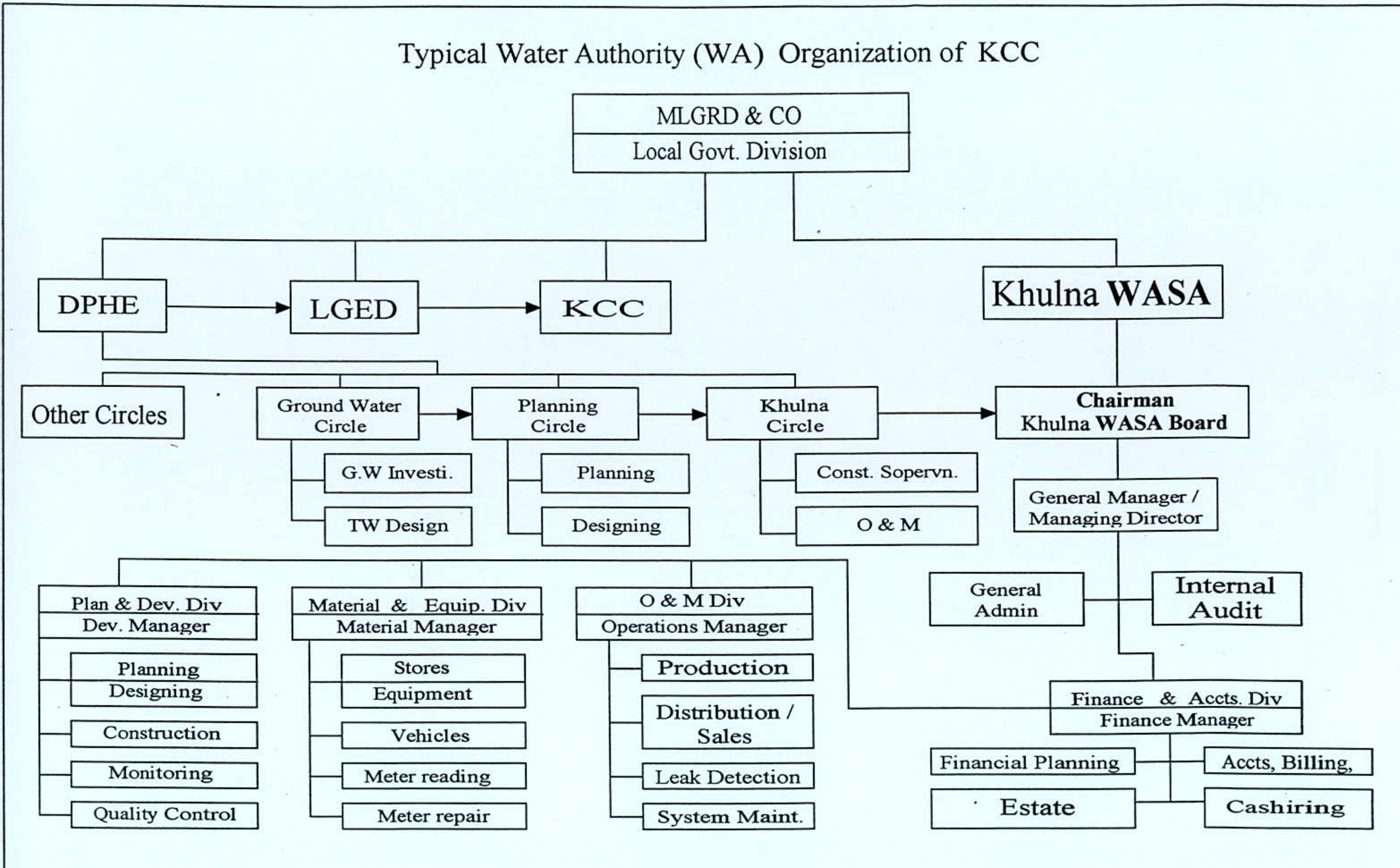


Figure 7.3 Typical Water Authority (WA) Organization of KCC

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

Khulna City Corporation was upgraded to its present status in 1984 inherited from the then Khulna Municipality established in 1884. The Municipality was established with a few areas of only 12 Km2 has now been extended to 45.65 Km2 having population of about 0.90 millions. Though 100 years had been passed after the establishment of Khulna Municipality and again 20 years have already been elapsed as City Corporation but no substantial development has achieved on certain areas as on water supply and drainage facilities. To find out the present status of these two important civic facilities and associated problems behind it the study has been undertaken as named "Study on Water Supply and Drainage Problem in Khulna City". Based on the study and from its findings the following conclusions and recommendations are made.

8.2 Conclusion

1. The water supply from Khulna City Corporation mainly depends on ground water sources. About 97% of supply waters are abstracting from ground water resources and only 3% is from surface water resoures.

2. KCC has water supply network in 23 wards out of 31 wards and there is no water supply in 8 wards (from ward 1 to ward 8). It means about 25 % populations of the city are not getting water supply from KCC.

3. At present KCC is supplying about 26700 m^3 water per day. The present demand of water in the city is 71000m^3/day. KCC water supply is only 37.60% against the total requirement. It means that there is the huge gap between the KCC water supply and demand of the city people and at present, the supply and demand ratio is 1:1.60 and day by day the gap is increasing.

4. It reveals that only 7.54% peoples are drinking KCC supply water as its quality is not suitable to the users for drinking and remaining 92.46% people meet their drinking water demand from other sources mainly from Tube Wells water.KCC

supply water is mainly used for bathing, washing, cooking and recreational purposes.

5. Tube Wells both shallow and deep, the major sources of drinking water to the city peoples, were installed by users privately in their premises, by KCC and by the Directorate of Public Health Engineering (DPHE). People are still installing tube wells privately mean the dependency of city people on ground water is increasing rapidly.

6. Water Works Department (WWD) of KCC is responsible for water supply and to look after the related problems has no sufficient staff to monitor and organize the total water supply properly through out the whole area of KCC. There is no skilled man power to monitor the discharging rate and yielding capacity of production wells regularly and intensively.

7. Khulna City Corporation has no skilled technical staff to monitor and look after the quality of water and to make necessary suggestions with recommendations for further action from authority. KCC has no testing laboratory, necessary equipments and tools, chemicals and other materials required to investigate the essential water quality parameters of supply water.

8. There has no sufficient drainage facility in KCC area, only 38% people are availing some sorts of drainage facilities. There are 528.12 kms drains in the city out of which 68.74% are pucca and 31.26% are kutcha and most of the drains are uncovered. The average drainage density in the city is about 11.56 km/km^2 which is insufficient and even the density of drains from ward to ward varies widely from 3.06 km/km^2 to 33.88 km/km^2.

9. The cleaning and maintenance of drains by KCC is very poor and unsatisfactory. KCC is responsible to look after these maintenance activities through the respective ward commissioners but the task is not performing properly either from any end. Due to the siltation in drains which ultimately reduces the efeective depth and blockages come out from the lack of maintenance sometimes overflows the wastes polluting the environment also enhancing the water logging in the city.

10. Khulna City Corporation management does not pay attention and addresses properly these two important sectors of water supply and drainages in funding to execute the necessary works in time. The management of Khulna City Corporation should also give priority to these sectors in fund allocation.

8.3 Recommendations for Future studies

1. The authentic and sufficient data on groundwater reserves in the City Corporation area is not available, it is recommended to undertake a detail groundwater modelling study to investigate the availability of groundwater and its quality in and around Khulna City.

2. Details surface water modelling study on the rivers Bhairab and Rupsha is roccommended to investigate the sustainable use of surface water including the quality due to the influence of industrial wastes and salinity from sea.

3. Details quality investigations on all the quality parameters of water of KCC production wells and of the consumers' pipelines and taps in all months round the year, particularly the bacteriological parameters to assess the health risk to the users due to microbial contaminants.

RFERENCES

1. Ahmed, M.F.; and Rahman, M.M.; 2003; "Water Supply & Sanitation: Rural and Low Income Urban Communities. ITN-Bangladesh, Center for Water Supply and Waste Management, BUET, 2nd Edition, June 2003.

2. AQUA-SHELTECH CONSORTIUM, 2002; Structure plan, Master plan and detailled Area plan for Khulna City; Khulna Development Authority, Ministry of Housing and Public Works; Draft final report, Volume III, March 2002.

3. Assessing Microbial Safety of Drinking Water - Improving Approaches and Methods, 2004; a report published on behalf of the World Health Organization (WHO) and the Organization of Economic Co-operation and Development (OECD) by International Water Association.

4. BRGM., Local Government Engineering Department, 2005; Groundwater Resources & Hydro-Geological Investigations In And Around Khulna City; Municipal Services Project; Local Government Division, Final report, Volume-7, Annex VIII, Groundwater Modelling.

5. Environmental Conservation Rules, 1997; Schedule-9, Standard for Sewerage discharges on inland water bodies and surface waters.

6. Environmental Maps & Work book for Khulna City, Khulna University, USAID, 1999; prepared for USAID, Dhaka, Bangladesh, PP.175.

7. Farhat Consulting Engineers and Architects Ltd, 2004; Surface Water Treatment Plant of Khulna City by Procuring Surface Water from North of City Area; Final report, Volume-1, August, 2004.

8. Guidelines for Drinking-Water Quality, 2006; First Addendum to the Third Edition, Volume-1 Recommendations; WHO, Geneva, Switzerland.

9. Khulna City Corporation, Budget, 2006; Information on Water Supply, Roads, drains etc.

10. Mott.M McDonald Ltd, 1997; Final Feasibility Report on Khulna Water Supply Expansion Components, Local Gofernment Engineering Department; Main report, Volume –I.

11. MSP, 2001; Feasibility study on Water Supply and Groundwater Evaluation in Khulna City Corporation area.

12. M.F.Ahmed; G.Howard; D.Deere; S.G.mahmud; S.A.J.Shamsuddin;2006.; Quantitative Health Risk Assessment for arsenic and microbial contamination of drinking water. Arsenic Policy Support Unit, Ministry of Local Government, Rural Development and Cooperatives, Government of Bangladesh, February, 2006.

13. National Resource Planners Limited, 2004; Survey Map Preparation of Khulna City Corporation, Final report, March, 2004.

14. Risk Assessment of Arsenic Mitigation Option (RAAMO), 2005; ITN-Bangladesh, Center for Water Supply and Waste management, BUET, Dhaka, Bangladesh; Final report, September, 2005.

15. Rahman. A., Murtaza. G., 2003; Environmental Risk Management Action Plan for Khulna City, Bangladesh; under assistance from Regional Urban Development Office (RUDO) for South Asia and United States Agency for International Development (USAID), India and Bangladesh.

Appendix –A

Sources of Drinking Water Supply in 31 Wards in KCC Area (in percentage)

(Source: ERMA Plan for Khulna City by Dr. G Murtaza and Dr. M. A. Rahman, 2005)

Ward No.	Pipe Water	Deep Tubewell	Shallow Tubewell	Total Households
1	0.0	22.4	77.6	100
2	0.0	0.0	100.0	100
3	1.7	0.0	98.3	100
4	0.0	84.8	15.2	100
5	0.0	6.1	93.9	100
6	2.0	13.7	84.3	100
7	0.0	20.9	79.1	100
8	27.3	43.6	29.1	100
9	5.3	18.4	76.3	100
10	1.1	61.3	37.6	100
11	0.0	13.6	86.4	100
12	0.0	72.5	27.5	100
13	3.5	36.8	59.6	100
14	3.3	43.3	53.3	100
15	2.0	63.3	34.7	100
16	1.4	71.4	27.1	100
17	6.3	89.1	4.7	100
18	2.2	60.0	37.8	100
19	1.7	57.6	40.7	100
20	2.0	63.3	34.7	100
21	3.2	36.5	60.3	100
22	14.3	85.7	0.0	100
23	5.0	40.0	55.0	100
24	7.9	60.7	31.5	100
25	2.3	0.0	97.7	100
26	10.8	13.5	75.7	100
27	0.0	93.1	6.9	100
28	7.3	85.4	7.3	100
29	6.3	67.2	26.6	100
30	9.3	69.1	21.6	100
31	4.2	56.9	38.9	100
Total	4.2	48.6	47.2	100

Appendix –B

Sources of Cooking Water Supply in 31 Wards in KCC Area (in percentage)

(Source: ERMA Plan for Khulna City by Dr. G Murtaza and Dr. M. A. Rahman, 2005)

Ward No.	Pipe Water	Deep Tubewell	Shallow Tubewell	Pond	River	Total Households
1	9.0	16.4	44.8	23.9	6.0	100
2	0.0	0.0	100.0	0.0	0.0	100
3	3.4	0.0	74.1	22.4	0.0	100
4	0.0	63.6	15.2	21.2	0.0	100
5	3.0	4.5	92.4	0.0	0.0	100
6	9.8	9.8	66.7	13.7	0.0	100
7	2.3	23.3	74.4	0.0	0.0	100
8	61.8	20.0	18.2	0.0	0.0	100
9	25.0	10.5	60.5	3.9	0.0	100
10	45.2	21.5	33.3	0.0	0.0	100
11	27.3	6.8	65.9	0.0	0.0	100
12	53.8	31.3	13.8	1.3	0.0	100
13	26.3	35.1	38.6	0.0	0.0	100
14	38.3	10.0	46.7	5.0	0.0	100
15	14.3	30.6	55.1	0.0	0.0	100
16	48.6	35.7	11.4	1.4	2.9	100
17	56.3	32.8	6.3	4.7	0.0	100
18	42.2	26.7	31.1	0.0	0.0	100
19	54.2	8.5	37.3	0.0	0.0	100
20	34.7	10.2	55.1	0.0	0.0	100
21	36.5	12.7	50.8	0.0	0.0	100
22	71.4	25.7	2.9	0.0	0.0	100
23	45.0	7.5	47.5	0.0	0.0	100
24	67.4	18.0	14.6	0.0	0.0	100
25	4.5	0.0	65.9	29.5	0.0	100
26	35.1	24.3	40.5	0.0	0.0	100
27	32.8	43.1	19.0	5.2	0.0	100
28	24.4	31.7	43.9	0.0	0.0	100
29	53.1	29.7	12.5	4.7	0.0	100
30	26.8	24.7	46.4	2.1	0.0	100
31	11.1	47.2	30.6	11.1	0.0	100
Total	32.9	21.6	40.5	4.6	0.3	100

Appendix –C

Sources of Washing Water Supply in 31 Wards in KCC Area (in percentage)

(Source: ERMA Plan for Khulna City by Dr. G Murtaza and Dr. M. A. Rahman, 2005)

Ward No.	Pipe Water	Deep Tubewell	Shallow Tubewell	Pond	River	Total Households
1	7.5	10.4	34.3	40.3	7.5	100
2	0.0	0.0	100.0	0.0	0.0	100
3	1.7	0.0	79.3	19.0	0.0	100
4	3.0	12.1	3.0	81.8	0.0	100
5	4.5	1.5	89.4	4.5	0.0	100
6	11.8	5.9	72.5	9.8	0.0	100
7	0.0	20.9	79.1	0.0	0.0	100
8	70.9	10.9	16.4	0.0	1.8	100
9	31.6	2.6	53.9	11.8	0.0	100
10	60.2	7.5	32.3	0.0	0.0	100
11	36.4	4.5	59.1	0.0	0.0	100
12	67.5	17.5	12.5	2.5	0.0	100
13	35.1	35.1	29.8	0.0	0.0	100
14	30.0	20.0	36.7	13.3	0.0	100
15	18.4	20.4	49.0	12.2	0.0	100
16	57.1	18.6	7.1	14.3	2.9	100
17	70.3	17.2	9.4	3.1	0.0	100
18	64.4	6.7	17.8	11.1	0.0	100
19	59.3	3.4	35.6	1.7	0.0	100
20	40.8	6.1	53.1	0.0	0.0	100
21	36.5	11.1	46.0	3.2	3.2	100
22	74.3	22.9	0.0	0.0	2.9	100
23	65.0	7.5	27.5	0.0	0.0	100
24	85.4	2.2	9.0	2.2	1.1	100
25	2.3	0.0	72.7	25.0	0.0	100
26	32.4	29.7	37.8	0.0	0.0	100
27	53.4	25.9	20.7	0.0	0.0	100
28	31.7	12.2	48.8	7.3	0.0	100
29	65.6	14.1	14.1	6.3	0.0	100
30	25.8	11.3	52.6	10.3	0.0	100
31	12.5	11.1	15.3	59.7	1.4	100
Total	39.5	11.7	37.4	10.7	0.7	100

Appendix –D

Sources of Bathing Water Supply in 31 Wards in KCC Area (in percentage)

(Source: ERMA Plan for Khulna City by Dr. G Murtaza and Dr. M. A. Rahman, 2005)

Ward No.	Pipe Water	Deep Tubewell	Shallow Tubewell	Pond	River	Total Households
1	7.5	9.0	38.8	35.8	9.0	100
2	0.0	0.0	73.1	26.9	0.0	100
3	1.7	0.0	69.0	29.3	0.0	100
4	3.0	12.1	3.0	81.8	0.0	100
5	6.1	1.5	86.4	6.1	0.0	100
6	11.8	2.0	60.8	6.1	0.0	100
7	0.0	18.6	79.1	2.3	0.0	100
8	69.1	10.9	18.2	0.0	1.8	100
9	28.9	2.6	52.6	15.8	0.0	100
10	60.2	7.5	32.3	0.0	0.0	100
11	36.4	4.5	59.1	0.0	0.0	100
12	67.5	16.3	12.5	3.8	0.0	100
13	35.1	35.1	29.8	0.0	0.0	100
14	30.0	35.0	28.3	6.7	0.0	100
15	18.4	20.4	46.9	14.3	0.0	100
16	57.1	17.1	5.7	15.7	4.3	100
17	70.3	18.8	6.3	4.7	0.0	100
18	64.4	6.7	20.0	8.9	0.0	100
19	59.3	5.1	32.2	3.4	0.0	100
20	38.8	6.1	46.9	8.2	0.0	100
21	36.5	19.0	44.4	0.0	0.0	100
22	74.3	20.0	0.0	0.0	5.7	100
23	60.0	7.5	32.5	0.0	0.0	100
24	83.1	1.1	9.0	4.5	2.2	100
25	2.3	0.0	72.7	25.0	0.0	100
26	32.4	16.2	35.1	16.2	0.0	100
27	55.2	27.6	15.5	1.7	0.0	100
28	31.7	9.8	51.2	7.3	0.0	100
29	68.8	9.4	18.8	3.1	0.0	100
30	26.8	14.4	49.5	9.3	0.0	100
31	11.1	13.9	13.9	59.7	1.4	100
Total	39.3	11.9	35.5	12.4	0.8	100

Appendix –E (Source: BRGM/LGED, 2005)

Groundwater Abstraction by KCC wells from period 1984 – 2004

Sl.	TW description	1984	1985 (m)	1986 (m)	1987	1988 (m)	1989	1990 (m)	1991	1992	1993	1994	1995 (m)	1996 (m)	1997 (m)	1998	1999	2000	2001	2002	2003
1	Khalishpur-1	0	603	1205	1808	904	0	439	877	1316	1498	1078	809	539	269	0	719	686	685	686	686
2	Khalishpur-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Khalishpur-3	1056	1096	1136	1176	588	0	92	185	277	126	322	242	161	80	0	0	0	0	0	0
4	Khalishpur-4	408	272	136	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Bhuterbari	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Sheikh para-1	216	144	72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Ferry Ghate-1	564	429	295	160	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	K.D.A	1020	829	639	448	399	350	395	440	484	630	308	231	154	77	0	0	0	0	0	0
9	R.A.F. Compound	492	494	495	497	248	0	48	96	145	0	0	0	0	0	0	0	0	0	0	0
10	Gollamary	1200	1593	1987	2380	2681	2982	2682	2381	2081	2254	2240	2160	2080	2000	1920	1933	1940	1940	1940	1940
11	Toothpara (Hospital)	516	540	564	588	518	448	333	217	102	742	392	294	196	98	0	0	0	0	0	0
12	Tarer Pukur-1	636	424	212	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Water works	540	388	236	84	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Goalkhali	996	897	799	700	581	462	308	154	0	0	0	0	0	0	0	0	0	0	0	0
15	Zoragate	1212	1032	852	672	462	252	212	172	132	96	756	567	378	189	0	0	0	0	0	0
16	Rupsa-1(DPHE)	564	376	188	0	0	0	245	490	736	1776	792	657	523	388	254	170	0	0	0	0
17	Boyra Girls College	1032	1103	1175	1246	833	420	590	760	931	1008	672	504	336	168	0	0	0	0	0	0
18	RHD Compound	0	511	1022	1533	1684	1834	1472	1110	748	1582	1036	877	719	560	401	402	221	197	220	99
19	Ajam Khan Comm. Collage	480	488	496	504	476	448	406	365	323	462	364	273	182	91	0	0	0	0	0	0
20	PTI More	0	397	793	1190	742	294	196	98	0	0	0	0	0	0	0	0	0	0	0	0
21	Shishu Park-1	1308	937	566	195	97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	Circuite House	1428	1433	1437	1442	1603	1764	1523	1282	1040	1484	1666	1504	1341	1179	1016	784	738	355	552	522
23	Ferry Ghate-2	960	982	1004	1026	1467	1908	1461	1014	566	1800	1800	1596	1393	1189	985	844	528	452	434	434
24	Baghmara	1368	1178	988	798	1267	1736	1558	1380	1201	546	868	758	648	538	429	417	382	99	0	0
25	Polli Mongol	876	906	936	966	896	826	788	749	711	924	588	571	554	537	520	0	279	165	165	165
26	Khalishpur Pourasova		555	1111	1666	1896	2125	1940	1756	1571	1764	1946	1535	1123	712	300	432	242	99	99	99
27	Taltala City College		47	93	140	280	420	384	348	312	406	350	263	175	87	0	0	0	0	0	0
28	Rupsa D.P.H.E Office		395	790	1185	1568	1950	1545	1140	736	638	418	314	209	104	0	0	0	0	0	0
29	Hadish Park		133	267	400	368	336	360	385	409	392	406	305	203	101	0	0	0	0	0	0
30	Khalishpur-5			910	1365	1638	1911	1643	1375	1108	336	1134	958	782	606	429	272	197	181	283	285
31	Islamadad				840	976	1112	1248	1384	1520	1680	616	462	308	154	0	0	0	0	0	0
32	S.K. Para Bazar				880	812	744	986	1229	1471	1296	996	927	857	788	719	656	213	114	84	84
33	Toothpara Weel Field					0	0	448	895	1343	1484	658	484	329	164	0	0	0	0	0	0
34	K.D.A Nirala-1					792	1584	1451	1319	1186	1260	1022	1003	985	966	947	710	712	622	638	556
35	K.D.A Nirala-2					0	0	297	594	891	560	740	555	370	185	0	0	0	0	0	0
36	K.D.A Nirala-3					816	1632	1398	1164	931	539	854	916	979	1041	1103	1046	674	528	377	545
37	Toothpara-2					876	1752	1515	1278	1040	1638	0	0	0	0	0	0	0	0	0	0
38	Toothpara-3					864	1728	1554	1379	1205	602	560	452	343	235	127	114	114	91	91	91
39	Muzgunni Well Field-1					918	1836	1746	1656	1566	1498	882	771	661	550	439	381	203	94	81	81
40	Muzgunni Well Field-2					912	1824	1746	1667	1589	1050	1736	1426	116	806	496	468	0	0	0	0
41	Muzgunni Well Filed –3					0	0	541	1082	1623	1456	1638	1370	1102	833	565	432	314	157	192	139

42	Shishu Park					774	1548	1193	839	484	742	1330	1071	812	554	295	170	127	99	0	0
43	Sonadanga					678	1356	1343	1329	1316	1400	1400	1304	1208	1112	1016	921	847	763	571	279
44	Arambagh					852	1704	1673	1643	1612	1260	1764	1653	1543	1432	1321	1340	1316	1032	944	869
45	Tarer Pukur					726	1452	1420	1388	1357	1400	1470	1352	1234	1116	998	520	334	574	302	416
46	M. T. Road												318	637	955	1274	1321	1167	904	607	556
47	Khalishpur 12 No Road												225	450	676	901	646	351	181	176	161
48	Khalishpur T.V Centre												181	362	543	725	550	301	584	171	144
49	Rupshan- 3												0	0	0	0	888	556	90	90	90
50	Nur Nagor												115	231	346	461	351	221	81	0	0
51	Zila School												211	422	633	844	496	369	301	278	255
52	Islamabad- 2												232	464	696	928	1249	1107	904	811	789
53	Purbo Bania Khamar												104	207	311	415	429	285	193	276	255
54	Ferry Ghate – 3												310	620	930	1240	1184	924	924	626	416
55	Khalishpur Durbar Club												93	186	280	373	170	171	79	786	786
56	Alia Madrasa												412	824	1236	1648	1467	1167	561	0	0
57	Hazi Abdul Malek												312	625	937	1249	1204	1134	1093	1012	890
58	Sonadanga – 2												342	683	1025	1367	1147	1084	639	1045	1450
59	Rayer Mohol												257	514	771	1028	683	686	1525	1136	545
60	S.K. Para Bazar- 3												182	364	545	727	710	411	181	81	81
61	Baghmara- 2												328	656	984	1312	1240	950	463	626	789
62	250 Hospital												198	396	594	792	866	970	712	917	1176
63	Boyra Community Centre												152	304	455	607	844	811	575	292	255
64	Rupsha Collegiate Girl's School												276	552	827	1103	888	599	503	474	445
65	Darul Ulum Madrasa													499	748	998	921	738	738	572	556
66	Khalishpur Scaout Bhaban													0	0	0	0	0	0	0	0
67	Nur Nagor Fire Briget													410	614	819	1114	624	351	278	255
68	Boyra Locost Colony													683	1025	1367	1199	931	90	90	0
69	Rupsea Cosal Khana													470	706	941	1081	1084	1064	810	754
70	Sonadanga Shishu Park													490	734	979	617	712	90	90	90
71	Musolman Para																656	0	575	57	0
72	DC ofice compound																		1049	972	904
73	Tootpara Taltala hospital																		987	871	802
74	Iqbal Road Chil. park/ Golakmani																		840	886	886
75	Khalishpur Jhil Pukur																		840	931	931
76	Charabati Boyra Main Road																		840	840	840
77	Mistry para																		840	840	840
78	Babu Khan Road																		840	840	840
79	Nirala Children Park																			840	840
80	Old Mosque Road																			840	840
81	Basupara Grave Yard																			840	840
	Year	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	Total Abstraction (m^3/day)	16872	18183	20403	23889	31314	38738	37180	35621	34063	36329	32802	32420	34590	35485	36379	34652	27419	27884	27659	26590

Appendix – F

Wastewater quality parameters in summer season

Sl No.	Location of out falls	Sampling Date	Flow rate (m^3/day)	Temp. (°C)	pH	Alkalinity as $caco_3$ (mg/L)	Chloride Cl^- (mg/L)	SO_4 (mg/L)	Sulphide (SO_2) (µg/L)	Nitrate (NO_3-N) (mg/L)	PO_4 _P (mg/L)
1	Cable Factory Ghat	07-05-06	572.5	34.5	11.9	740.00	505.00	11	229.00	.70	7.14
2	I.D. Hospital Ghat	09-05-06	-	-	-	-	-	-	-	-	-
3	Shasan Ghat	09-05-06	-	-	-	-	-	-	-	-	-
4	Nagar Ghat	09-05-06	-	-	-	-	-	-	-	-	-
5	Jamuna Ghat	09-05-06	-	-	-	-	-	-	-	-	-
6	Hardbord Ghat	09-05-06	-	-	-	-	-	-	-	-	-
7	Charerhat Ghat	09-05-06	-	-	-	-	-	-	-	-	-
8	Khalispur College Ghat	09-05-06	-	-	-	-	-	-	-	-	-
9	Port Road	09-05-06	-	-	-	-	-	-	-	-	-
10	6No. Ghat	13-05-06	-	-	-	-	-	-	-	-	-
11	BIWTA Steamer Ghat	14-05-06	531	37.6	9.75	667.00	750.00	9.5	245.00	1.50	5.85
12	Dab Ghat	14-05-06	-	-	-	-	-	-	-	-	-
13	Kalibari kheya Ghat	14-05-06	-	-	-	-	-	-	-	-	-
14	Panshi Ghat	14-05-06	577.40	35.1	10.00	786.00	665.00	7	215.00	0.80	6.90
15	Panshi Ghat	20-05-06	-	-	-	-	-	-	-	-	-
16	Hospital Ghat	20-05-06	-	-	-	-	-	-	-	-	-
17	Hospital Road Ghat	20-05-06	-	-	-	-	-	-	-	-	-
18	Jailkhana Ghat	20-05-06	-	-	-	-	-	-	-	-	-
19	Circuit HouseRd	20-05-06	-	-	-	-	-	-	-	-	-
20	1No.Custom Ghat	20-05-06	-	-	-	-	-	-	-	-	-
21	Rupsha Beribadh Road	20-05-06	587.52	36.5	11.1	798.00	900.00	8.2	300.00	1.70	6.57
22	N.Bazar Ap.Rd	28-05-06	-	-	-	-	-	-	-	-	-
23	Belayet Hossain Rd	28-05-06	-	-	-	-	-	-	-	-	-
24	Rupsha Feri Ghat	28-05-06	652.18	36.5	10.2	808.00	910.00	8.2	310.00	1.90	6.57
25	Rupsha Feri Ghat	28-05-06	-	-	-		-	-	-	-	-

26	Ispahany Macth Factory	28-05-06	-	-	-	-	-	-	-	-	-
27	Labanchara	28-05-06	-	-	-	-	-	-	-	-	-
28	Mohammadia Para	28-05-06	972.5	38.1	11.9	720.00	632.00	7.60	283.5	1.30	5.90
29	South Labanchara	30-05-06	-	-	-	-	-	-	-	-	-
30	Hazi Ali Rd	30-05-06	-	-	-	-	-	-	-	-	-
31	Ziaur Rahaman Sarak	30-05-06	-	-	-	-	-	-	-	-	-
32	Graveyard	30-05-06	-	-	-	-	-	-	-	-	-
33	Nirala Residential Area	30-05-06	-	-	-	-	-	-	-	-	-
34	Gallamari	30-05-06	678.4	35.6	10.2	730.00	530.00	8.10	305.00	1.10	6.24
35	UPHCC (Arambag Road)	30-05-06	-	-	-	-	-	-	-	-	-
36	Hazi Tamizuddin Rd	30-05-06	-	-	-	-	-	-	-	-	-
37	G. Moktadir School Rd	17-06-06	-	-	-	-	-	-	-	-	-
38	Madrasa Road	17-06-06	-	-	-	-	-	-	-	-	-
39	Khulna Hospital (500 Bed)	17-06-06	516.40	36.8	10.7	755.00	490.00	10.5	290.00	.90	6.90
40	Islamia College Road	17-06-06	-	-	-	-	-	-	-	-	-
41	Mollic Bari Road	17-06-06	-	-	-	-	-	-	-	-	-
42	Mirerghat Road	17-06-06	-	-	-	-	-	-	-	-	-
43	Mujgunni Main Road	17-06-06	635.9	37	10.2	800.00	825.00	10.00	179.00	1.20	5.80
44	Mujgunni Housing Main Rd	24-06-06	-	-	-	-	-	-	-	-	-
45	Karigarpara	24-06-06	-	-	-	-	-	-	-	-	-
46	L.G.E.D. Road	24-06-06	-	-	-	-	-	-	-	-	-
47	Deana Yatimkhana Rd	24-06-06	-	-	-	-	-	-	-	-	-
48	Deana Para Main Rd	24-06-06	-	-	-	-	-	-	-	-	-
49	Moheshwarpasha	24-06-06	2125.4	34.9	11.9	785.00	505.00	7.00	235.00	0.95	6.15

(Continuation of Appendix - F) Wastewater quality parameters in summer season

Sl No.	Location of out falls	Sampling Date	Flow rate (m^3/day)	Temp. (° C)	Color (pt-Co) unit	DO (mg/L)	COD (mg/L)	Suspended solid (mg/L)	Dissolved solid (mg/L)	Volatile solid (mg/L)	Fixed solid (mg/L)
1	Cable Factory Ghat	07-05-06	572.5	34.5	684.60	0.89	640.00	2760.00	1400.00	2120.00	360.00
2	I.D. Hospital Ghat	09-05-06	-	-	-	-	-	-		-	-
3	Shasan Ghat	09-05-06	-	-	-	-	-	-		-	-
4	Nagar Ghat	09-05-06	-	-	-	-	-	-		-	-
5	Jamuna Ghat	09-05-06	-	-	-	-	-	-		-	-
6	Hardbord Ghat	09-05-06	-	-	-	-	-	-		-	-
7	Charerhat Ghat	09-05-06	-	-	-	-	-	-		-	-
8	Khalishpur College Ghat	09-05-06	-	-	-	-	-	-		-	-
9	Port Road	09-05-06	-	-	-	-	-	-		-	-
10	6No. Ghat	13-05-06	-	-	-	-	-	-		-	-
11	BIWTA Steamer Ghat	14-05-06	531	37.6	604.00	1.02	720.00	3440.00	1800.00	2220.00	460.00
12	Dab Ghat	14-05-06	-	-	-	-	-	-		-	-
13	Kalibari kheya Ghat	14-05-06	-	-	-	-	-	-		-	-
14	Panshi Ghat	14-05-06	577.40	35.1	670.00	0.90	620.00	3260.00	1860.00	1980.00	380.00
15	Panshi Ghat	20-05-06	-	-	-	-	-	-		-	-
16	Hospital Ghat	20-05-06	-	-	-	-	-	-		-	-
17	Hospital Road Ghat	20-05-06	-	-	-	-	-	-		-	-
18	Jailkhana Ghat	20-05-06	-	-	-	-	-	-		-	-
19	Circuit HouseRd	20-05-06	-	-	-	-	-	-		-	-
20	1No.Custom Ghat	20-05-06	-	-	-	-	-	-		-	-
21	Rupsha Beribadh	20-05-06	587.52	36.5	624.60	1.10	700.00	2780.00	1440.00	2100.00	390.00
22	N.Bazar Ap.Rd	28-05-06	-	-	-	--	-	-		-	-
23	Belayet Hossain Rd	28-05-06	-	-	-	-	-	-		-	-
24	Rupsha Feri Ghat	28-05-06	652.18	36.5	18.3.00	1.00	910.00	3120.20	1650.0	2250.0	400.0
25	Rupsha Feri Ghat	28-05-06	-	-	-	-	-	-		-	-
26	Ispahany Macth Factory	28-05-06	-	-	-	-	-	-		-	-
27	Labanchara	28-05-06	-	-	-	-	-	-		-	-
28	Mohammadia Para	28-05-06	972.5	38.1	694.20	1.47	680.00	3420.00	1790.00	2020.00	390.00

29	South Labanchara	30-05-06	-	-	-	-	-	-		-	-
30	Hazi Ali Rd	30-05-06	-	-	-	-	-	-		-	-
31	Ziaur Rahaman Sarak	30-05-06	-	-	-	-	-	-		-	-
32	Graveyard	30-05-06	-	-	-	-	-	-		-	-
33	Nirala Residential Area	30-05-06	-	-	-	-	-	-		-	-
34	Gallamari	30-05-06	678.4	35.6	696.00	-	1040.00	3210.00	1850.0	2100.00	375.00
35	UPHCC (Arambag Road)	30-05-06	-	-	-	-	-	-		-	-
36	Hazi Tamizuddin Rd	30-05-06	-	-	-	-	-	-		-	-
37	G. Moktadir School Rd	17-06-06	-	-	-	-	-	-		-	-
38	Madrasa Road	17-06-06	-	-	-	-	-	-		-	-
39	Khulna Hospital (500 Bed)	17-06-06	516.52	36.8	580.00	0-.96	820.00	3280.00	1900.00	2150.00	396.00
40	Islamia College Road	17-06-06	-	-	-	-	-	-		-	-
41	Mollic Bari Road	17-06-06	-	-	-	-	-	-		-	-
42	Mirerghat Road	17-06-06	-	-	-	-	-	-		-	-
43	Mujgunni Main Road	17-06-06	635.9	37	640.00	1.10	690.00	3460.00	1700.00	2140.00	400.20
44	Mujgunni Housing Main Rd	24-06-06	-	-	-	-	-	-		-	-
45	Karigarpara	24-06-06	-	-	-	-	-	-		-	-
46	L.G.E.D. Road	24-06-06	-	-	-	-	-	-		-	-
47	Deana Yatimkhana Rd	24-06-06	-	-	-	-	-	-		-	-
48	Deana Para Main Rd	24-06-06	-	-	-	-	-	-		-	-
49	Moheshwarpasha	24-06-06	2125.4	34.9	620.00	0.92	650.00	3420.00	1920.00	2130.00	380.00

(Continuation of Appendix - F) Wastewater quality parameters in rainy season

SI No.	Location of out falls	Sampling Date	Flow rate (m^3/day)	Temp. (°C)	pH	Alkalinity as $caco_3$ (mg/L)	Chloride Cl^- (mg/L)	SO_4 (mg/L)	Sulphide (µg/L)	Nitrate (NO_3-N) (mg/L)	PO_4.P (mg/L)
1	Cable Factory Ghat	07-08-06	1020	31.7	9.2	730.0	680.0	9.3	230.0	1.9	7.5
2	I.D. Hospital Ghat	23-08-06	1160	33	8.7	685.0	655.0	7.8	215.0	.9	4.8
3	Shasan Ghat	23-08-06	1420	31.2	8.9	680.0	602.0	8.2	235.0	1.2	4.6
4	Nagar Ghat	23-08-06	750	30.9	9.1	705.0	556.0	8.2	230.0	.85	6.5
5	Jamuna Ghat	03-09-06	800	33	7.9	705.0	685.0	7.9	220.0	1.47	6.2
6	Hardbord Ghat	03-09-06	584	35.1	8.5	780.0	680.0	8.55	230.0	1.5	4.9
7	Charerhat Ghat	03-09-06	950	34	7.8	760.0	700.0	8.6	215.0	.9	5.2
8	Khalishpur College Ghat	03-09-06	800	33	7.7	655.0	630.0	7.9	215.0	.8	5.5
9	Port Road	03-09-06	1160	31.1	10.2	705.0	680.0	7.8	220.0	.95	6.8
10	.6No. Ghat	03-09-06	700	32.3	9.8	709.0	612.0	8.0	220.0	1.8	6.8
11	BIWTA Steamer Ghat	20-08-06	1470	31.1	9.2	670.0	590.0	8.4	245.0	2.5	3.48
12	Dab Ghat	07-09-06	900.5	32.9	9.7	685.0	585.0	8.1	238.0	2.1	3.88
13	Kalibari kheya Ghat	07-09-06	1150	31.7	8.8	720.0	601.0	8.2	230.0	1.9	4.60
14	Panshi Ghat	20-08-06	1270	34	10.1	740.0	560.0	6.5	210.0	1.5	5.9
15	Panshi Ghat	07-09-06	746	32	10.0	810.0	690.0	7.9	215.0	.75	6.18
16	Hospital Ghat	07-09-06	1250.5	32.5	10.2	795.0	655.0	7.4	212.0	1.2	6.6
17	Hospital Road Ghat	07-09-06	1160	31.3	9.6	720.0	705.0	7.6	260.0	1.1	7.2
18	Jailkhana Ghat	07-09-06	1220	31	9.2	689.0	675.0	8.0	235.0	.9	8.00
19	Circuit HouseRd	07-09-06	1350	32.8	8.9	670.0	598.0	8.1	248.0	.85	7.2
20	1No.Custom Ghat	07-09-06	1510	32.6	8.8	680.0	780.0	7.8	175.0	1.1	6.5
21	Rupsha Beribadh Road	20-09-06	1050	33	11.2	762.0	632.5	7.2	190.0	2.1	6.8
22	N.Bazar Ap.Rd	08-09-06	975	30.8	9.1	690.0	556.0	7.8	315.0	1.2	6.24
23	Belayet Hossain Rd	08-09-06	1820	30	9.3	720.0	685.0	7.6	298.0	.98	4.15
24	Rupsha Feri Ghat	08-09-06	700	33	10.2	750.0	705.0	7.4	278.0	.9	1.48
25	Rupsha Feri Ghat	08-09-06	1500	32.8	7.9	720.0	674.0	8.1	315.0	.95	6.85
26	Ispahany Macth Factory	08-09-06	1300	34.5	8.5	703.0	650.0	8.0	300.0	1.2	6.25
27	Labanchara	08-09-06	1790	30.9	8.9	699.0	701.0	7.9	285.0	1.1	3.89
28	Mohammadia Para	20-08-06	1650	31	9.5	668.0	560.0	7.8	220.0	0.9	6.45
29	South Labanchara	10-09-06	850	34.1	7.9	670.0	560.0	7.3	198.0	.85	6.95

30	Hazi Ali Rd	10-09-06	1050	34	7.8	720.0	685.0	7.9	230.0	.90	7.15
31	Ziaur Rahaman Sarak	10-09-06	1200	33	7.6	690.0	680.0	7.7	248.0	.90	7.2
32	Graveyard	10-09-06	950	33.7	8.9	685.0	580.0	7.7	290.0	1.1	3.9
33	Nirala Residential Area	10-09-06	550	32.1	8.5	698.0	810.0	7.6	280.0	1.0	4.59
34	Gallamari	12-09-06	1920	32.9	8.9	755.0	640.0	6.5	210.0	1.1	7.4
35	UPHCC (Arambag Road)	03-09-06	1250	33	9.2	705.0	700.0	6.9	290.0	1.3	7.5
36	Hazi Tamizuddin Rd	03-09-06	1750	32	9.6	715.0	650.0	7.1	215.0	1.4	6.78
37	G. Moktadir School Rd	03-09-06	1000	34	9.1	740.0	640.0	7.4	300.0	.9	7.5
38	Madrasa Road	03-09-06	850	33.7	7.9	810.0	680.0	8.0	325.0	.70	5.4
39	Khulna Hospital (500 Bed)	12-09-06	1970	32.2	9.9	805.0	550.0	10.0	235.0	4.1	6.8
40	Islamia College Road	03-09-06	800	32.9	8.9	805.0	598.0	8.9	260.0	3.0	5.8
41	Mollic Bari Road	09-09-06	1350	33	7.9	802.5	568.0	9.2	315.0	2.5	6.9
42	Mirerghat Road	09-09-06	1200	32	8.8	800.0	590.0	8.9	285.0	1.6	7.2
43	Mujgunni Main Road	20-09-06	1790	32.4	8.7	1020.0	632.0	7.8	215.0	3.3	1.9
44	Mujgunni Housing Main Rd	09-09-06	1320	31	8.9	980.0	680.0	8.8	240.0	3.2	2.8
45	Karigarpara	15-09-06	850	31.7	10.0	760.0	690.0	8.5	268.0	1.9	5.60
46	L.G.E.D. Road	15-09-06	1250	31.6	10.0	850.0	650.0	8.2	290.0	2.50	6.24
47	Deana Yatimkhana Rd	15-09-06	1850	30.8	9.8	805.0	655.0	7.8	300.0	2.15	5.4
48	Deana Para Main Rd	15-09-06	1960	32	8.9	810.0	678.0	7.2			
49	Moheshwarpasha	15-09-06	1050	32.1	8.6	705.0	590.0	6.5	198.0	0.8	0.7

(Continuation of Appendix - F) Wastewater quality parameters in rainy season

Sl No.	Location of out falls	Sampling Date	Flow rate (m^3/day)	Temp. (°C)	Color (pt-Co) unit	DO (mg/L)	COD (mg/L)	Suspended solid (mg/L)	Dissolved solid (mg/L)	Volatile solid (mg/L)	Fixed solid (mg/L)
1	Cable Factory Ghat	07-08-06	1382	31.7	584.0	1.20	450.0	2650.0	1320.0	2000.0	420.0
2	I.D. Hospital Ghat	23-08-06	1050	33	485.0	.90	540.0	2760.0	1110.0	2110.0	390.0
3	Shasan Ghat	23-08-06	1489	31.2	505.0	.85	580.0	2640.0	1400.0	1850.0	350.0
4	Nagar Ghat	23-08-06	935	30.9	485.0	1.10	450.0	2950.0	1450.0	1780.0	360.0
5	Jamuna Ghat	03-09-06	879	33	615.0	1.20	460.0	3210.0	1800.0	2120.0	450.0
6	Hardbord Ghat	03-09-06	584	35.1	580.0	.90	590.0	3400.0	1650.0	1950.0	430.0
7	Charerhat Ghat	03-09-06	987	34	560.0	.80	520.0	3290.0	1400.0	2000.0	400.0
8	Khalishpur College Ghat	03-09-06	825	33	400.0	1.1	490.0	2850.0	1400.0	2100.0	420.0
9	.Port Road	03-09-06	1745	31.1	385.0	1.3	420.0	2760.0	1350.0	2130.0	380.0
10	6No. Ghat	03-09-06	617	32.3	620.0	.80	530.0	2690.0	1360.0	1800.0	380.0
11	BIWTA Steamer Ghat	20-08-06	2011.2	31.1	480.0	.90	520.0	2680.0	1400.0	1780.0	400.0
12	Dab Ghat	07-09-06	834.5	32.9	550.0	1.10	490.0	3120.0	1450.0	2000.0	420.0
13	Kalibari kheya Ghat	07-09-06	1085	31.7	560.0	1.20	490.0	3210.0	1700.0	2230.0	450.0
14	Panshi Ghat	20-09-06	1165	34	505.0	.90	560.0	3210.0	1650.0	2310.0	480.0
15	Panshi Ghat	07-09-06	746	32	604.0	1.20	450.0	2950.0	1450.0	1980.0	490.0
16	Hospital Ghat	07-09-06	1190.5	32.5	600.0	1.40	430.0	2650.0	1350.0	1800.0	380.0
17	Hospital Road Ghat	07-09-06	1578	31.3	590.0	1.30	420.0	3240.0	1800.0	2180.0	500.0
18	Jailkhana Ghat	07-09-06	1755	31	580.0	1.10	400.0	3120.0	1440.0	2130.0	460.0
19	Circuit HouseRd	07-09-06	979.4	32.8	600.0	1.80	350.0	3020.0	1420.0	2050.0	380.0
20	1No.Custom Ghat	07-09-06	2257	32.6	580.0	1.60	350.0	2980.0	1380.0	1850.0	390.0
21	Rupsha Beribadh Road	20-08-06	1008	33	600.0	1.10	430.0	3250.0	1460.0	2310.0	450.0
22	N.Bazar Ap.Rd	08-09-06	977	30.8	540.0	.90	560.0	2850.0	1400.0	1980.0	430.0
23	Belayet Hossain Rd	08-09-06	3062	30	560.0	.90	550.0	2860.0	1450.0	2100.0	440.0
24	Rupsha Feri Ghat	08-09-06	2871	33	480.0	1.10	500.0	3250.0	1480.0	2310.0	460.0
25	Rupsha Feri Ghat	08-09-06	2012	32.8	490.0	1.10	490.0	2860.0	1400.0	1980.0	390.0
26	Ispahany Macth Factory	08-09-06	124	34.5	500.0	1.50	420.0	2750.0	1380.0	1490.0	350.0
27	Labanchara	08-09-06	2105	30.9	520.0	.95	560.0	2980.0	1400.0	1460.0	380.0
28	Mohammadia Para	20-08-06	1543	31	460.0	.85	530.0	3250.0	1800.0	2140.0	490.0

29	South Labanchara	10-09-06	746	34.1	550.0	1.10	480.0	2890.0	1500.0	1950.0	400.0
30	Hazi Ali Rd	10-09-06	1014	34	520.0	1.20	400.0	2875.0	1460.0	1890.0	460.0
31	Ziaur Rahaman Sarak	10-09-06	1875	33	460.0	1.50	390.0	2680.0	1350.0	1680.0	390.0
32	Graveyard	10-09-06	978	33.7	500.0	1.48	380.0	2780.0	1420.0	1980.0	400.0
33	Nirala Residential Area	10-09-06	467	32.1	480.0	1.45	420.0	2680.0	1360.0	1790.0	350.0
34	Gallamari	12-08-06	2387	32.9	380.0	1.1	390.0	3120.0	1500.0	2120.0	340.0
35	UPHCC (Arambag Road)	03-09-06	1284	33	450.0	.90	560.0	3210.0	1800.0	2250.0	500.0
36	Hazi Tamizuddin Rd	03-09-06	1978	32	480.0	1.20	450.0	2590.0	1420.0	1760.0	400.0
37	G. Moktadir School Rd	.03-09-06	974	34	550.0	1.4	400.0	3650.0	1900.0	2380.0	520.0
38	Madrasa Road	03-09-06	875	33.7	480.0	.70	560.0	2820.0	1420.0	2120.0	360.0
39	Khulna Hospital (500 bed)	12-08-06	3056	32.2	450.0	.80	520.0	2750.0	1350.0	2020.0	390.0
40	Islamia College Road	03-09-06	741	32.9	500.0	1.10	450.0	2680.0	1360.0	1980.0	320.0
41	Mollic Bari Road	09-09-06	1580	33	480.0	.90	520.0	3320.0	1800.0	2350.0	450.0
42	Mirerdanga ghat Road	09-09-06	1238	32	590.0	.80	530.0	3150.0	1750.00	2210.0	460.0
43	Mujgunni Main Road	20-08-06	2304	32.4	480.0	1.20	450.0	3210.0	1840.0	2340.0	420.0
44	Mujgunni Housing Main Rd	09-09-06	1785	31	520.0	1.10	460.0	3250.0	1680.0	2300.0	400.0
45	Karigarpara	15-09-06	709	31.7	520.0	1.20	390.0	3120.0	1560.0	2120.0	390.0
46	L.G.E.D. Road	15-09-06	1154	31.6	480.0	.90	560.0	2980.0	1450.0	1890.0	360.0
47	Deana Yatimkhana Rd	15-09-06	1983	30.8	460.0	1.20	450.0	2780.0	1460.0	2000.0	400.0
48	Deana Para Main Rd	15-09-06	2074	32	500.0	.95	460.0	2760.0	1700.0	1990.0	450.0
49	Moheshwarpasha	12-08-06	1537	32.1	550.0	1.10	460.0	2840.0	1650.0	1890.0	460.0

(Continuation of Appendix -F) Wastewater quality parameters in winter season

Sl No.	Location of out falls	Sampling Date	Flow rate (m^3/day)	Temp. (°C)	pH	Alkalinity as $CaCO_3$ (mg/L)	Chloride Cl^- (mg/L)	SO_4 (mg/L)	Sulphide (µg/L)	Nitrate (NO_3-N) (mg/L)	PO_4.P (mg/L)
1	Cable Factory Ghat	27-11-06	610.4	19	9.8	820.0	560.0	8.5	315.0	.70	7.0
2	I.D. Hospital Ghat	27-11-06	-	-	-	-	-	-	-	-	-
3	Shasan Ghat	27-11-06	351	20	8.8	790.0	540.0	8.2	300.0	.80	6.9
4	Nagar Ghat	27-11-06	421	19.5	8.9	800.0	690.0	9.10	285.0	.85	6.7
5	Jamuna Ghat	28-11-06	-	-	-	-	-	-	-	-	-
6	Hardbord Ghat	28-11-06	277	18	10.2	880.0	650.0	8.5	260.0	1.1	7.0
7	Charerhat Ghat	28-11-062	-	-	-	-	-	-	-	-	-
8	Khalishpur College Ghat	28-11-06	298.6	18.7	9.5	790.0	570.0	8.0	260.0	1.0	8.2
9	Port Road	03-12-06	-	-	-	-	-	-	-	-	-
10	.6No. Ghat	03-12-06	-	-	-	-	-	-	-	-	-
11	BIWTA Steamer Ghat	03-12-06	701.8	17.5	8.5	720.0	650.0	7.2	190.0	1.3	6.50
12	Dab Ghat	03-1206	179.2	18.3	7.9	690.0	680.0	7.1	186.0	1.32	6.40
13	Kalibari kheya Ghat	03-12-06	-	-	-	-	-	-	-	-	-
14	Panshi Ghat	05-12-06	592.0	21	9.9	830.0	540.0	8.0	250.0	.90	7.0
15	Panshi Ghat	05-12-06	-	-	-	-	-	-	-	-	-
16	Hospital Ghat	05-12-06	192.7	18.2	8.8	800.0	570.0	7.8	290.0	.70	7.6
17	Hospital Road Ghat	05-12-06	-	-	-	-	-	-	-	-	-
18	Jailkhana Ghat	05-12-06	179.0	17	7.9	700.0	660.0	7.1	190.0	1.2	7.1
19	Circuit HouseRd	06-12-06	-	-	-	-	-	-	-	-	-
20	1No.Custom Ghat	06-12-06	436.2	20.5	8.7	810.0	570.0	7.7	300.0	.90	7.2
21	Rupsha Beribadh Road	06-12-06	371.0	19.5	9.6	810.0	580.0	8.9	350.0	.80	6.9
22	N.Bazar Ap.Rd	06-12-06	-	-	-	-	-	-	-	-	-
23	Belayet Hossain Rd	06-12-06	239.4	17.4	8.7	720.0	665.0	7.0	200.0	1.1	6.9
24	Rupsha Feri Ghat	06-12-06	-	-	-	-	-	-	-	-	-
25	Rupsha Feri Ghat	06-12-06	794.0	20.8	8.7	710.0	650.0	6.5	360.0	.90	7.0
26	Ispahany Macth Factory	06-12-06	125.0	18.7	8.9	810.0	560.0	7.0	285.0	.86	6.5
27	Labanchara	09-12-06	-	-	-	-	-	-	-	-	-
28	Mohammadia Para	09-12-06	678.0	17.5	7.9	700.0	660.0	7.5	290.0	.80	7.2
29	South Labanchara	09-12-06	-	-	-	-	-	-	-	-	-

30	Hazi Ali Rd	09-12-06	179	18.9	8.6	690.0	670.0	6.7	290.0	.90	7.50.
31	Ziaur Rahaman Sarak	09-12-06	-	-	-	-	-	-	-	-	-
32	Graveyard	10-12-06	-	-	-	-	-	-	-	-	-
33	Nirala Residential Area	10-12-06	254	19.2	8.7	720.0	670.0	7.0	290.0	1.0	8.20
34	Gallamari	10-12-06	315.2	18.6	7.9	680.0	660.0	7.1	290.0	1.2	8.30
35	UPHCC (Arambag Road)	10-12-06	-	-	-	-	-	-	-	-	-
36	Hazi Tamizuddin Rd	10-12-06	-	-	-	-	-	-	-	-	-
37	G. Moktadir School Rd	12-12-06	678	17.3	8.6	700.0	680.0	7.2	300.0	1.0	8.30
38	Madrasa Road	12-12-06	-	-	-	-	-	-	-	-	-
39	Khulna Hospital (500 Bed)	12-12-06	544	18.9	9.2	810.0	570.0	8.0	285.0	1.1	7.60
40	Islamia College Road	12-12-06	174	19	9.2	860.0	550.0	7.1	190.0	1.3	10.2
41	Mollic Bari Road	12-12-06	-	-	-	-	-	-	-	-	-
42	Mirerghat Road	13-12-06	-	-	-	-	-	-	-	-	-
43	Mujgunni Main Road	13-12-06	971	17	8.7	710.0	660.0	7.9	290.0	.90	6.80
44	Mujgunni Housing Main Rd	13-12-06	-	-	-	-	-	-	-	-	-
45	Karigarpara	13-12-06	512	19.5	8.9	770.0	540.0	6.7	300.0	1.1	7.0
46	L.G.E.D. Road	13-12-06	362.5	18.3	8.6	720.0	650.0	7.4	290.0	1.2	5.0
47	Deana Yatimkhana Rd	13-12-06	-	-	-	-	-	-	-	-	-
48	Deana Para Main Rd	13-12-06	-	-	-	-	-	-	-	-	-
49	Moheshwarpasha	13-12-06	514.6	17.7	9.3	820.0	670.0	7.7	300.0	.90	4.5

(Continuation of Appendix - F) Wastewater quality parameters in winter season

Sl No.	Location of out falls	Sampling Date	Flow rate (m^3/day)	Temp. (°C)	Color (pt-Co) unit	DO (mg/L)	COD (mg/L)	Suspended solid (mg/L)	Dissolved solid (mg/L)	Volatile solid (mg/L)	Fixed solid (mg/L)
1	Cable Factory Ghat	27-11-06	610.4	19	750.0	1.42	590.0	3210.0	1520.0	2230.0	430.0
2	I.D. Hospital Ghat	27-11-06	-	-	-	-	-	-	-	-	-
3	Shasan Ghat	27-11-06	351	20	600.0	1.1	640.0	3350.0	1440.0	2320.0	480.0
4	Nagar Ghat	27-11-06	421	19.5	720.0	.90	690.0	2950.0	1460.0	1960.0	390.0
5	Jamuna Ghat	28-11-06	-	-	-	-	-	-	-	-	-
6	Hardbord Ghat	28-11-06	277	18	680.0	1.2	620.0	2760.0	1440.0	2100.0	380.0
7	Charerhat Ghat	28-11-062	-	-	-	-	-	-	-	-	-
8	Khalishpur College Ghat	28-11-06	298.6	18.7	690.0	1.3	620.0	2860.0	1510.0	2080.0	410.0
9	Port Road	03-12-06	-	-	-	-	-	-	-	-	-
10	6No. Ghat	03-12-06	-	-	-	-	-	-	-	-	-
11	BIWTA Steamer Ghat	03-12-06	701.8	17.5	760.0	1.2	630.0	2980.0	1620.0	2120.0	380.0
12	Dab Ghat	03-1206	179.2	18.3	720.0	.99	700.0	3260.0	1250.0	2320.0	440.0
13	Kalibari kheya Ghat	03-12-06	-	-	-	-	-	-	-	-	-
14	Panshi Ghat	05-12-06	592	21	620.0	.90	720.0	3150.0	1440.0	2150.0	450.0
15	Panshi Ghat	05-12-06	-	-	-	-	-	-	-	-	-
16	Hospital Ghat	05-12-06	192.7	18.2	670.0	1.1	690.0	3560.0	1880.0	2360.0	510.0
17	Hospital Road Ghat	05-12-06	-	-	-	-	-	-	-	-	-
18	Jailkhana Ghat	05-12-06	179	17	730.0	1.3	680.0	3220.0	1800.0	2080.0	390.0
19	Circuit HouseRd	06-12-06	-	-	-	-	-	-	-	-	-
20	1No.Custom Ghat	06-12-06	436.2	20.5	800.0	1.2	620.0	3420.0	1540.0	2130.0	400.0
21	Rupsha Beribadh Road	06-12-06	371	19.5	810.0	1.1	630.0	3360.0	1900.0	2250.0	480.0
22	N.Bazar Ap.Rd	06-12-06	-	-	-	-	-	-	-	-	-
23	Belayet Hossain Rd	06-12-06	239.4	17.4	690.0	.90	700.0	3260.0	1880.0	2300.0	460.0
24	Rupsha Feri Ghat	06-12-06	794	20.8	620.0	.85	760.0	3130.0	1760.0	2100.0	380.0
25	Rupsha Feri Ghat	06-12-06	-	-	-	-	-	-	-	-	-
26	Ispahany Macth Factory	06-12-06	125	18.7	850.0	1.1	690.0	3440.0	1880.0	2210.0	400.0
27	Labanchara	09-12-06	-	-	-	-	-	-	-	-	-

28	Mohammadia Para	09-12-06	678	17.5	620.0	1.2	650.0	2800.0	1440.0	1980.0	390.0
29	South Labanchara	09-12-06	-	-	-	-	-	-	-	-	-
30	Hazi Ali Rd	09-12-06	179	18.9	590.0	.90	650.0	2960.0	1850.0	2160.0	370.0
31	Ziaur Rahaman Sarak	09-12-06	-	-	-	-	-	-	-	-	-
32	Graveyard	10-12-06	-	-	-	-	-	-	-	-	-
33	Nirala Residential Area	10-12-06	254	19.2	760.0	1.1	600.0	3000.0	1480.0	2130.0	380.0
34	Gallamari	10-12-06	3152	18.6	820.0	.90	720.0	3420.0	1880.0	2230.0	440.0
35	UPHCC (Arambag Road)	10-12-06	-	-	-	-	-	-	-	-	-
36	Hazi Tamizuddin Rd	10-12-06	-	-	-	-	-	-	-	-	-
37	G. Moktadir School Rd	12-12-06	678	17.3	750.0	.90	700.0	3620.0	1650.0	2430.0	290.0
38	Madrasa Road	12-12-06	-	-	-	-	-	-	-	-	-
39	Khulna Hospital (500 Bed)	12-12-06	544	18.9	860.0	.60	820.00	3500.0	1880.0	2230.0	450.0
40	Islamia College Road	12-12-06	174	19	550.0	.90	690.0	2980.0	1440.0	2120.0	390.0
41	Mollic Bari Road	12-12-06	-	-	-	-	-	-	-	-	-
42	Mirerghat Road	13-12-06	-	-	-	-	-	-	-	-	-
43	. Mujgunni Main Road	13-12-06	971	17	600.0	1.2	530.0	2760.0	1420.0	2020.0	390.0
44	Mujgunni Housing Main Rd	13-12-06	-	-	-	-	-	-	-	-	-
45	Karigarpara	13-12-06	512	19.5	620.0	.85	690.0	3210.0	1650.0	2110.0	400.0
46	L.G.E.D. Road	13-12-06	362.5	18.3	650.0	.90	680.0	2950.0	1420.0	1980.0	420.0
47	Deana Yatimkhana Rd	13-12-06	-	-	-	-	-	-	-	-	-
48	Deana Para Main Rd	13-12-06	-	-	-	-	-	-	-	-	-
49	Moheshwarpasha	13-12-06	514.6	17.7	600.0	1.1	700.0	3210.0	1850.0	2100.0	420.0

(Continuation of Appendix -F) Wastewater quality parameters in spring season

Sl No.	Location of out falls	Sampling Date	Flow rate (m^3/day)	Temp. (°C)	pH	Alkalinity as $CaCO_3$ (mg/L)	Chloride Cl^- (mg/L)	SO_4 (mg/L)	Sulphide (µg/L)	Nitrate (NO_3-N) (mg/L)	PO_4.P (mg/L)
1	Cable Factory Ghat	18-02-07	596.5	24	7.9	740.0	605.0	6.5	520.0	1.1	4.5
2	I.D. Hospital Ghat	18-02-07	-	-	-	-	-	-	-	-	-
3	Shasan Ghat	18-02-07	-	-	-	-	-	-	-	-	-
4	Nagar Ghat	18-02-07	302	27	8.2	790.0	618.0	7.1	415.0	.9	3.9
5	Jamuna Ghat	19-02-07	-	-	-	-	-	-	-	-	-
6	Hardbord Ghat	19-02-07	-	-	-	-	-	-	-	-	-
7	Charerhat Ghat	19-02-07	431	26.5	7.9	750.0	600.0	6.5	500.0	1.1	4.6
8	Khalishpur College Ghat	19-02-07	243.4	23	8.1	790.0	615.0	5.9	520.0	.90	4.0
9	Port Road	19-02-07	-	-	-	-	-	-	-	-	-
10	6No. Ghat	20-02-07	328	24	7.5	720.0	580.0	7.1	420.0	.8	3.5
11	BIWTA Steamer Ghat	20-02-07	602	25	6.9	680.0	520.0	6.9	350.0	.75	4.2
12	Dab Ghat	20-02-07	-	-	-	-	-	-	-	-	-
13	Kalibari kheya Ghat	20-02-07	-	-	-	-	-	-	-	-	-
14	Panshi Ghat	20-02-07	532	22.5	10.1	890.0	650.0	5.9	500.0	1.0	4.5
15	Panshi Ghat	20-02-07	-	-	-	-	-	-	-	-	-
16	Hospital Ghat	20-02-07	154.5	27	8.8	780.0	615.0	6.6	450.0	.90	4.0
17	Hospital Road Ghat	20-02-07	-	-	-	-	-	-	-	-	-
18	Jailkhana Ghat	20-02-07	-	-	-	-	-	-	-	-	-
19	Circuit HouseRd	21-02-07	-	-	-	-	-	-	-	-	-
20	1No.Custom Ghat	21-02-07	340.6	25	7.8	760.0	640.0	6.4	315.0	.78	4.5
21	Rupsha Beribadh Road	21-02-07	389	26	9.2	810.0	740.0	6.9	300.0	.80	5.5
22	N.Bazar Ap.Rd	21-02-07	-	-	-	-	-	-	-	-	-
23	Belayet Hossain Rd	21-02-07	190.5	23	9.1	800.0	700.0	6.00	290.0	1.1	5.2
24	Rupsha Feri Ghat	21-02-07	-	-	-	-	-	-	-	-	-
25	Rupsha Feri Ghat	21-02-07	852.0	26	8.7	780.0	660.0	6.7	490.0	.90	6.6
26	Ispahany Macth Factory	21-02-07	89.5	27	8.6	700.0	560.0	6.2	420.0	.80	6.1
27	Labanchara	22-02-07	-	-	-	-	-	-	-	-	-
28	Mohammadia Para	22-02-07	530	23.6	9.1	760.0	540.0	5.9	415.0	1.1	6.2
29	South Labanchara	22-02-07	-	-	-	-	-	-	-	-	-

30	Hazi Ali Rd	22-02-07	203.5	28	8.9	760.0	610.0	5.8	260.0	.90	4.2
31	Ziaur Rahaman Sarak	22-02-07	-	-	-	-	-	-	-	-	-
32	Graveyard	22-02-07	-	-	-	-	-	-	-	-	-
33	Nirala Residential Area	22-02-07	-	-	-	-	-	-	-	-	-
34	Gallamari	24-02-07	2859.5	26.5	8.5	770.0	650.0	6.1	346.0	1.1	5.6
35	UPHCC (Arambag Road)	24-02-07	-	-	-	-	-	-	-	-	-
36	Hazi Tamizuddin Rd	24-02-07	-	-	-	-	-	-	-	-	-
37	G. Moktadir School Rd	24-02-07	528	23	8.8	790.0	650.0	6.2	468.0	.90	5.5
38	Madrasa Road	24-02-07	-	-	-	-	-	-	-	-	-
39	Khulna Hospital (500 Bed)	24-02-07	398.5	26	8.4	780.0	600.0	7.9	650.0	1.9	4.6
40	Islamia College Road	24-02-07	-	-	-	-	-	-	-	-	-
41	Mollic Bari Road	24-02-07	-	-	-	-	-	-	-	-	-
42	Mirerghat Road	24-02-07	425	24.5	10.1	990.0	650.0	5.6	416.0	1.1	6.5
43	Mujgunni Main Road	24-02-07	532.5	28	9.5	850.0	509.0	6.2	505.0	.9	5.4
44	Mujgunni Housing Main Rd	26-02-07	-	-	-	-	-	-	-	-	-
45	Karigarpara	26-02-07	-	-	-	-	-	-	-	-	-
46	L.G.E.D. Road	26-02-07	201.6	27.5	9.1	860.0	550.0	6.7	510.0	1.1	6.8
47	Deana Yatimkhana Rd	26-02-07	-	-	-	-	-	-	-	-	-
48	Deana Para Main Rd	26-02-07	-	-	-	-	-	-	-	-	-
49	Moheshwarpasha	26-02-07	1579	23.5	8.7	760.0	560.0	4.2	315.0	1.0	6.7

(Continuation of Appendix -F) Wastewater quality parameters in spring season

Sl No.	Location of out falls	Sampling Date	Flow rate (m^3/day)	Temp. (°C)	Color (pt-Co) unit	DO (mg/L)	COD (mg/L)	Suspended solid (mg/L)	Dissolved solid (mg/L)	Volatile solid (mg/L)	Fixed solid (mg/L)
1	Cable Factory Ghat	18-02-07	596.5	24	650.0	1.1	640.0	2760.0	1400.0	2130.0	390.0
2	I.D. Hospital Ghat	18-02-07	-	-	-	-	-	-	-	-	-
3	Shasan Ghat	18-02-07	-	-	-	-	-	-	-	-	-
4	Nagar Ghat	18-02-07	302	27	750.0	.90	850.0	2980.0	1880.0	2230.0	450.0
5	Jamuna Ghat	19-02-07	-	-	-	-	-	-	-	-	-
6	Hardbord Ghat	19-02-07	-	-	-	-	-	-	-	-	-
7	Charerhat Ghat	19-02-07	431	26.5	650.0	1.2	650.0	3250.0	1680.0	2120.0	450.0
8	Khalishpur College Ghat	19-02-07	243.4	23	600.0	1.1	640.0	3310.0	1950.0	2250.0	480.0
9	Port Road	19-02-07	-	-	-	-	-	-	-	-	-
10	6No. Ghat	20-02-07	328	24	590.0	.90	760.0	2980.0	1840.0	2110.0	480.0
11	BIWTA Steamer Ghat	20-02-07	602	25	600.0	.80	700.0	3020.0	1490.0	2230.0	480.0
12	Dab Ghat	20-02-07	-	-	-	-	-	-	-	-	-
13	Kalibari kheya Ghat	20-02-07	-	-	-	-	-	-	-	-	-
14	Panshi Ghat	20-02-07	532	22.5	620.0	1.0	680.0	3120.0	1650.0	2050.0	480.0
15	Panshi Ghat	20-02-07	-	-	-	-	-	-	-	-	-
16	Hospital Ghat	20-02-07	154.5	27	720.0	1.1	690.0	3220.0	1880.0	2120.0	410.0
17	Hospital Road Ghat	20-02-07	-	-	-	-	-	-	-	-	-
18	Jailkhana Ghat	20-02-07	-	-	-	-	-	-	-	-	-
19	Circuit HouseRd	21-02-07	-	-	-	-	-	-	-	-	-
20	1No.Custom Ghat	21-02-07	340.6	25	750.0	1.2	650.0	3010.0	1660.0	2020.0	500.0
21	Rupsha Beribadh Road	21-02-07	389	26	760.0	1.0	640.0	3120.0	1460.0	2110.0	490.0
22	N.Bazar Ap.Rd	21-02-07	-	-	-	-	-	-	-	-	-
23	Belayet Hossain Rd	21-02-07	190.5	23	620.	1.1	600.0	3110.0	1550.0	20210	460.0
24	Rupsha Feri Ghat	21-02-07	852.0	26	700.0	1.0	620.0	3410.0	1660.0	2310.0	470.0
25	Rupsha Feri Ghat	21-02-07	-	-	-	-	-	-	-	-	-
26	Ispahany Macth Factory	21-02-07	89.5	27	680.0	.90	800.0	3110.0	1640.0	2110.0	480.0
27	Labanchara	22-02-07	-	-	-	-	-	-	-	-	-
28	Mohammadia Para	22-02-07	530	23.6	720.0	.70	760.0	3220.0	1440.0	2210.0	500.0

29	South Labanchara	22-02-07	-	-	650.0	.90	750.0	3120.0	1660.0	2110.0	480.0
30	Hazi Ali Rd	22-02-07	203.5	28	680.0	1.0	700.0	3110.0	1540.0	2020.0	490.0
31	Ziaur Rahaman Sarak	22-02-07	-	-	-	-	-	-	-	-	-
32	Graveyard	22-02-07	-	-	-	-	-	-	-	-	-
33	Nirala Residential Area	22-02-07	-	-	-	-	-	-	-	-	-
34	Gallamari	24-02-07	2859.5	26.5	780.0	1.0	650.0	3220.0	1850.0	2110.0	490.0
35	UPHCC (Arambag Road)	24-02-07	-	-	-	-	-	-	-	-	-
36	Hazi Tamizuddin Rd	24-02-07	-	-	-	-	-	-	-	-	-
37	G. Moktadir School Rd	24-02-07	528	23	690.0	1.1	650.0	3400.0	1880.0	2230.0	520.0
38	Madrasa Road	24-02-07	-	-	720.0	.90	760.0	3240.0	1670.0	2110.0	500.0
39	Khulna Hospital (500 Bed)	24-02-07	398.5	26	760.0	.70	750.0	3110.0	1480.0	2020.0	480.0
40	Islamia College Road	24-02-07	-	-	-	-	-	-	-	-	-
41	Mollic Bari Road	24-02-07	-	-	-	-	-	-	-	-	-
42	Mirerghat Road	24-02-07	425	24.5	690.0	.80	720.0	3320.0	1550.0	2110.0	420.0
43	Mujgunni Main Road	24-02-07	532.5	28	680.0	1.0	700.0	2750.0	1460.0	2210.0	400.0
44	Mujgunni Housing Main Rd	26-02-07	-	-	-	-	-	-	-	-	-
45	Karigarpara	26-02-07	-	-	-	-	-	-	-	-	-
46	L.G.E.D. Road	26-02-07	201.6	27.5	680.0	1.0	720.0	3250.0	1680.0	2120.0	460.0
47	Deana Yatimkhana Rd	26-02-07	-	-	-	-	-	-	-	-	-
48	Deana Para Main Rd	26-02-07	-	-	-	-	-	-	-	-	-
49	Moheshwarpasha	26-02-07	1579	23.5	720.0	.90	720.0	2980.0	1640.0	2130.0	480.0

Appendix-G

QUESTIONNAIRES FOR THESIS ON WATER SUPPLY AND DRAINAGE SYSTEM IN

KHULNA CITY CORPORATION (KCC)

A. General information:

01. Name of the respondent:

(a) Age: ________ Years (b) Sex: Male / Female : _______________

(d) Educational Qualification: SSC/HSC/Graduate/Masters/Others: __________

02 Ward No.:______ 03. Total no. of household represented: ____________

04. Area covered: ____

B. About Water supply:

01. Sources of water for drinking:

(a) Tube well:________ (b) Well:________ (c) River:________ (d) Pond:__________

(e) KCC supplied: ________ (f) Others:__________

02. If supply is from KCC:

(a) Does the supply water becomes red in 30 minutes of supply ? : Yes / No

(b) Does the washing needs huge detergent? : Yes / No

(c) Taste of water: Sweet / Saline

(d) Quality of water:

(i) Bathing: --Good for hair: Yes / No; -- Huge soap consumption: Yes / No

(ii) Drinking: Taste is good: Yes / No

03. Is the water supply from KCC sufficient? : Yes / No

04. Existing condition in context of supply system:

(i) Regular / Irregular / Intermittent

05. Frequency or duration of supply:

(i) Whole day: Yes / No; (ii) Supply per day :Once / Twice (iv) Others:_________

06. When does the supply available? (i) Morning; (ii) Evening; (iii) Night:

07. Availability of supply:

(i) Sufficient : (a) Dry season (b) Wet season

(ii) Insufficient: (a) Dry season (b) Wet season

08. Payment and Rent:

(i) Monthly basis: Yes / No (ii) How much per month:___________________

09. Source of water for other purposes: KCC supply / Well / River / Pond

10. Distance of water source from household:

(i) Drinking water: _______________ (ii) Bathing / Washing:_______________

11. Does the quantity of supply satisfy the demand? Yes / No

12. Any comment on the existing water supply system : _________________________

B. Questions About Drainage:

13. Type of drainage system: (i) Pucca: _________ (ii) Earthen:_______________

14. If pucca then: Covered / Uncovered

15. Liquid waste generated approximate quantity (Volume / Weight):_______________

16. Waste disposal system and Location of disposal sites:

(a) Distances from settlement:______________________

(b) Tick (√) appropriate one of the following of the present disposal system:

(i) Household / Slum ⟶ Drain ⟶ River

(ii) Household / Slum ⟶ Drain ⟶ Treatment ⟶ River

17. How the drain is cleaned :

(a) By involvement of KCC by its own system: ____________________________

(b) By any GOVT. or private organization (name it):

18. Any comment on existing drainage condition: ______________________

____

____

______

D. About Health, Hygene and Environmental condition:

19. Water borne diseases: I) Cholera / Diarrhea /Typhoid / Any other: ______________

20. Occupational health issues:

(a) Working area: Spacious / congested / Suffocating

(b) Living area : Spacious / congested / Suffocating

21. Any comment on health care, facility and practices:__________________________

22. Visible / Perceived impacts on the Environment:

(i) Surface water: Impairment of domestic issue / Aquatic weeds / Recreation

(ii) Ground water: Effect on TW water or other

(iii) Land: Wastes of land / Conversion in to marshy land

(iv) Ecological: Any imbalance on economy

(v) Cultural : Any religious / Cultural / Ethnic problem

23. Is there any participation of community or NGO in water supply and Drainage activities:

24. Overall comment on Water supply and Drainage

management:_________________

APPROVAL

This is to certify that the thesis submitted by Gazi Mohammad Mohsin entitled as "Study on Water Supply and Drainage Problem in Khulna City" has been approved by the board of examiners for the partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh in November 2007.

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Professor and Head
Department of Civil Engineering
Khulna University of Engineering & Technology, Khulna

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Professor
Department of Civil Engineering
Khulna University of Engineering & Technology, Khulna

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Dr. Kh. Md. Shafiul Islam
Associate Professor
Department of Civil Engineering
Khulna University of Engineering & Technology, Khulna

5. ____________________ **Member (External)**

Dr. Md. Ashraf Ali
Associate Professor
Department of Civil Engineering
Bangladesh University of Engineering & Technology, Dhaka