Drinking Water Quality Assessment in Khulna City Corporation Slum Area

by

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Declaration

This is to certify that the thesis work entitled "**Drinking Water Quality Assessment in Khulna City Corporation Slum Area**" has been carried out by Abanti Kundu, Roll No: 1553505 in the Department of Chemistry, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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Abstract

Drinking water is characterized as free from microorganisms, terribly toxic compounds and that have no adverse effects on health. Waterborne disease is a major concern of public health and it is important to know the microbial as well as the physico-chemical qualities of drinking water. This study was conducted to assess the quality and suitability of groundwater for drinking purposes in different slum area of Khulna City Corporation (KCC) and explored the variation of bacteriological status of water between sources (deep Tube-wells) and household stored water. The study was conducted from July 22, to August 28, 2016. A total of 100 samples; 50 from sources and other 50 samples from household storage vessels were collected for exploring physico-chemical and bacteriological status. The parameters that were investigated found to have variation in the range of pH 7.4 to 8.55 was slightly basic, electrical conductivity 544 µS/cm to 2.21 mS/cm; Hardness 50 to 650 as $CaCO_3$ considered, hardness classification shows that maximum sample are hard type and very hard type. Total Dissolved Solid (TDS) 281 to 1176 mg/L, However, TDS classification of GW shows that maximum samples lie within good (300-600 mg/L), Chloride 31.68 to 721 mg/L, As <LOQ (Limit of Quantitation) mg/L to 0.02 mg/L, Fe 0.01 to 0.91 mg/L and Mn 0.01 to 0.68 mg/L. Comparing to WHO and BDS guideline, few of the water sources found to have one or more trace metals (Fe, As and Mn) levels outside acceptable limit set for drinking water. Most of them however have levels safe for human consumption. Physico-chemical parameters of maximum samples were satisfactory and met the standard guideline value of drinking water of BDS and WHO. However few samples from Khalishpur and Daulatpur industrial area, Khulna were beyond the limit recommended by World Health Organization (WHO) and Bangladesh Drinking Standard (BDS).

The samples were examined bacteriological status, total coliform (TC), fecal coliform (FC) were counted in different samples. Result shows that 74% TWs provide FC free water where only 10% household water sample was found FC free. At the same time 19% TWs provide TC free water where no household water sample was found TC free. In all household samples and 29 TWs samples, the TC and FC counts were above the recommended limit of WHO for drinking water quality (0 CFU/100mL for TC, 0 CFU/100mL for FC). It is very much alarming that both FC and TC in household storage water were considerably higher than those from sources. High level of coliform bacteria in water sources of these study area confirmed the presence of pathogenic organisms that generate a threat to people who consume this waters. This is may be due the to lack of good water treatment, lack of the protection of the water sources, unhealthy sewerage conditions, improper water handling practices, unhealthy sanitation, poor housing condition, dirty containers, improper waste management and illiteracy of slum dwellers. Thus, safety of water sources accompanied by sanitation and hygiene promotion programs and health education along with regular water quality monitoring can improve the water quality of slum area.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbols/Abbreviations	Explanations
μm	Micro meter
μS/cm	Micro Siemens Per Centimeter
AAS	Atomic Absorption Spectrophotometer
As	Arsenic
ASC	Auto Sample Changer
BBS	Bangladesh Bureau of Statistics
BDHS	Bangladesh Demographic and Health Survey
BDS	Bangladesh Drinking Standard
BGS	British Geological Survey
BWDB	Bangladesh Water Development Board
CFU	Colony Forming Unit
CRM	Certified Reference Material
CUS	Center for Urban Studies
DPHE	Department of Public Health Engineering
EBT	Eriochrome Black T
EC	Electrical Conductivity
EDTA	Ethylene Diamine Tetracetic Acid
ETC	Electro Thermal Controller
FAO	Food and Agricultural Organization
FC	Fecal Coliform
Fe	Iron
GW	Ground Water
HCL	Hollow Cathode Lamp
HCl	Hydrochloric Acid
HDPE	High Density Polyethylene
HSD	Housing & Settlement Department
HVG	Hydride Vapor Generation
JECFA	Joint Expert Committee on Food Additives
KCC	Khulna City Corporation

KDA	Khulna Development Authority
KI	Potassium Iodide
km	Kilo Meter
KWASA	Khulna Water Supply and Sewerage Authority
LOQ	Limit of Quantitation
MDL	Method detection limit
mg/L	Milligram Per Liter
mg	Milligram
MICS	Multiple Indicator Cluster Surveys
mL	Milliliter
mm	Millimeter
Mn	Manganese
MnC	Montur Colony
MRT	Measurement Record Table
MSP	Municipal Support Project
NDWQS	National Drinking Water Quality Survey
NGO	Non-Government Organization
NW	North Western
PMTDI	Provisional Maximum Tolerable Daily Intake
QA	Quality Assurance
QC	Quality Control
QL	Quantitation limit
RSD	Relative Standard Deviation
SD	Standard Deviation
SOP	Standard Operating Procedure
SS	Suspended Solids
STD	Standard
SW	South Western
TC	Total Coliform
TDS	Total Dissolved Solids
TS	Total Solids
TWs	Tube-wells

UK	United Kingdom
UNICEF	United Nations Children's Fund
WHO	World Health Organization

CHAPTER I

Introduction

1.1 General

Water is one of the most important compounds of the ecosystem. Human on earth are under remarkable threat due to undesired changes in the physical, chemical and biological prominence of air, water and soil. Due to increased human population, industrialization, use of fertilizers and man-made activity water is highly polluted with different harmful contaminants. Natural water contaminates due to the weathering of rocks and leaching of soils, mining processing etc. Further because of very low awareness among the population high levels of recontamination by microorganism in household storage containers are founded, suggesting the need for monitoring and healing beyond the water source itself. It is obligatory that the quality of drinking water should be checked at regular time interval, because due to the use of tainted drinking water, human population suffers from various water borne diseases. The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life. It is necessary to be acquainted with details about different physico-chemical, and microbiological parameters used for testing of water quality.

The quality of ground water depends on various chemical constituents and their concentration, which are mostly derived from the geological data of the particular region. Industrial waste and the municipal solid waste have emerged as one of the leading cause of pollution of surface and ground water. In many parts of the country available water is rendered non-potable because of the presence of heavy metal in excess. The situation gets worsened during the summer season due to water scarcity and rain water discharge. Contamination of water resources available for household and drinking purposes with heavy elements, metal ions and harmful microorganisms is one of the serious major health problems. The recent research in India (Haryana) concluded that it is the high rate of exploration then its recharging, inappropriate dumping of solid and liquid wastes, lack of strict enforcement of law and loose governance are the cause of deterioration of ground water quality [1].

The availability of good quality water is an indispensable feature for preventing diseases and improving quality of life. Natural water contains different types of impurities are introduced in to aquatic system by different ways such as weathering of rocks and leaching of soils, dissolution of aerosol particles from the atmosphere and from several human activities, including mining, processing and the use of metal based materials. The increased use of metal-based fertilizer in agricultural revolution of the government could result in continued rise in concentration of metal pollutions in fresh water reservoir due to the water run-off. Also fecal pollution of drinking water causes water born disease which has led to the death of millions of people [2].

Unsafe drinking water, along with poor sanitation and hygiene, are the main contributors to an estimated 4 billion cases of diarrheal disease annually, causing more than 1.5 million deaths, mostly among children under 5 years of age [3]. Fecal contamination levels in household water containers were generally high even when the source water was of good quality. Under conditions such as this, it is questionable whether public water treatment will have a significant impact on the incidence of endemic childhood diarrhea [4].

1.2 Importance of Ground Water

In recent decades it has become evident in many countries of the world, particularly in Asia that GW is one of the most important natural resources. As a source of water supply GW has a number of essential advantages when compared with surface water: as a rule it is of higher quality, better protected from possible pollution including infection, less subject to seasonal and perennial fluctuations, and much more uniformly spread over large regions than surface water. GW makes up about 1% of the water on Earth (most water is in oceans). GW occurs everywhere beneath the Earth's surface [5].

Bangladesh is a country laced with rivers and ponds, sources of surface water that have supplied its population's needs for centuries. Unfortunately, however, innumerable lives were being lost from diarrheal diseases contracted by drinking surface water contaminated with bacteria. But GW is abundant in Bangladesh and the aquifers are highly productive.

Therefore, in the 1970s and 1980s, the Bangladeshi government collaborated with international aid agencies led by UNICEF to build tube wells (hand-operated pumps that draw water from underground aquifers) in every village. In addition to providing access to pathogen-free water, the tube-wells were welcomed because they brought relief to village women who used to trudge vast distances with pails dangling off their arms and pots of water balanced on their heads. By the 1990s, 95 percent of the country had access to tube-well-drawn water. 10 million tube-wells had been installed in the country of 146 million in what was touted as a rare public health and humanitarian success story [6]. Today, 97% of the population relies on GW not only for potable supplies but also for other important issues such as irrigation, industry etc. GW levels across Bangladesh become depressed during the dry season, but the aquifers replenish fully during the monsoon. The number of tube-wells in Bangladesh is not accurately known but estimation put the number at around 11 million. In some areas, notably the south and the Sylhet Basin of north-east Bangladesh, deep tube-wells abstract GW from depths of 150 m or more. In the south, the deep tube-wells have been installed to avoid high salinity at shallower levels [7]. Till 1995 it was thought that GW is perfectly safe for drinking purposes. After then people came to know that GW in some area are contaminated with higher level of arsenic which is very much poisonous to human health. And also it is observed that people specially live in poor locality are affected with water-borne diseases such as diarrhea, dysentery, hepatitis, etc. although they are using safe GW sources. Research found that GW also can be contaminated in several ways.

1.2.1 Ground Water Contamination

It has been discussed that GW is one of the big source of drinking water and it is very much essential for good health. If everyone in the world has good access to safe water, half of the world's sickness would disappear. Poverty, contaminated water and sickness go together. It is disgraceful that such a large proportion of the world's population use unsafe water, particularly in countries like ours and many of those in south Asia. As I discussed earlier that contaminated water is a major cause of illness, giving rise to water-borne diseases such as diarrhea, cholera, dysentery, hepatitis, gastroenteritis and worms which debilitate and sometimes destroy lives. It is said that contamination of water can be occurred physically, chemically and micro-biologically.

In nature, even the potable water contains some impurities that come from the erosion of natural rock formations. Just as our surface fresh water resources (i.e., rivers, pond etc) are influenced by geologic processes and the activities of humans, so too is GW. GW is an important source of drinking water, and its quality is currently threatened by a combination of over-abstraction, microbiological and chemical contamination [8]. Here few GW contamination sources are discussed.

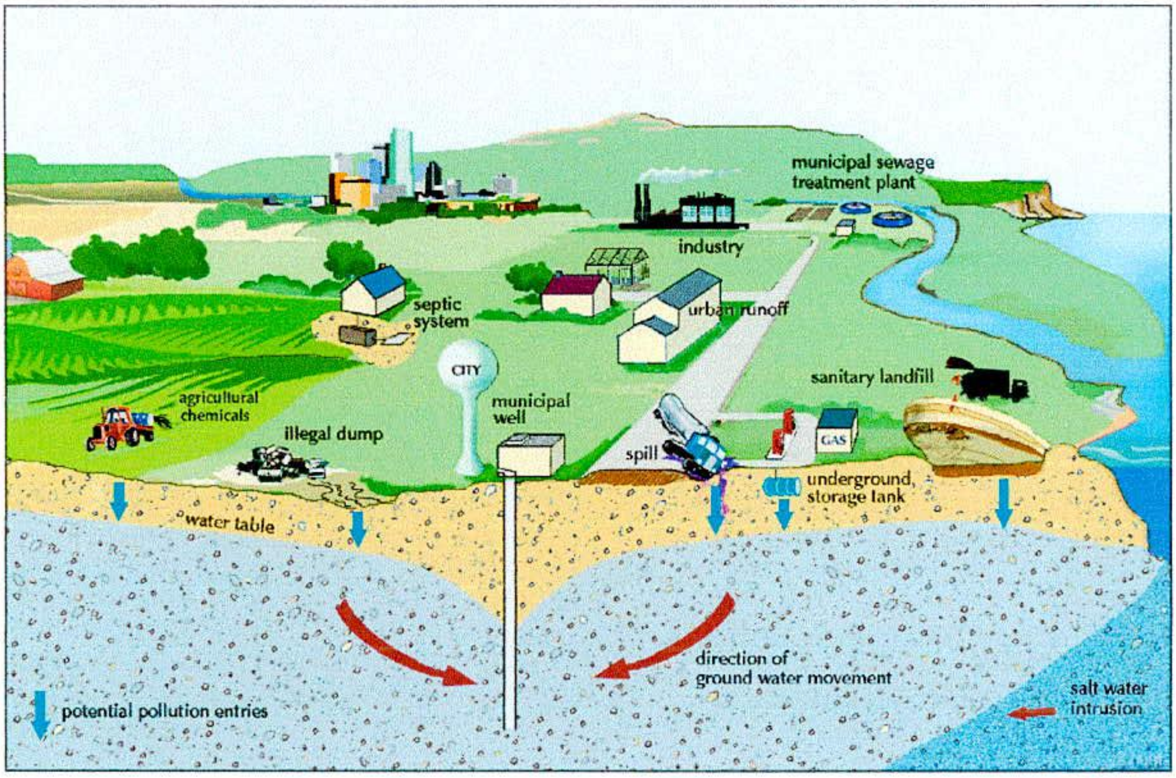


Figure 1.1: Sources of GW contamination are numerous and are as diverse as human activities. (Source: Zaporozec and Miller, 2000) [9]

1.2.1.1 Improper Disposal of Hazardous Waste

Hazardous waste should always be disposed of properly, that is to say, by a licensed hazardous waste handler or through municipal hazardous waste collection days. Many chemicals of household septic systems, including oils (e.g., cooking, motor etc), lawn and garden chemicals, paints and paint thinners, disinfectants, medicines, photographic chemicals, and swimming pool chemicals are disposed in improper ways. Similarly, many substances used in built-up processes disposed into drains at the workplace.

Land disposal of solid waste is the GW contamination source of most current concern to the general public in many developed countries. Disposed materials often are very susceptible to leaching into GW. The most hazardous solid waste disposal generally results from industrial and manufacturing activities as well as some governmental energy and defense activities. The many different types and the large quantities of chemicals used at industrial locations are vulnerable for GW protection. Both developed and developing countries, where there is active and disrupted industrial activity, throw their hazardous waste both direct and indirect way into ground without any recycling treatment. And also Liquid wastes resulting from numerous industrial processes and from petroleum production are sometimes injected directly into the GW system through wells.

1.2.1.2 Sewage Disposal

Proper treatment of sewage disposal is important for the modern community. Sewages provide pathogens, nitrates, and a variety of organic and inorganic chemicals to GW if untreated sewages are directly applied to the land surface. Land application of sewages can provide a direct contaminant source via infiltration. Sewage dump gradually penetrate into the soil layer. The operation and cleaning of septic tanks and cesspools are often thought to result in localized contamination sources, affecting only nearby wells. Combination of a large number of septic tanks in an area may act as a source of regional GW contamination. In addition, use of solvents to clean out the systems can cause groundwater contamination by synthetic organic compounds.

1.2.1.3 Spills and Leaks from Storage and Transport of Liquids

A related category of GW contamination sources includes spills and leaks resulting from transport and storage of liquids. Leaks and spills can occur as hazardous liquids are transported via pipelines, trucks, or trains or stored in tanks and other containers. This transportation and storage may either be above or below ground. Depending on their magnitude, their location, and the local geo-hydrologic conditions, these leaks and spills can be significant sources of GW contamination. Leaking fuel tanks, in particular, and oil spillage expose the subsurface to hydrocarbons and are a big threat to GW.

1.2.1.4 Agricultural Activities

Numerous agricultural activities can result in non-point sources of GW contamination. Fertilizers, pesticides, and herbicides are applied as part of common agricultural practice throughout the world. These applications can act as sources of contamination to GW supplies serving large populations. Improper management in agricultural sector such as, changing hydrogeologic conditions, biochemical processes and application methods of fertilizers, pesticides, and herbicides become sources of GW contamination. Agricultural activities related to animals also can be GW contamination sources. These include the feeding of animals and the storage and disposal of their waste. Animal wastes and feedlot runoff are commonly collected in some sort of pit or tank creating the contamination threat described earlier for sewage disposal.

1.2.1.5 Improperly Constructed Wells

Problems associated with improperly constructed wells can result in GW contamination when contaminated surface or GW is introduced into the well. Space between tube-well exterior and rock may not be properly sealed and space near the surface is not properly cemented or otherwise sealed, in that cases contaminants from the land surface may enter the groundwater system along. Tube-well pipe (steel or plastic) may not be properly welded or subject to corrosion, which results in the development of holes in a well-casing column. In this way shortcut are created that may allow the entry of contaminated water at higher levels in a pumped well. The risk of groundwater contamination is especially high in developing countries where incorrect well design, insufficient sealing of wells, and poor technique during well construction has resulted in many cases of local groundwater contamination.

1.2.1.6 Saline Intrusion

In coastal areas, too much demand on potable GW can create induced recharge from ocean waters, resulting in saline intrusion into GW supplies. This can also happen in times of severe drought. As a result of over pumping, the wedge-shaped saline bottom part of the groundwater system connected with seawater extends inland, and the original interface between saline and fresh groundwater shifts toward the pumping wells. Improper well-field siting, well screening, and in particular, excessive pumping has caused seawater intrusion in practically all populated coastal areas around the world. Careful planning of coastal communities and water conservation are ways to avoid saline intrusion into groundwater supplies.

1.2.1.7 Surface Water and Atmospheric Contaminants

Groundwater quality is very much influenced by surface-water conditions and vice versa. Contamination of any surface water bodies that recharge the groundwater system is a source of groundwater contamination. This includes "natural" recharge sources such as lakes and rivers as well as "man-made" recharge sources such as artificial recharge ponds/injection wells and infiltration of urban runoff. More generally, it is significant to consider the interaction of all environmental sources and pathways of pollution.

1.3 Household Water Implication

Microbiological contamination of water between source and point-of-use is widespread and often significant. Increased FC and TC counts in stored domestic water are especially found in urban areas with uncontaminated supplies [10]. The results imply that samples taken from storage vessels may provide a better reflection of the quality of water consumed than source samples, particularly in urban poor areas with safe water sources. According to WHO (2002) Risks of waterborne infectious diseases increase from inadequately stored water compared to water stored in an improved vessel (safe storage). Numerous studies have documented inadequate storage conditions and vulnerable water storage containers as factors contributing to increased microbial contamination and decreased either microbial quality compared to source waters or water stored in improved vessels. Because unrestricted and unhygienic water collection activities, soiled hands and unclean water collection vessels were potential contributor for the contamination of drinking water. The highest level of household water contamination found in stored water, since stored water becomes contaminated when unclean objects touch it over dipping.

1.4 Potable Water and Water-borne Diseases

Water related diseases are classified into four types relating to the path of transmission: i) Waterborne diseases, such as cholera and typhoid, are the diseases that are transmitted through drinking water. ii) Water-washed (water-scarce) diseases, such as polio, are diseases caused by improper attention to effective sanitation, washing and personal hygiene. Not washing of hands, especially after going to the toilet, improper washing and unhygienic environment during food preparation, waste disposal and fly control etc. iii) Water based diseases are diseases transmitted by contact with water, e.g. recreational swimming iv) water vector diseases, such as malaria, are diseases that are transmitted by a vector, such as the mosquito, which needs water or moisture in order to breed.

Water related diseases can often be attributed to exposure to elevated heavy metal concentrations of both organic and inorganic contaminants. Many of these compounds exist naturally, but their concentration has increased as a result of anthropogenic activities. [11]. Chemical toxicity of water seems to be a breakdown of the immune system, which opens the gateway for all kinds of diseases in the body. Also, another major symptom seems to be damage to the nervous system and increased nervousness. Toxic doses of chemicals cause either acute or chronic health effects. The levels of chemicals in drinking water, however, are seldom high enough to cause acute health effects. They are more likely to cause chronic health effects that occur long after exposure to small amounts of a chemical. Examples of chronic health effects include cancer, birth defects, organ damage, disorders of the nervous system, and damage to the immune system [12]. WHO and UNICEF [13] Reported that Worldwide, infectious waterborne diseases are the number one killer of children under five years old and more people die from unsafe water annually than from all forms of sources. Unsafe or inadequate water, sanitation, and hygiene cause approximately 3.1% of all deaths worldwide, and 3.7% of disability adjusted life years worldwide. Unsafe water causes 4 billion cases of diarrhea each year, and results in 2.2 million deaths, mostly of children under five. This means that 15% of child deaths each year are attributable to diarrhea: a child dying every 15 seconds. In India alone, the single largest cause of ill health and death among children is diarrhea, which kills nearly half a million children each year.

One of the major concerns of the drinking water quality in coastal area of Bangladesh was the salinity. Generally the population of coastal area collects water from different source namely rivers, tube well and ponds for different purposes use including the drinking and cooking. Approximately 20 million people living along the coast are affected by varying degrees of salinity in drinking water (>4 ppt) obtained from various natural sources. The high level salt in drinking water has been becoming a public health concern in the area [14]. Slums concentrate many known risk factors for parasitic, waterborne diseases, including: flooding, poor water drainage, open sewers and overcrowding. [15]

1.5 Water Quality Parameters

The thesis will be accessible on the water quality testing of different parameter such as pH, Conductivity, Total Hardness, TDS, Chloride, Arsenic, Iron, Manganese, Fecal Coliform and Total Coliform.

1.5.1 pH

pH is one of the most important parameters of water quality. In order to know, whether the water solution is acidic or alkali, the measurement of pH is must. Particularly every phase of water supply and wastewater treatment knowing pH is necessary. pH is dependent on temperature. Although the pH of pure water is 7, drinking water and natural water exhibits a pH range because it contains dissolved minerals and gases. Surface waters typically range from pH 6.5 to 8.5 while groundwater ranges from pH 6 to 8.5. Water with a pH less than 6.5 is considered acidic. This water typically is corrosive and soft. It may contain metal ions, such as copper, iron, lead, manganese and zinc. The metal ions may be toxic, may produce a metallic taste, and can stain fixtures and fabrics. Water with a pH higher than 8.5 is considered basic or alkaline. However, the WHO [16] recommend that public water systems maintain pH levels of between 6.5 and 8.5.

1.5.2 Electrical conductivity (EC)

Conductivity is a measure of the ability of water to conduct an electrical current and is directly related to the total dissolved salt content of the water. Ions come from the breakdown of compounds and conduct electricity because they are negatively or positively charged when dissolved in water. Some ions also occur naturally as water flows over certain types of rocks or soil. Calcium and carbonate ions dissolve into water when calcite containing rocks such as, lime stone and shale, are present. Conductivity is an indirect measure of the presence of dissolved solids and can be used as an indicator of water pollution. Electrical conductivity is widely used to indicate the total ionized constituents of water. It is widely related to the sum of cations or anions as determined chemically and is closely correlated, in general, with the total salt concentration. Human activities also influence conductivity. Acid mine drainage can add iron, sulphate, copper, cadmium and other ions if minerals containing them are exposed to air and water. Sewage and farm runoff can raise conductivity due to the presence of nitrate and phosphate. Runoff roads can also carry salt and other materials that contribute ions to water. WHO recommended 1000μS/cm maximum contaminant limit for drinking water.

1.5.3 Total dissolved solids (TDS)

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc. These minerals produced un-wanted taste and diluted color in appearance of water. There is no agreement have been developed on negative or positive effects of water that exceeds the WHO standard limit of 1,000 ppm. TDS in drinking water is originates many ways from sewage to urban industrial wastewater etc. Therefore, TDS test is considered a sign to determine the general quality of the water.

1.5.4 Total Hardness

The hardness of water is a measure of the amount of minerals, primarily calcium and magnesium, it contains. The hardness criterion is used exclusively for determining the usability of the water resources under study for domestic and drinking purposes. Hardness of water for domestic use relates mainly to its reaction with soap. Since soap is precipitated principally by Ca^{2+} and Mg^{2+} salts, hardness is defined as the sum of the concentrations of these ions expressed as mg/L of $CaCO_3$. The degree of hardness of drinking water may be classified in terms of its calcium carbonate concentration as follows: soft, 0 to <60 mg/L; medium hard, 60 to <120 mg/L; hard, 120 to < 180 mg/L; and very hard, 180 mg/L. In areas with hard water, household pipes can become clogged with scale; hard waters also cause incrustations on kitchen utensils and increase soap consumption. Hard water is thus both a nuisance and an economic burden to the consumer. Public acceptance of hardness varies among communities; it is often related to the hardness to which the consumer has become accustomed, and in many communities hardness greater than 200 mg/L is tolerated. It has been suggested that a hardness level of

80 to 100 mg/L (as $CaCO_3$) provides an acceptable balance between corrosion and incrustation [17, 18]. However, waters with hardness in excess of 500 mg/L are unacceptable for most domestic purposes.

1.5.5 Chloride

Chlorides in ground water can be naturally occurring in deep aquifers. Or caused by pollution from sea water, brine, or industrial or domestic wastes. Chloride are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$) [19]. It has key importance for metabolism activity in human body and other main physiological processes. High chloride concentration damage metallic pipes and structure as well as harms growing plants. According to WHO standards concentration of chloride should not exceed 250 mg/L.

1.5.6 Some Metals

The term heavy metal is used for metals with a density more than 5 g/cm^3 [20]. Heavy metals important in environmental and health issues include iron, arsenic, manganese and many others. Those are not normally a part of the human body and are more poisonous to us if it exceeds the acceptable limit.

1.5.6.1 Iron

Fe is an essential element in human nutrition. The most common sources of iron in GW are naturally occurring, for example from weathering of iron bearing minerals and rocks. Industrial effluent, acid-mine drainage, sewage and landfill leachate may also contribute iron to local GW. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50 mg/day [21]. In drinking-water supplies, Fe(II) salts are unstable and are precipitated as insoluble Fe(III) hydroxide, which settles out as a rust-coloured silt. Ground water may contain Fe(II) at concentrations of up to several milligrams per litre without discolouration or turbidity in the water when directly pumped from a well. Turbidity and discolouration may develop in piped systems at Fe levels above 0.05-0.1 mg/L, although iron concentrations of 1-3 mg/L can be acceptable for people drinking well-water (WHO, 1996) but WHO [16] prescribes 0.3 mg/L as the limited Fe level allowable in water for drinking and domestic purposes.

1.5.6.2 Arsenic

Arsenic is a naturally occurring, common element found in the earth's crust. Arsenic occurs naturally in the mineral mispickel or arsenopyrites. Very low levels of arsenic are also present in plants and foods such as fish as well as in the air. Arsenic is typically found in combination with other elements. Arsenic compounds has no distinctive taste or smell. Many of these compounds occur naturally but some are man-made. At very low levels, there is relatively little concern. Most people consume small amounts of arsenic in the food they eat, but drinking water with even low to moderate levels of arsenic can provide more. The most toxic form of arsenic, known as inorganic arsenic, is the form typically found in GW. Inorganic As compounds are classified as carcinogenic to humans. Clinical symptoms of acute intoxication of As include abdominal pain, vomiting, diarrhoea, muscular pain, and weakness, with flushing of the skin [21].

Studies have shown that people drinking well water with elevated levels of arsenic have higher risks of some diseases. Drinking well water with low to moderately elevated levels of arsenic over a long period of time may lead to chronic health effects. Chronic health effects, such as cancer, develop over a number of years and can be difficult to detect, especially in the early stages. Higher levels of arsenic can also lead to more immediate or acute health effects that usually have more noticeable symptoms.

Within a month, one may show progressive deterioration in motor and sensory responses. Signs of chronic arsenicalism, including dermal lesions, skin cancer, and peripheral vascular disease, have been observed in populations ingesting arsenic-contaminated drinking-water. In view of reducing the concentration of As in drinking-water, a provisional guideline value of 0.01 mg/L is recommended. The guideline value is derived based on the estimated lifetime cancer risk [22]. The amount of arsenic in water is measured in micrograms of arsenic per liter of water, abbreviated as µg/L, or as milligrams per liter, abbreviated as mg/L.

1.5.6.3 Manganese

Mn is a heavy metal. Manganese like iron is a metallic element present in many types of rock. Mn is commonly found in water and is an essential element required in small amounts by all living organisms. Concentration of manganese in GW is often higher than that measured in surface waters. The most common sources of manganese like iron in GW are naturally occurring, for example from weathering of manganese bearing minerals and rocks. Industrial effluent, acid-mine drainage, sewage and landfill leachate may also contribute manganese to local GW. Mn concentrations above 0.1 mg/L impart an undesirable taste to drinking water. Even at about 0.02 mg/L, Mn will form coatings on piping that may later tear off as a black precipitate. Mn is believed to have a neurotoxic effect.

1.5.7 Total coliforms and Fecal coliforms

The microbial quality of water is determined by the presence of bacteria indicative of fecal contamination, namely, total coliforms and fecal coliforms such as *Escherichia coli*. Coliforms occur naturally in soil and in the gut of humans and animals. Their presence therefore indicates definite fecal pollution. The presence of coliform bacteria in well water may be as a result of surface water infiltration or seepage from a septic [23]. The presence of *E. coli* in water indicates recent fecal contamination and may indicate the possible presence of disease-causing pathogens, such as bacteria, viruses, and parasites. Although all strains of *E. coli* bacteria are not harmful, certain strains, such as *E. coli O157:H7*, may cause illness, such as hemorrhagic diarrhea and hemolytic uremic syndrome which causes kidney failure, especially in young children and elderly persons [24]. Total coliforms and *E. coli* are used as indicators to measure the degree of pollution and sanitary quality of well water, because testing for all known pathogens is a complicated and expensive process. The main source of pathogens in drinking water is through recent contamination from human or animal waste and lacking of proper hygienic knowledge. In water, coliform bacteria have no taste, smell, or color. The Canadian drinking water quality guideline for total coliforms is none detectable per 100 mL. The Canadian drinking water quality guideline for *Escherichia coli* is none detectable per 100 mL. This means that in order to conform to the guideline: For every 100 mL of drinking water tested, no total coliforms or *E. coli* should be detected [(0 CFU/100 mL)]. *E. coli* in drinking water indicates the water has been contaminated with fecal material that may contain disease-causing microorganisms n only be detected through a laboratory test [25].

1.6 Study Area

Khulna, the industrial and port city, is the third largest city of Bangladesh which is situated in the southwest region of Bangladesh and lies in the delta of the Ganges.

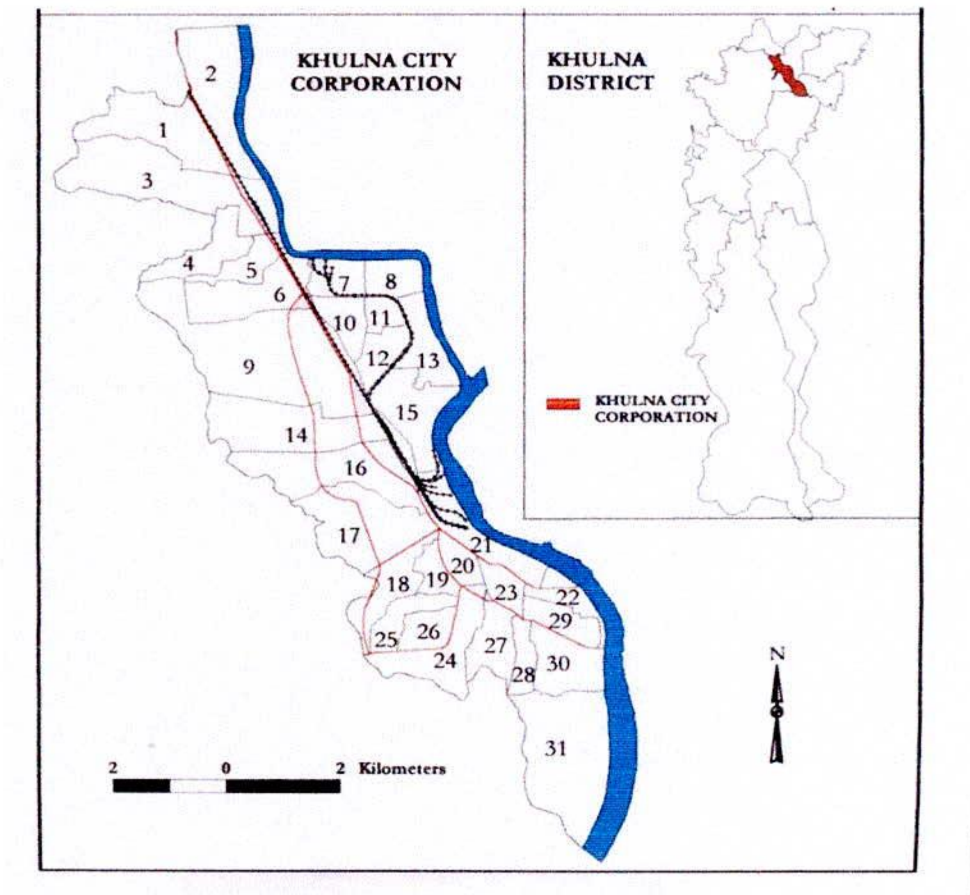


Figure 1.2: Khulna city corporation map

The second largest seaport of the country Mongla is only few km from the city. The city is surrounded by lots of industry nevertheless it has plenty of importance for its geographical, political, historical, and financial reasons.

1.6.1 Location

It is located in the southwestern region of the country, which is bounded by latitudes 22°46'0"–22°58'0"N and longitudes 89°28'0"–89°37'0"E. The city has an elevation above mean sea level of 9 m in the north to 2 m towards the SW. It covers an area of 37 km^2; however, the city and its outskirts are expanding continuously owing to rapid urbanization. The population of Khulna City is over 1.5 million. Geographically, the city area is characterized by the Ganges tidal floodplains in the south and deltaic plain in the north with low relief and crisscrossed by rivers [26]. The city is surrounded by four tidal rivers: the Rupsha, Bhairab, Mayurand Hatia. It is bounded by the Rupsha in the SE and by the Bhairabin the NE). The Mayur and Hatia flow from NW to SW along the western boundary of the city. Several marshes and swamps are also located in and around the city. The subsurface of the city area consists of alluvium to a depth of 40 m or more, composed of sand, silt, clay, organic clay and peat in varied proportion, the surface geology of the city consists of deltaic deposits, which are composed of tidal deltaic deposits, deltaic silt deposits and mangrove swamp deposits [27].

1.6.2 Geology

The KCC consists of late Holocene to Recent Alluvium of the Ganges deltaic plain in north and tidal plain in south. The area is composed of sand, silt and clay in various proportions with small amount of coarse sand, which is classified into seven litho-stratigraphic units from base to top. Stratigraphic cross-sections and pannel diagram through the KCC area indicate presence of seven sedimentary cycles, each cycle resembling fining upward sequence. Complexes of channels of fluvial/tidal origin, natural levees, bars, swamps and plains like floodplain, deltaic plains, estuarine plains or coastal plain constitute the KCC area. Channels (tidal as well as fluvial), natural levee, flood plain, flood basin, ox-bow lake, abandoned channels, bars, swamps/ flood basins and estuarine plain have been recognized as geomorphological units within the KCC area. Of these the area occupied by the natural levee, flood plain and bars are ranked high for future urban development [28].

1.6.3 Temperature

Remarkable changes in temperature can be found with the changes of seasons in Khulna city. April is the hottest month showing a monthly maximum temperature of up to 35 °C. However, Khulna city shows a mild summer than of inland areas, particularly northwestern district, where summer temperature sometime exceeds 40 °C. In June, there is sharp fall in temperature due to the outbreaks of monsoon. During the monsoon, the monthly maximum temperature is about 30 °C. The cool dry winter season begins in November, and January is the coldest month with a minimum monthly temperature of about 10 °C [29].

1.6.4 Rainfall

Khulna receives an average rainfall of about 1800 mm. The main source of rainfall is the southwestern monsoon. Nearly 81% of total rainfall occurs during June-October. During March-May some rainfall also occur due to Nor'easter effect. Winter is the dry period with little or nearly no rainfall. However, during the months of December and January little rainfall is recorded [29].

1.6.5 Slum Area

According to CUS report (Slums of Urban Bangladesh-Mapping and Census) in 2006 there are 520 slums in Khulna city. Most of the slums of Khulna City have established after 1971, the year of independence of Bangladesh. About 73% slums have been established after 1971. In the slums of Khulna city 188,442 poor and landless people live. Density of population per acre and per kilometer in the slum area is 538 and 132,988 respectively.

Khulna, located in the southwestern region, is the third largest metropolitan as well as an important industrial city of Bangladesh. It is also the divisional headquarters of Khulna Division comprising of 10 districts. Due to both push and pull factors, the population of Khulna City has been increasing tremendously in the recent years. A vast majority of the population of Khulna is living below poverty level and most of them are engaged either in various informal sector jobs or small, medium and large sized industries as workers. As a result, they are compelled to live in slums and squatter areas without having least access to basic urban services and facilities. The overall environmental conditions of the slum areas are worse and unhealthy from any consideration. The existing services and facilities provided by different agencies (viz. Khulna Development Authority (KDA), KCC, Local Government Engineering Department (LGED), Department Public Health Engineering (DPHE) etc.) are not adequate to cope with ever increasing demand for these services and facilities.

Consequently, the quality of delivery system of these services is deteriorating gradually and thus the quality of living condition of the people is at stake. Apart from these, wastes generated from various sources are not scientifically disposed off. Notably, wastes generated from informal sector industries such as welding workshop, motor repair garage, saw mills, spice crushing' mills, soap factories, etc. are not treated scientifically. On the other hand, the large scale industries such as Khulna Hardboard Mills, different Jute Mills, Match Factories, Khulna Ship Yard, Khulna Power Station, etc. generate a lot of wastes which are discharged either in the nearby rivers or elsewhere without adequate treatment. Due to excessive dependence on the ground water for water supply for the purposes of both drinking and other household activities, there are some evidences of arsenic contamination in water in some wards of KCC areas.

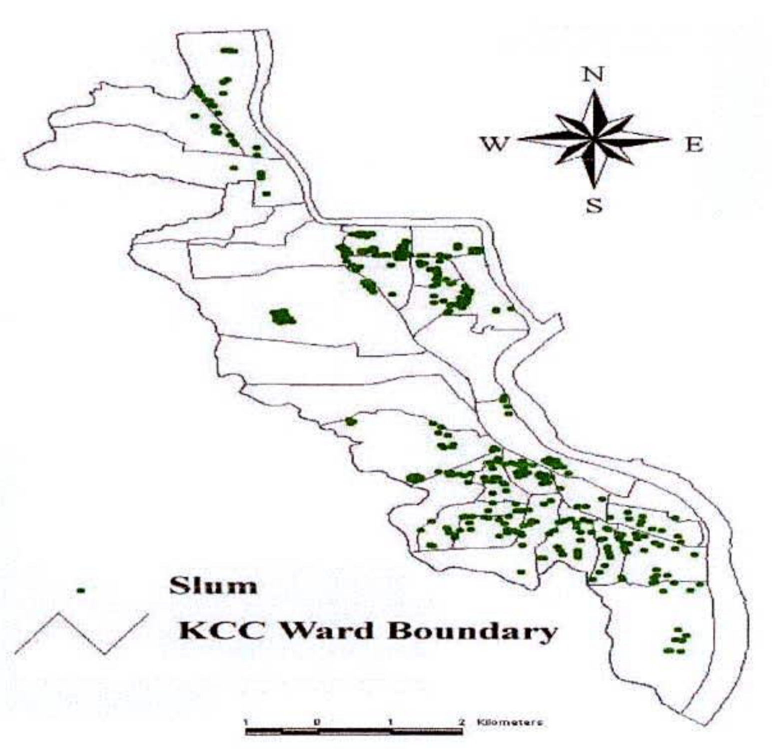


Figure 1.3: Location of major slums in KCC

1.7 Water bodies system in KCC:

The Khulna water supply system dates back to 1921 with a small surface water treatment plant of capacity 9.0 lakh liters (900 m^3) per day. The water supply system was expanded in 1960, by the DPHE and the HSD (Housing & Settlement Department) by installing deep production tube wells, connecting them to the network and extending distribution system in some new areas. The quantity of supply reached at 150 lakh liters (15000 m^3) per day during 1980-81 through 12 production wells. The capacity of water supply was raised up to 2.50 Crore liters (25000 m^3) in 1994 through implementing different development activities. After implementing further development program by DPHE of government fund in 1997, the capacity augmented up to 3.25 Crore liters (32500 m^3). Due to lack of development activity most of the production tube wells become chocked up that causes the depletion of the present water supply to 2.36 Crore liters (23600 m^3). It can also be mentioned that some existing tube wells become abandoned by this time [30].

To mitigate the water crisis of Khulna city, MSP, LGED carried out a feasibility study by Mott MacDonald (1994) under financial assistance of World Bank. This study was completed in 1997. After study, 10 (ten) production tube wells of capacity 16 MLD has been installed by MSP project in 2002 [31].

1.7.1 Water supply system coverage

A large number of deep and shallow hand tube wells, fitted with hand pumps, supply water to residents, especially in the northern part of the KCC area. Many private organizations, factories, schools and other educational institutions have their own tube wells because the public supply is so unreliable. There is no legislation to control the exploitation of GW in Khulna. Private tube wells can be sunk without a permit.

Currently Khulna water supply system entirely depends on GW source. About two-thirds of the water used by the city dwellers comes from tube-wells. Table 1.1 shows the population coverage by various sources of water supply.

Table 1.1: Existing Water Supply System in Khulna City Corporation (Source: ERMAP for Khulna, 2002 [32])

Area	Estimated Population	Source	Population Coverage (%)
KCC	847,500	- Piped Water	25.7
		- Street Hydrant	4.5
		- Tube Well	63.8
		- Others (pond, river, well, etc.)	6.0

The population of Khulna City is increasing day by day and thus increasing water demand. To meet the future water demand in Khulna the provision of extension of GW development is very limited. Meanwhile salinity intrusion during several months of surface water surrounding rivers is the most significant issue for development of future drinking water resource for Khulna people. Therefore, to fulfill the future water demand it is very essential to use the GW and surface water in a combined manner.

1.8 Justification of study

GW quality is also influenced by the effects of human activities which cause pollution at the land surface because most GW originates by recharge of rainwater infiltrating from the surface. The rainwater itself may also have an increased acidity due to human activity. The unsaturated zone can help reduce the concentrations of some pollutants entering GW (especially micro-organisms), but it can also act as a store for significant quantities of pollutants, which may eventually be released. Some contaminants enter GW directly from abandoned wells, mines, and covered sewerage pipes which by-pass the unsaturated zone and, therefore, the possibility of some natural decontamination processes. So, before any monitoring and management of GW in any area the chemical, physical and biological characteristics of GW must have to be evaluated to identifying the quality of water we used. In this regard laboratory analysis is very much significant to fulfill the study.

Frequently people of our country are simply unconscious of the relationship between household water contamination (which occurs during collection on, transportation, storage and consumption) and disease. For example a study of the quality of drinking water in a slum area of Chittagong City found that about 80% of households were consuming contaminated water even though they had collected it from a tested safe and sound source, proving that fecal contamination had occurred at some stage between collection, storage, handling and consumption. The presence of coliform bacteria in stored water probably resulted from unhygienic water-handling practices.

CHAPTER II

Literature Review

2.1 General

Before embarking on to the study of any area of interest it is essential to look into the pertinent work previously done on it. Since it gives a fabulous insight about the topic and process of exploration of the research study. It helps in finding out the new horizons of research. Therefore this chapter is devoted for an analysis of various literatures available on water quality.

The quality of drinking water is a powerful environmental determinant of the health of a community. The problem of the quality of water resources in general, and groundwater resources in particular, is becoming increasingly important in both industrialized and developing nation especially in slum area. Slums are categorised by poor sanitation, overcrowded and crude habitation, inadequate water supply, hazardous location and insecurity of tenure. The people living in slums are highly vulnerable to different forms of risks- both natural and man-made their living conditions depict poverty in terms of both inadequate incomes and environmental deprivation. Studies show that slum poverty puts major stress on people's lives through pollution, congestion, noise, stagnant water and flooding. Households living in these poor surroundings have poorer health status, while the country has made substantial progress in water and sanitation. It has done poorly in improving the lives of people in slums and in providing quality of life for most of the urban poor.

When we use any portion of environment for our daily life it is necessary, or at least desirable, to adopt modernization that is compatible with the environment, i.e., that will have a sustainable impact. When aiming for environmental sustainability, groundwater and surface water play a leading role because they are of fundamental importance to mankind [33]. Therefore, developing countries like Bangladesh the essential concerns as regards water resources are their quantity, availability and suitability.

2.2 Ground Water Chemistry

The quality of groundwater depends on a large number of individual hydrological, physical, chemical and biological factors. Generally higher proportions of dissolved constituents are found in groundwater than in surface water because of greater interaction of ground water with various materials in geologic levels. The contamination of groundwater by heavy metals has assumed great significance during recent years due to their toxicity and accumulative behaviour. These elements, contrary to most pollutants, are not biodegradable and undergo a global eco-biological cycle in which natural waters are the main pathways [34].

Groundwater can be affected by the presence of elevated concentrations of inorganic and organic constituents that make the water unacceptable for potable use due to health concerns or due to negative aesthetic characteristics. The elevated concentrations of these constituents are derived from human activity and natural sources. In some cases, this water may be acceptable for non-potable uses in place of potable groundwater. Some mega or big-cities are allocated near shore or the groundwater resources are underlain by salt waters. In these cases excessive groundwater abstraction may force salt water to move either laterally or vertically into the fresh water, so deteriorating groundwater quality [35]. For evaluating the suitability of groundwater for different purposes, understanding the chemical composition of groundwater is necessary. Further, it is possible to understand the change in quality due to rock- water interaction (weathering) or any type of anthropogenic influence [36].

Site-specific characteristics such as soil type, depth of the aquifer, weather, season and the recharge rate of an aquifer all influence the probability and severity of a particular contamination incident. The saturated zone is recharged through the percolation of water through the unsaturated zone. Any contamination that has percolated through the unsaturated zone has the potential to reach the saturated zone, thereby contaminating the groundwater held in the saturated zone. Areas that are replenished at a higher rate are generally more vulnerable to contamination than those replenished at a lower rate. Large fractures in bedrock also contribute to contamination by providing a pathway for the contaminants [37]. Hasan *et al.* [38] shows that higher concentration of total iron in groundwater may lead to the encrustation and corrosion to deep tube-wells, which may deteriorate their efficiency in Thakurgaon District, Northern Bangladesh. Ahmed and Rahman *et at* [39] reveals that the watershed and fractured portions is shale and limestone that occur in the southernmost and central portion of watershed area constitute the productive water-bearing zones categorized as good groundwater potential aquifer. Sivasankaran and Ramesh [40] appears that the natural agencies are most predominant in controlling the groundwater chemistry than anthropogenic activities in Pondicherry Region, India.

A recent study has examined the relationship of groundwater As levels in alluvial aquifers with topographic elevation, slope, and groundwater level in Bangladesh. Results show that high As (> 50 μg/L) tube-wells are located in low lying areas, where mean surface elevation is approximately 10 m. Similarly, high As concentrations are found within extremely low slopes in the country. High As tube-wells are located mainly in the Ganges–Brahmaputra–Meghna delta, Sylhet Trough, and recent floodplains, where groundwater elevation in shallow aquifers is low with a mean value of 4.5 m above the Public Works Datum level. At low horizontal hydraulic gradients and under reducing conditions, As is released in groundwater by microbial activity, causing widespread contamination in the low-lying deltaic and floodplain areas, where As is being recycled with time due to complex biogeochemical processes [41].

Throughout Bangladesh ineffective water management, insufficient governance and the lack of infrastructure greatly affects water security, and drinking water. Also Bangladesh is susceptible to a variety of environmental stresses and natural disasters; these stresses can exacerbate the difficulties accessing potable water [42]. In Bangladesh, the main issues surrounding water quality are microbial pathogens, As in GW and salinity [43].

2.3 Slum Area Review

The burgeoning urban working classes moved into overcrowded and poorly serviced tenements, living in slum close to the factories and industrial plants that employed them. [44]. Slums are the product of rapid and unplanned growth of urban areas predominantly over the last 50 years. They accompanied the economic growth of cities as new industries created jobs and wealth attracting immigrants from beleaguered rural areas. Slums offered cheap and available housing in cities that promised more secure food and water security and public services [45].

According to World Bank Slum is an unhealthy area where basic amenities like water supply, drainage for standard living are lacking, unsanitary conditions prevail and diseases flourish. Slums have legal owner of its land. The ownership may be public, organizational or private. Squatter settlements contain the same unhygienic condition like slums having no legal owner of its land. Rapid urbanization and inadequate capability of the respective authority to manage with the housing needs of people in urban areas have contributed to the development of informal settlements. Living in these settlements often poses significant health risks. The sanitation and drinking water quality of the informal settlements are often poor. About 30 percent (9 million) of them are living under poverty level and about 17 percent (5 million) are living in slum areas [46].

The issues of urban environmental health arise because of the unrelenting process of urbanization in the developing countries. The health condition in the poor communities in the Third World cities is alarming as thousands of children still die every day from preventable disease related to the inadequate provision of water and sanitation [47]. Access to adequate clean water is vital for the health and economic prosperity of society. In many developing countries, the high rate of urbanization, the lack of Basic water infrastructure ,and ineffective enforcement of existing environmental regulations have resulted in the pollution of natural waterways [48].

Despite such interest in the environment and human health, around 4 billion cases of diarrhoea are reported in the world each year, killing some 2.2 million children under the age of five because of lack of access to adequate water and sanitation [49]. In the developing countries over five million children aged between 0-14 years die every year due to various disease such as malaria, dengue, acute respiratory infections and diarrhoea which are preventable and emanated from the poor environmental services [50].

A large number of people in Bangladesh lack access to potable drinking water. Among them, urban slum dwellers face the greatest challenges. Their water quality is affected by unsafe water supply, unhygienic sanitation facilities, poor solid waste management, unhygienic practices particularly with regard to hand washing, insecure land tenure, poor socio-economic backing, and crowded living conditions [51]. Over 37% of the city populations live in slums that occupy only 4% of city land. Slums are the most densely populated areas with over 200 times the normal density of Bangladesh at 531,000 persons per square mile. Overcrowding creates huge increases in communicable diseases like diarrhea [52]. In developing countries, slum people are living in urban communities and have to collect their drinking water some distances away from the household and transport it back in various types of containers. Microbiological contamination of the water may occur between the collection point and the point-of-use in the household due to unhygienic practices causing the water to become a health risk [53]. Feachem [54] stated that his study findings suggest that improved water quality, increased water availability and quantity associated with better hygiene practices, and improved sanitation facilities may reduce the ingestion of pathogens that cause diarrhea.

2.4 Review of previous study

Water supply systems and drinking water inaccessibility in developing countries is a global concern that calls for immediate action. About 884 million people in the world still do not get their drinking water from approved sources, and almost all of these people are in developing regions [55]. In Bangladesh natural disaster and man-made activity will significantly different environmental determinants of health including the water supply and sanitation and hygiene by increasing the rate of non-functionality, inaccessibility, unavailability and deteriorating the quality of water. This will cause spread of different types of water and vector borne infectious diseases with varying degree and magnitude considering the different geographic area of the country [56].

This interdisciplinary study has demonstrated that both groundwater and surface water drinking sources in the south-west coastal area of Bangladesh have levels of arsenic, salinity and a multitude of other contaminants above Bangladesh's drinking water criteria. The security and sustainability of drinking water supplies is clearly threatened, and is expected to continue to be as the population increases over time [57].

The real features of the quality of drinking water in slum-dwellers in KCC Areas and where meets the water quality standards are actually unknown. Khulna WASA is responsible exclusively for water supply and sanitation in KCC areas. But they have no adequate plan to ensure delivery of safe and potable water to the poor community [58]. Adhikary [59] covered 6 wards of central part in KCC area and the study shows that, only 1% of pH value exceeds BDS and WHO standards. The major finding of the study was evaluating of salinity of GW and during the study period, 76% samples exceeds WHO standard whereas 22% samples exceeds BDS allowable limits, which reveals that the study area have been facing tremendous salinity problem especially in non-monsoon period and water is unsuitable for drinking. In case of iron, 45% and 17% samples exceed WHO and BDS recommended values. Higher concentration of hardness (>500 mg/L) noticed in 58% of the samples, which lead to unsuitability of drinking. The samples exceeding WHO and BDS recommended. TDS values are only 16% but in case of alkalinity 8% samples exceed BDS recommended value. However, about 57% samples are exceeding the recommended EC value by BDS guidelines. Sikder et al [60] in recent times publicized that the groundwater of the western peri-urban fringe of the KCC is dominated by Na+ and Cl- ions. pH values reveal that the groundwater is alkaline in nature. The overall groundwater quality of the study area was evaluated by WHO and Bangladesh standards and found suitable for drinking purposes. But research regarding bacteriological status was showed that 36.36% pump water and 42.86% of household water were contaminated with fecal-coliform and coliform of non-fecal origin , this study conclude that study concludes that 71.43% drinking water sources of Khulna city are unsafe & not potable [61]. Also research work of Md Rahaman *et al.,* in slum area of KCC represent a huge fecal or microbial contamination of GW rather than physio-chemical contamination. This study covered the physio-chemical and biological properties of GW of 26 slum located in KCC [62]. A study conducted in rural Bangladesh showed water stored for longer period increase vibro cholera rate by 10 folds [63].

2.5 Objective of the Study

This research includes water quality testing of poor communities of KCC areas. The following are the objectives of the research work for carrying out water quality testing to ensure delivery of safe and potable water to the community. The specific aims are:

- to determine the physico-chemical condition of GW sources from slum communities of KCC area and to compare with levels obtained with the drinking water quality standard (WHO or BDS),

- to determine the microbial contamination of both TWs water and household stored drinking water from poor communities of KCC area ensuring the better health to the slum people,
- to investigate the actual reason of contamination of water in this area and
- to make awareness among the people regarding water quality and waterborne diseases of investigated area.

CHAPTER III

Methodology

This chapter includes how the total research has been carried out, i.e. collection of water samples, analyses of water samples, field investigation, and laboratory experiments for determination of physico-chemical and biological parameters, calculation techniques, assessment of groundwater. This also includes physiographic location and geologic structure of study area.

3.1 Water Sampling

GW is one of the reliable water resource for human consumption throughout the different parts of our country. Moreover when aiming for environmental sustainability, ground-water plays a leading role because it is of fundamental importance to mankind and thus the quality of water in slum or poor area may be distorted by many moderating object from surrounding environment. So it is urgent to assessment and determine the quality and characteristics of the ground water in a slum area where the community people are mostly dependent on this source of water. In order to assessment of the groundwater and to know its suitability for drinking purposes related researches were reviewed. Sample collection, data collection, an investigation survey has been conducted in different places of the slum area of KCC. This sampling, survey and analysis has helped to realize the existing condition of the area.

3.1.1 Selection of the Study Area

Selection of the study area is very much momentous for any study. It is remarkable that the ultimately success of any research work fully depends on the selection of the study area. Urban slum area is a much-talked issue of present time that seeks effective attention. Some studies have been conducted on this issue in the country. But most of them have considered the issue of capital city Dhaka and its peripheral areas as the capital city surely has due importance from various points of view. As Khulna is one of the divisional city of the country and Khulna city is the third largest city of Bangladesh. This city is rapidly being urbanized and also an industrial city. A large number of poor community is growing up. There are 520 slums in KCC. The population of Khulna City is over 1.5 million among them 188,442 are poor and landless. It is located in the southwestern region of the country, which is bounded by latitudes 22°46'0"–22°58'0"N and longitudes 89°28'0"–89°37'0"E. The city has an elevation above mean sea level of 9 m in the north to 2 m towards the SW. It covers an area of 37 km^2; however, the city and its outskirts are expanding continuously owing to rapid grow without basic urban facilities. Potable water safety is one of them. Considering all these, 50 different located slums of Khulna city has been chosen for the study. The sample area (slum of KCC) of the present study have been selected on the basis of size and location pattern and other essential characteristics which are essential aspects for the study.

The criteria of this selection include:

- Khulna is one of the most unique dense regions of Bangladesh and is, therefore, subject to pollution.
- Slums of the Khulna city is the unplanned residential area in the context of its dense population and defective environmental management system towards human health.

3.1.2 Collection and analysis of water samples

The study was conducted on the slum area of KCC. 100 water samples were collected from 50 different slums located in KCC area, shown in Figure 3.1(A) and 3.1(B)

Figure 3.1(A): Water sample collection from Tube-well

Figure 3.1(B): Water sample collection from Household

Each sampling location includes one deep tube-well and one household water sample. Sampling was done directly from drinking-water sources, and household water were collected from stored vessels or in case of a drinking cup which they use for their drinking purpose. In most (89%) households, transport vessels also served as storage vessels. The sample and data was collected during the time period from July 22, to August 28, 2016. All sort of laboratory analyses were accomplished in Khulna Public Heath Office zonal Laboratory Rupsha, Khulna.

Table 3.1: Sampling station ID

Sample No.	Sources Sample ID	Household Sample ID	Sample Station	Ward No.
1	S-1	H-1	Moksed goli, Rupsha	22
2	S-2	H-2	Mumshi Bari, Rupsha Ghat	29
3	S-3	H-3	Sat Vai goli, Notun Bazar chor goli, Rupsha	22
4	S-4	H-4	2 no. customs ghat, beri badh Road, Kagoji Bari.	22
5	S-5	H-5	Motiakhali pancham goli	31
6	S-6	H-6	Rupsha Mach bazar boshti	30
7	S-7	H-7	Mohi barir mor, south tootpara.	28
8	S-8	H-8	Chotokhal Para, circuler Road, Tootpara.	30
9	S-9	H-9	Daroga Para	28
10	S-10	H-10	Bulbuler Bosthi	28
11	S-11	H-11	Shekh Bari Modina Mosjid, Motlober Mor	27
12	S-12	H-12	Barek Member Bari, Khulna	27
13	S-13	H-13	Binodini Hospital, Halim Uukil Bosthi. Mia para	28
14	S-14	H-14	Commerder Bari, Mia Para	28
15	S-15	H-15	Nazrul Islam sarak, Karpara, Khulna sadar	28
16	S-16	H-16	Mistripara Khalpar slum, Purba Bagmara.	27

17	S-17	H-17	Slum of Mr Jalil, Purba Bagmara, Khulna Sadar	27
18	S-18	H-18	Mushir Goli, 2 no. cross Road	24
19	S-19	H-19	Nirala Dhighir paar	24
20	S-20	H-20	No-4, Kasem nagor road, Gollamari Dakshin	24
21	S-21	H-21	Gollamari Bridge Side	24
22	S-22	H-22	Gollamari Rishi Para	25
23	S-23	H-23	Bil slum(khora slum), Sonadanga	17
24	S-24	H-24	Sonadanga slum	17
25	S-25	H-25	Biswas Bari, Khalasi, Uttar Gobarchaka Main Road	18
26	S-26	H-26	5 no. Mach Ghat Rail colony	21
27	S-27	H-27	Greenland Abasik Rail colony	21
28	S-28	H-28	7 no. Ghat Kacha Bazar	21
29	S-29	S-29	Boroi tola Railway colony	21
30	S-30	H-30	Joragate Monur Colony	21
31	S-31	H-31	Noyabati Siddik Munshir Bari, Khalishpur	10
32	S-32	H-32	No-2 Platinum Jublee Labour Colony, Khalishpur	11
33	S-33	H-33	Kashipur Pora Bari, Lkhalishpur	7
34	S-34	H-34	Rajanigandha Colony(Cricent Jute Mill) Khalishpur	8
35	S-35	H-35	Camp no. 7, old Colony Khalishpur	12
36	S-36	H-36	3 no. Camp, Khalishpur	12
37	S-37	H-37	Alam Nagar Pora Mosjid, Khaluishpur	13
38	S-38	H-38	GMB bastuhara colony	9
39	S-39	H-39	Mujguni Rail Crossing Road	9
40	S-40	H-40	Gabtola Slum Railway, Khalishpur	15
41	S-41	H-41	Ispahani Laboure colony	3
42	S-42	H-42	Palpara, Doulotpur	3
43	S-43	H-43	Raligate Resir Bagan	2

44	S-44	H-44	Nogor Ghat Raligate	2
45	S-45	H-45	Helal colony , Doulotpur	3
46	S-46	H-46	Diyana Uttor para	4
47	S-47	H-47	Anjuman Road Amtola	5
48	S-48	H-48	Rishi para Doulotput	5
49	S-49	H-49	Pabla teen dokaner Mor	5
50	S-50	H-50	Kawser bosthi, Kashipur	6

3.1.2.1 Sampling procedure

a) For Physico-chemical parameter analysis

It is the most important part of the present study for the degree of accuracy of analytical results. Every possible precaution was taken to obtain a non-contaminated sample. Water sample was collected in high density polyethylene (HDPE) bottle. The containers (500 mL) (Shown in Figure 3.3) were washed with detergents, followed by tap water and finally several times with distilled water before sampling, and lastly dried it properly. Water sample was filled into the bottles completely and was closed by the caps tightly. Then it was stored at a low temperature for analyzing. Analysis of samples, the samples were done without delay preferably within 2 days.

Figure 3.2: Sample container for physico-chemical parameter analysis

b) For Microbiological analysis

All possible ways of contamination were avoided at best. The water sample was collected in 200 mL (Shown in Figure 3.3) sterilized borosilicate glass bottles. It is secured to keep 10-20% free space at the top of sample bottles. Residual chlorine was avoided by using sodium thiosulphate. Bacteriological test was done immediately (within 4-8 hours) after sampling. While it is desired to conduct the test within 6-12 hours. Sometime (in case of necessary) the sample were stored in ice box bellow 4 °C.

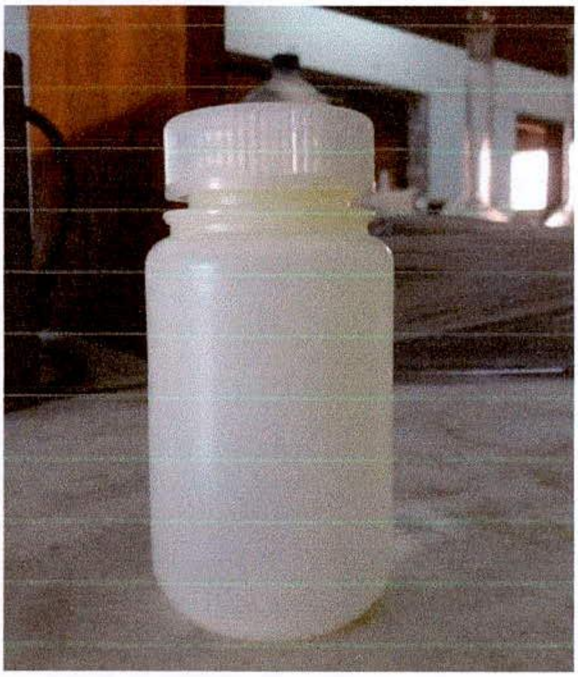


Figure 3.3: Sample container for microbiological parameter analysis

3.1.3 Household survey

In order to collect primary data relating to human health and environmental aspects/issues at the household level a household survey was carried out. In all 50 sample households were interviewed in 31 Wards of KCC slum area. The sampling technique used in conducting the household survey and the questionnaire used for the survey purposes is presented later. A group of field investigators was engaged to conduct the whole household level survey work.

3.1.4 Analysis of water samples

To measure quality of the collected sample the following tests were performed in respect to health hazard in the ground water of the study area.

Table 3.2: Selected Physico-chemical and Biological parameters for analysis

Physical	pH
	EC
	TDS
Chemical	Hardness
	Chloride (Cl^-)
	Iron(Fe)
	Manganese (Mn)
	Arsenic (As)
Biological	Fecal coliform (FC)
	Total coliform (TC)

3.2 pH Determination

pH of any solution was measured by pH meter/Ion meter. There are combined electrodes like one selective electrode another one reference electrode. Probe/electrode was set up with pH meter. pH was measured by introducing the probe/Electrode into the solution.

Apparatus

i) Ion/pH meter (model: Metrohm-781) shown in Figure 3.4

ii) Beaker

iii) Glass rod etc.

Reagents

Three type of standard solution (STD) were used to calibrate the pH meter. Standard solution were preserved in 25 °C. They are mentioned here.

(i) Phthalate pH Standard Solution (STD-1) (pH-4.01)

(ii) Phosphate pH Standard Solution(STD-2) (pH-6.86) and

(iii) Carbonate pH Standard Solution (STD-3) (pH-10.01)

Procedure

Before Calibration inner and outer Solution was checked. The black rubber portion was opened and inserted liquid junction (KCl Solution) into the electrode. Before using the Electrode it was sink in the water at least for one hour. Then Electrode was ready for the next experiments. STD set or Calibration of the pH meter (shown in Figure 3.4) were performed by three different standard solutions (STD-1 pH 4.01, STD-2 pH 6.86, and STD-3 pH 10.01) before doing experiment for unknown samples. Samples were tested by standard electrometric method [64] and data were recorded for the analysis of results.

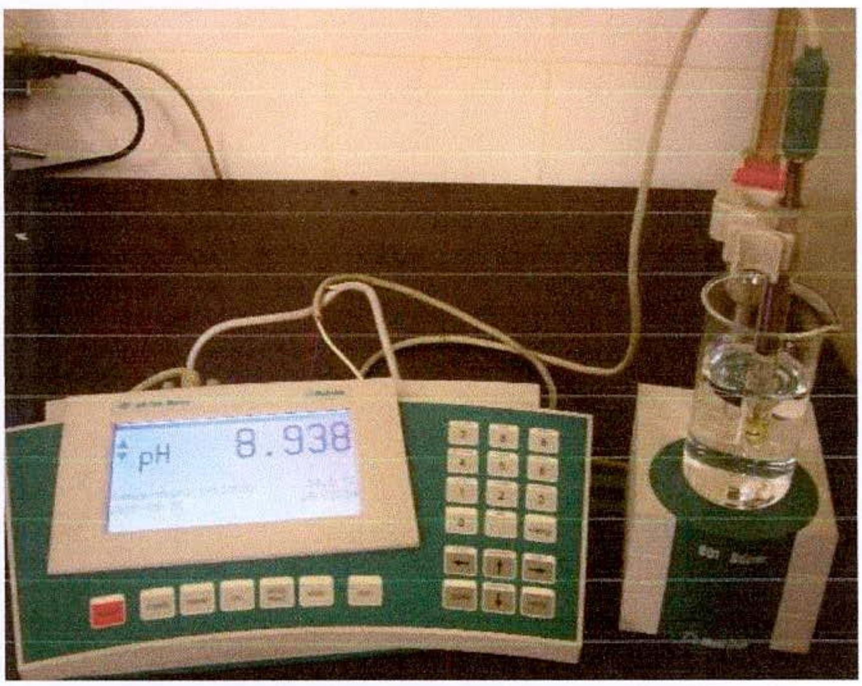
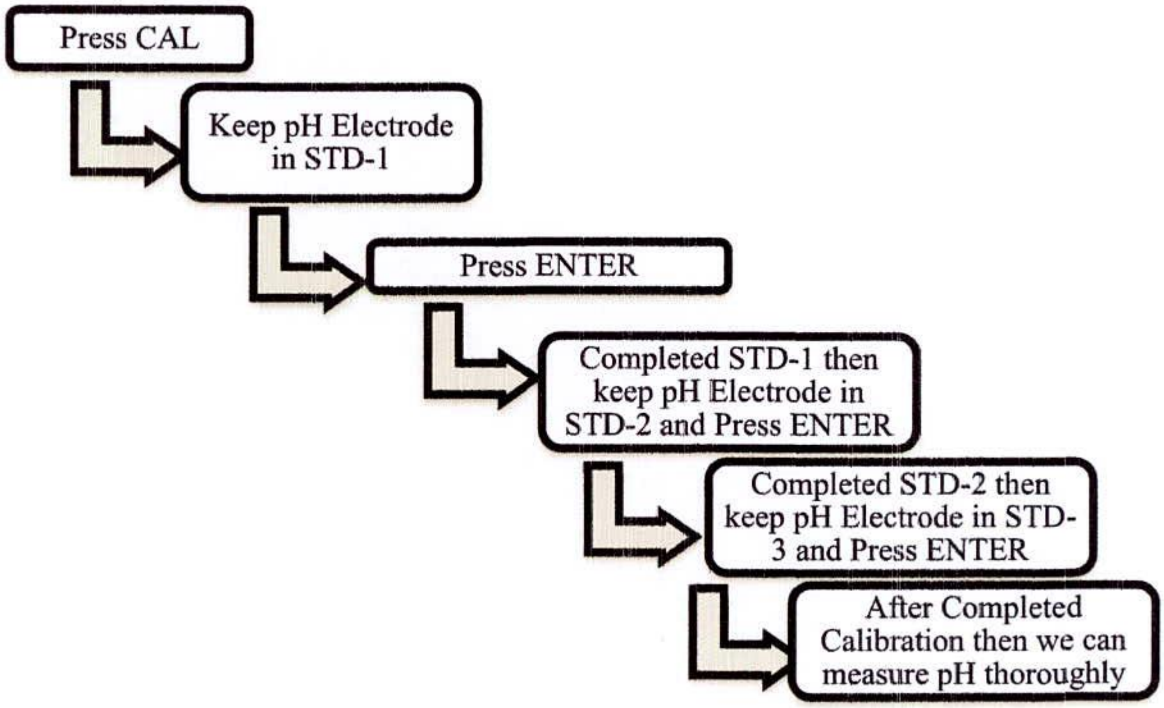


Figure 3.4: Ion/pH Meter (Model: Metrohm-781)

Flow Chart for pH Calibration



3.3 Determination of Electrical Conductivity (EC)

HACH Multi meter (model: HACH Sension-156) was used to measure the EC of the solution. The conductivity probe was fixed as it should be with Multi meter. EC assessments the total amounts of TDS (mg/L) or the total dissolved ions in water. We can develop awareness about the salinity and TDS from EC. It also assesses degree of mineralization of distilled and de-ionized water. EC estimates whether the sample water contains sewage, industrial drainage and seawater

Apparatus

i) Multi meter (model: HACH Sension-156), shown in Figure 3.5

ii) Beaker,

iii) Glass rod etc.

Reagents

i) NaCl (1000 μS/cm) standard solution was used to calibrate the multi meter. It was produced by dissolving 49.1 mg extra pure NaCl in 100 mL distilled water.

ii) Deionized water was used for cleaning and washing the sensor.

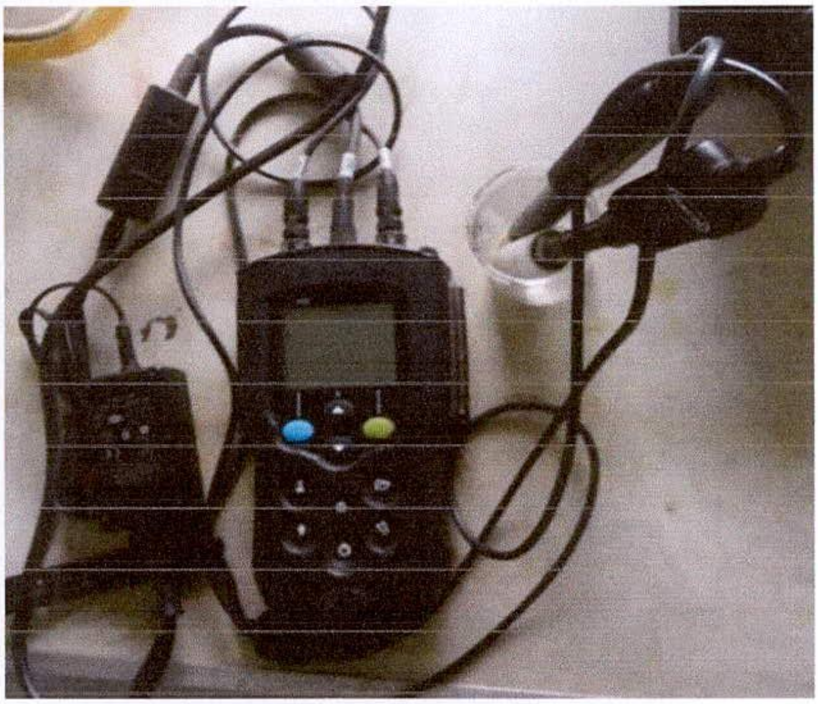
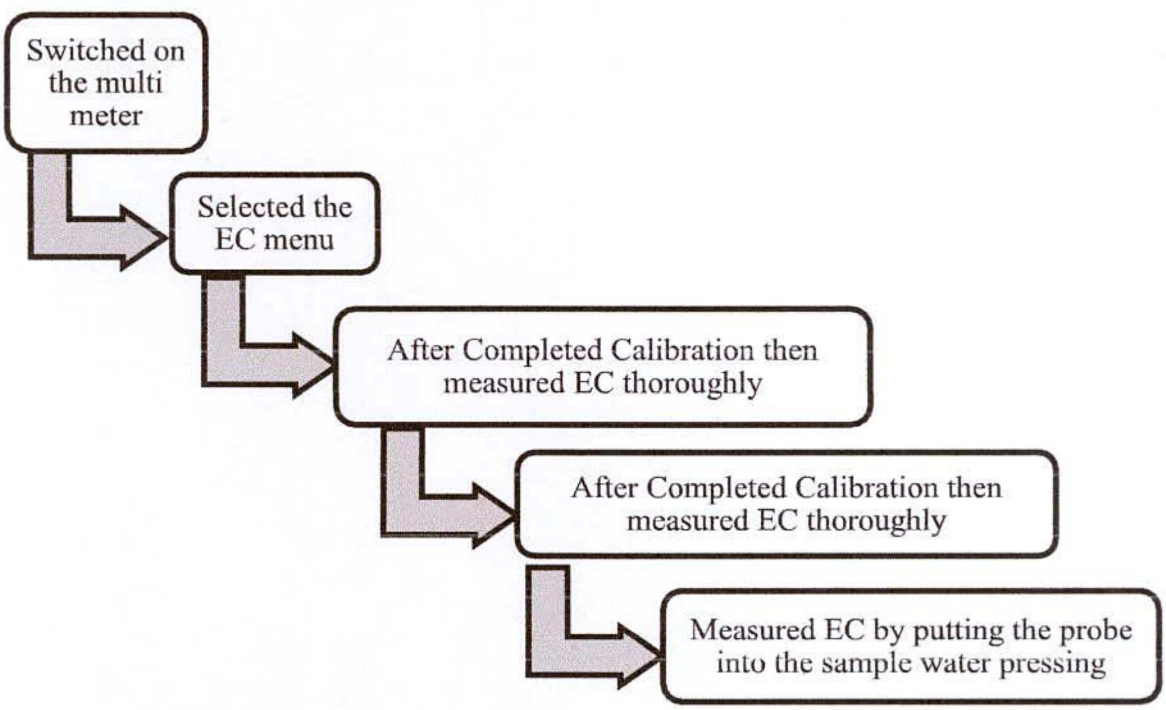


Figure 3.5: Multi meter (Model-HACH - Sension-156)

Procedure

EC of different samples were performed by the standard method [64] given the following flow chart and data were noted after the analysis of results.

Flow Chart for EC determination



3.4 Determination of Total Dissolved Solids (TDS)

The presence of high levels of TDS in drinking water may be objectionable to consumers. A well-mixed sample was filtered through a standard glass fiber filter, and the filtrate was evaporated to dryness in a weighed dish and dried to constant weight at 180 °C.

Relation of TS (total solids), TDS (Total dissolve solid) and SS (Suspended Solids) is,

$$TDS\ (mg/L) = TS\ (mg/L) - SS\ (mg/L)$$

Apparatus

i) Oven, ii) Vacuum Pump, iii) Suction flask, iv) Forceps, v) Beaker, vi) Cylinder, vii) Evaporating dish, viii) Bulb pipette, ix) Glass fiber filter, etc.

Procedure

TDS was done by using Standard Gravimetric Method [65]. The evaporating dish was washed, dried and weighed (a mg) properly. The vacuum pump, suction flask, forceps, beaker, cylinder, evaporating dish, bulb pipette, tissue paper were made ready for the experiment. The glass fiber filter (1 μm pore) was put on filter disk and assembled filtration apparatus for filtration. 50 mL sample was taken in a 50 mL cylinder and poured it in suction flask and sucked by turning motor on. Then it was transferred carefully, the filtrated sample 25 mL (v mL) in an evaporating dish using bulb pipette. The evaporating dish was transferred in oven, heated at 105-110 °C for 2 hours. The evaporating dish was shifted in desiccators for cooling at room temperature. Evaporating dish was weight (b mg) again of by electric balance. Calculation of TDS was done by using the following equation:

$$TDS\ (mg/L) = \{(b-a)/v\} \times 1000$$

The determined result is expressed with two significant figures.

Precautions

1. Evaporating dish was handled carefully.
2. After evaporation weighted was taken at room temperature keeping in desiccators.
3. To meet the good precision 50 mL of sample was taken for each experiment.

3.5 Hardness Analysis

Hardness of water was determined by EDTA Titrimetric Method [66]. In titrimetric analysis volumetrically measures the amount of reagent, often called a titrant, required to complete a chemical reaction with the analyte. A generic chemical reaction for titrimetric analysis is

$$aA + tT \rightarrow Products$$

Where, a moles of analyte A contained in the sample reacts with t moles of the titrant T in the titrant solution. The reaction is generally carried out in a flask containing the sample. Titrant solution is volumetrically delivered to the reaction flask using a burette. Delivery of the titrant is called a titration. The titration was completed when sufficient titrant has been added to react with all the analyte. This is called the equivalence point. An indicator was added to the reaction flask to signal when all of the analyte has reacted. The titrant volume where the signal is generated is called the end point. The equivalence and end points were rarely the same.

This method is applicable to drinking, surface, and saline waters and domestic and industrial wastes. The method is suitable for all concentration ranges of hardness. Calcium and magnesium ions are the primary sources of hardness in aqueous samples. Samples were titrated with a di-sodium ethylenediamine tetraacetate solution (EDTA solution). The EDTA chelates the calcium and magnesium ions in the sample. The end point of the reaction was detected by means of Calmagite indicator, which had a red color in the presence of calcium and magnesium and a blue color when the cations were chelated by EDTA. The volume of EDTA solution was used; the total hardness in the sample is calculated and reported in units of mg/L $CaCO_3$.

Apparatus

Apparatus which were used for measuring hardness of water are Conical flask, Volumetric flask, Burette, Pipette, Pipette filler, Wash bottle, Tissue paper, Indicator bottle with dropper, Burette stand, Desiccators, etc.

3.5.1 Reagent

3.5.1.1 Preparation of 0.01M Standard EDTA Solution:

3.723 g EDTA was taken in a beaker and dissolved with small amount of distilled water. Then the solution was transferred in 1000 mL volumetric flask and makeup the volume with distilled water.

1 mL solution ≡1 mg $CaCO_3$.

3.5.1.2 Preparation of 0.01M Standard Calcium Solution:

1.0 g Calcium Carbonate ($CaCO_3$) was taken in a beaker and added small volume of 1:1 HCl to dissolve the $CaCO_3$. Then added it to distilled water 200 mL and boiled the solution few minute to expel CO_2. Methyl red was added 1/2 drops into the solution and added 1:1 HCl or NH_4OH (3N) to adjust orange color. The solution was transferred in 1000 mL volumetric flask. Total volume was made by adding distilled water up to the mark carefully.

3.5.1.3 Preparation of Buffer Solution (250 mL solution), NH_4Cl-NH_4OH: 16.90 g Ammonium Chloride was taken in a 250 mL beaker. Then it was dissolved with small amount of de-ionized water. 143 mL conc. ammonium hydroxide and 1.25 g magnesium salt of EDTA were added and was diluted the mixture to 250 mL with de-ionized water.

3.5.1.4 Preparation of Eriochrome Black T (EBT): 0.25 g Sodium salt of 1-(1-hydroxy-2-naphthylazo)-5-nitro-2-naphthol-4-sulfonic acid was dissolved in 50 g triethanolamine. 2 drops of EBT was added per 50 mL solution to be titrated.

Distilled or de-ionized water was used throughout the analysis if necessary.

3.5.2 Standardization of Na_2EDTA with Calcium ($CaCO_3$) Solution:

10 mL Calcium ($CaCO_3$) Solution was taken and diluted to about 50 mL in a conical flask. 2.0 mL buffer solution was added to it and then 1-2 drops of Erio-chrome Black T indicator was added. Finally EDTA titrant was added slowly until a radish to blue color end point was found.

3.5.2.1 Calculation

Strength of Na_2EDTA, in case of taken standard $CaCO_3$ 10 mL

$$V_1S_1=S_2V_2$$

$$S_2 = V_1S_1/V_2$$

Where, V_1= Taken 10 mL standard $CaCO_3$, S_1= Strength of standard $CaCO_3$ (0.01M), V_2 = used titrant of Na_2EDTA, S_2=? (Strength of Na_2EDTA).

Procedure

50 mL of samples was taken in the conical flask. 2.0 mL buffer solution was added to it and then added 2 drops of Eriochrome Black-T indicator. Finally EDTA titrant was added slowly with continuous stirring until the blue color end point was found.

Calculation

1.0 mL 1.0 M EDTA ≡ 1.0 mL 1.0 M $CaCO_3$ ≡ 100 mg of $CaCO_3$ ≡ 40 mg of Ca ($CaCO_3$)

$$\text{Hardness as mg } CaCO_3/L = \frac{A \times B \times 1000}{\text{mL of Sample}}$$

Where, A = mL titrant for sample, B = mg $CaCO_3$ equivalent to 1.00 mL EDTA titrant

(0.01mol/L EDTA equivalent 1 mg $CaCO_3$)

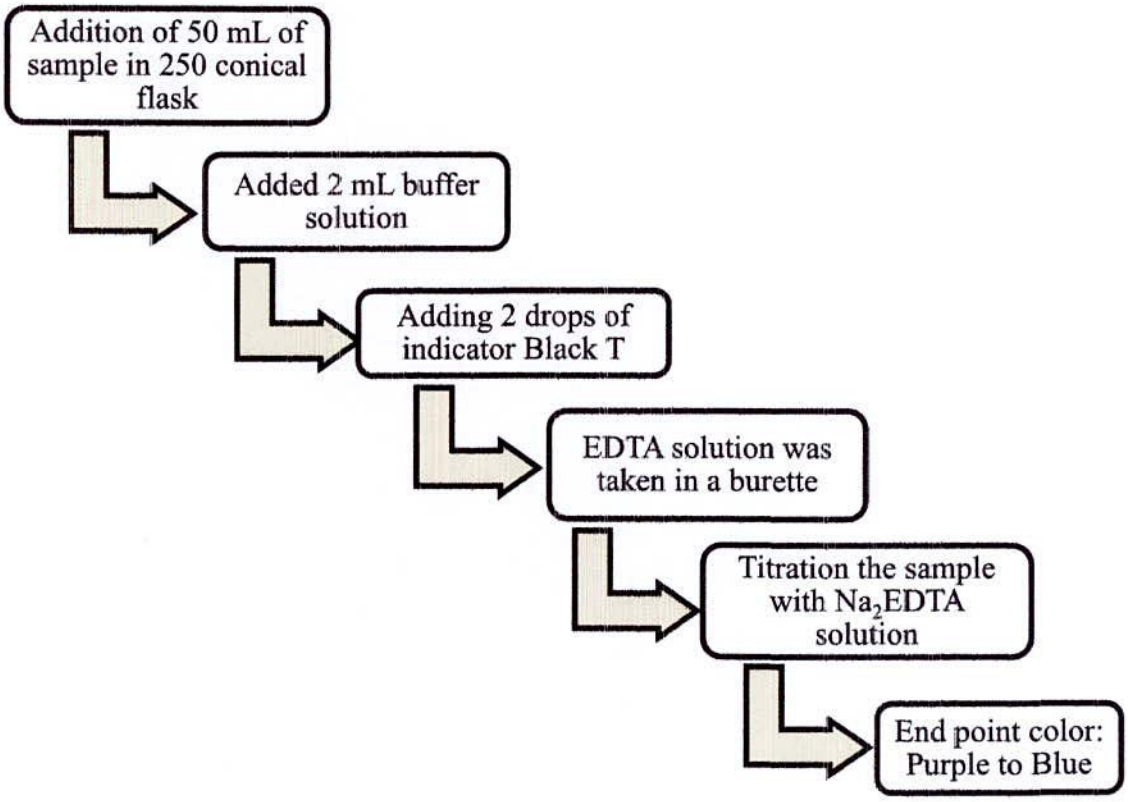
$$1\text{mL of } 0.01 \text{ mol/L EDTA} = (0.01/1000) \times 100 \times 1000 = 1 \text{ mg}$$

$$[1L= 1/1000 \text{ mL} \ \& \ 1g=1000 \text{ mg}]$$

$$CaCO_3=40+12+48=100 \text{ g}$$

Hardness (EDTA), as mg $CaCO_3$/L = 20 A, where A= mL titrant for 50 mL sample

Flow Diagram for Hardness Analysis



3.6 Chloride Analysis

Potassium chromate indicate the end point of the silver nitrate titration of chloride in a neutral or slightly alkaline solution. Silver chloride is precipitated quantitatively before red silver chromate is formed. Standard Argentometric Method was used to determine the amount of Chloride [67].

Apparatus

Apparatus which were used for measuring chloride of water are Conical flask, Volumetric flask, Burette, Pipette, Pipette filler, Wash bottle, Tissue paper, Indicator bottle with dropper, Burette stand, Desiccators, Stirrer, Magnate etc.

3.6.1 Reagents

3.6.1.1 Preparation of Indicator:

Potassium Chromate Solution was used as indicator. 5.0 g K_2CrO_4 was dissolved in a little distilled water. $AgNO_3$ solution was added until a definite red precipitate is formed. Then it was kept for 12 hours, then the resulting mixture was filtered and finally it was diluted to 100 mL with distilled water.

3.6.1.2 Preparation of 0.014M Standard Silver Nitrate:

$AgNO_3$ was used as titrant. 1.1975 g $AgNO_3$ was dissolved in a little distilled water and was diluted to 500 mL. Then it was standardized by Standard Sodium Chloride Solution.

3.6.1.3 Preparation of 0.014M Standard Sodium Chloride Solution:

412.0 mg NaCl was dissolved (dried at 140 °C) in a little distilled water and was diluted to 500 mL. 1.0 mL solution = 500 μg Cl. De-ionized water was used throughout the experiments (if necessary).

3.6.2 Collection of Samples

Water sample was collected in 500 mL high density polyethylene (HDPE) bottle (shown in Figure 3.2). Before sampling the bottle was washed with detergents, followed by tap water and finally several times with distilled water. Water sample was filled into the bottles completely and was closed by the caps tightly. Then it was stored at a low temperature prior to analysis. Analysis of samples the samples were done without delay preferably within 2 days. Agitation of samples and prolonged exposure to air was avoided.

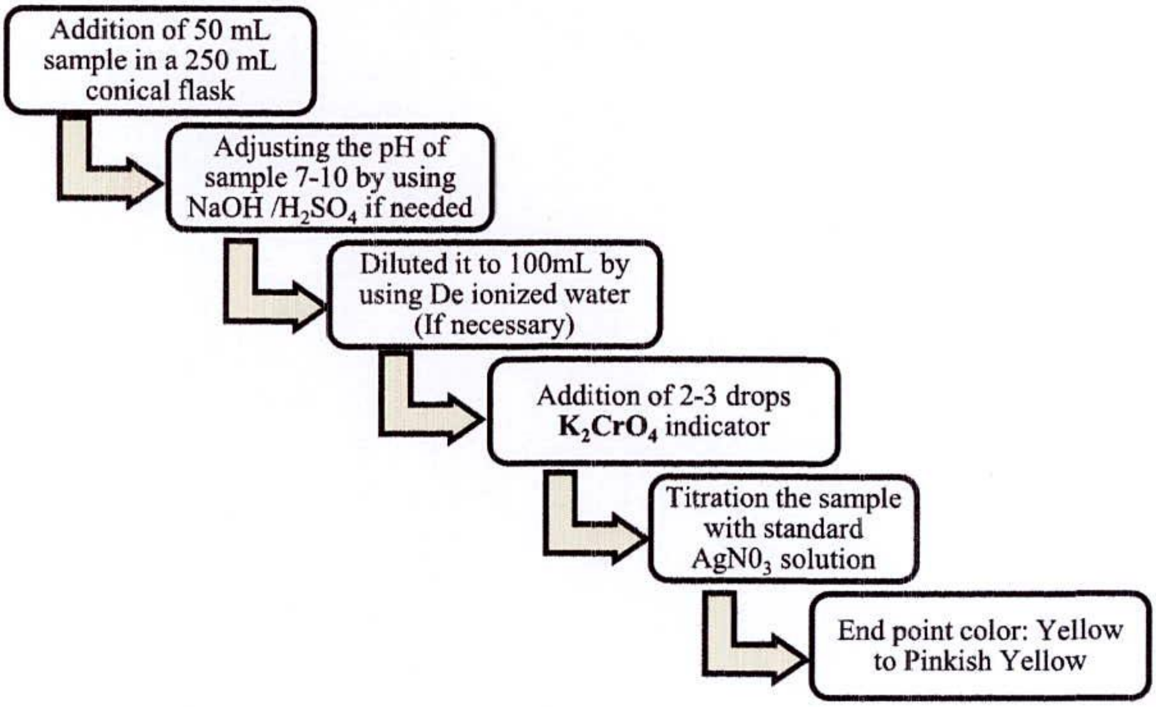
Procedure

50 mL of samples was taken in the conical flask. pH of the sample was adjusted to 7-10 with H_2SO_4 or NaOH. 2-3 drops of K_2CrO_4 indicator solution was added. Titration was completed with standard $AgNO_3$ until a pinkish yellow end point was found. A similar procedure was done for the blank.

Calculation:

$mg\ Cl^-/L = \frac{(A - B) \times N \times 35450}{mL\ of\ Sample}$; Where, A = mL titration for sample, B = mL titration for blank and N = normality of $AgNO_3$

Flow Diagram for Chloride Analysis



Titration the Blank at the same procedure (0.2-0.3 mL of $AgN0_3$ is usual).

3.7 Analysis of Arsenic

Arsenic of samples were estimated through Hydride Vapor Generation (HVG) method by means of Atomic Absorption Spectrometer (AAS Varian-220) [68]. The analyte is pre-reduced by appropriate technique. Arsenous acid the As(III) oxidation states of arsenic is instantaneously converted by sodium borohydride reagent in acid solution to its volatile hydride. The hydride is purged continuously by argon into a quartz cell heated by Electro Thermal Controller (ETC). The sodium borohydride reducing agent, by rapid generation of the elemental hydrides in an appropriate reaction cell, minimizes dilution of the hydrides by the carrier gas and provides rapid, sensitive determinations of arsenic.

$$As^{5+} + KI \rightarrow As^{3+}$$

$$NaBH_4 + HCl + 3\ H_2O \rightarrow \quad H_3BO_3 + NaCl + 8H^+$$

$$As^{3+} + 8H^+ \rightarrow \quad AsH_3\ (g) \quad + H_2\ (g)\ (Excess)$$

Arsine gas is produced only with As(III), reduction of As(V) to As(III) by KI. Arsine (AsH_3) gas is atomized in the quartz cell by 925 °C. Absorbance of light from the Hollow Cathode lamp (UV region) by the atomic plasma of As in the light path is proportional to As concentration, according to the Beer's Lambert's law of light absorption.

$$\text{Absorbance} = A = -\log I_0/I = -\log T = abc.$$

Where, I is the intensity of light of the radiation (Initial I_0 and transmitted I), path length = b (cm), a = absorptivity co-efficient, c= concentration.

3.7.1 Cautions

Arsenic and its hydrides are very poisonous. So, extra care was taken to handle it. Potassium Iodide was used for pre-reduction of As(V). Taking measured to baseline drift, because the stability of hollow-cathode lamp for these elements is not good.

3.7.2 Interferences

Low concentrations of noble metals (approximately 100 μg/L of Ag, Au, Pt, Pd, etc.), concentrations of copper, lead, and nickel at or greater than 1mg/L, and concentrations between 0.1 and 1 mg/L of hydride-forming elements (Bi, Sb, Sn, and Te) may suppress the response of As. Interference by transition metals depends strongly on HCl concentration. Interferences are less pronounced at 4N to 6N HCl than at lower concentrations. The presence of As or Se in each other's matrices can cause similar suppression. Reduced nitrogen oxides resulting from HNO_3 digestion and nitrite also can suppress instrumental response for both elements, $KMnO_4$ too.

3.7.3 Apparatus

1. Conical (Erlenmeyer) flasks: acid-washed and rinsed with water.
2. Volumetric flasks: used in different sizes
3. Watch glasses: Ribbed and unrobed
4. Pipettes: Used in different sizes
5. Beakers: Used in different sizes
6. Atomic Absorption Spectrophotometer(AAS): Model:AA-220,VARIAN, Australia Method: HVG-AAS, Wave length range : 180-900 nm
7. Hydride Vapor Generator
8. Electro Thermal Controller (ETC-60) with workhead.

Figure 3.6: Atomic Absorption Spectrophotometer (VarianAA-220)

3.7.4 Reagents

3.7.4.1 Preparation of 5M HCl Hydrochloric acid:

208 mL conc. HCl was diluted to make 500 mL with ultra-purified water. Concentrated HCl was handled under a fume hood.

3.7.4.2 Preparation of Sodium borohydride reagent (0.6% $NaBH_4$ solution):

2.5 g NaOH and 2.0 g $NaBH_4$ was dissolved with distilled water in 500 mL volumetric flask. The reagent was prepared immediately before use.

3.7.4.3 Preparation of 20% Potassium Iodide (KI) pre reluctant solution:

20g KI was dissolved in 100 mL volumetric flask with ultra-purified water. The solution was prepared fresh daily before analysis.

3.7.4.4 Preparation of As reference standard solution, 1000 mg/L:

Commercially available standard; Stock As solution (1000 ppm).

3.7.4.5 Preparation of 1st Intermediate As Solution (1ppm):

1 mL stock As solution (1000ppm) was diluted to 1000 mL with ultra-purified water.

3.7.4.6 Preparation of 2nd Intermediate As solution (100 ppb):

10 mL of 1st intermediate solution (1ppm) was diluted to 100 mL with ultra-purified water containing the same concentration of acid used for sample preservation.

3.7.4.7 Preparation of working standard solution (0 ppb, 5 ppb, 10 ppb, 15 ppb and 20 ppb):

Transferred 0 mL, 5 mL, 10 mL, 15 mL, & 20 mL from 2nd intermediate standard solution (100 ppb) and diluted to 100 mL volumetric flask with little ultra-purified water. Then 10 mL conc. HCl & 10 mL KI solution (20%) was added in each volumetric flask. Finally the flask was up to the mark with ultra-purified water.

3.7.4.8 Carrier gas:

Argon (commercial grade) was used as a carrier gas that was supplied by Linde Bangladesh formerly named BOC.

3.7.6 Sample preservation for As analysis

Samples were preserved immediately after sampling by acidifying with concentrated hydrochloric acid (HCl) of which pH is usually <2. 1 to 2 mL conc. HCl was sufficient for short-term preservation. Commercially available high-purity acid (37%) was used. After acidifying the sample was stored in a dark cool room to prevent change in volume due to evaporation.

3.7.7 Sample preparation and analysis

Potassium Iodide [KI (20%)] and HCl (10%) were used for reduction of Arsenic(V) to Arsenic(III).

3.7.8 Procedure

3.7.8.1 Pre-reduction

90 mL sample was taken in a volumetric flask. 5 mL conc. HCl and 5 mL 20% KI were added as pre-reductant solution. The solution was mixed well and leave to dark at least for 30 minutes.

3.7.8.2 Operation of AAS

Detailed operation procedure of Atomic Absorption Spectrophotometer is shown in below.

3.7.8.3 Operation HVG-AAS

The exhaust Duct was turned on. The Quartz cell was Set into the work-head of ETC-60. Then the Hollow Cathode lamp was set up. The UPS was turned on. Later both AAS-220 spectrophotometer and the computer were turned on one after another. The rinse tank was filled with ultra-pure water and the tubing of HVG was connected correctly. Argon gas supply was opened and supply pressure of the gas was adjusted. The secondary valve was made loose and then the primary valve was opened clock wise. The secondary valve was tighted and set the Ar gas pressure at 0.35MPa or 3.5 kg/cm^2. All tubes were put in water. The HVG was switched on and the flow rate was set for reductant and acid 1 mL/min, 6-7 mL for sample. Then the HVG tubes were put in corresponding reagents. The nozzle of auto sampler was set. The heater was turned on (Run →method→ As →start). The program of AAS was opened by double click Spectra icon on the desktop of the computer. All the required option in the software was filled up and also the label window by sample ID was filled. Finally analysis window was opened and click START icon to start analysis. After analysis the water sample the AAS was shut down according to Standard Operating Procedure (SOP).

3.7.8.4 Data Acquisition, Calculations & Data Reduction requirements

In this AAS system, construction a calibration curve by plotting peak areas of standards versus concentration of standards, measuring peak areas of samples and reading concentrations from curve were computerized. Therefore, reported concentrations can be read directly after standard calibration and actual concentrations were calculated by diluted factors.

Where: As mg/L = reported concentration multiply by dilution factor.

If the %RSD value more than 10 (ten) then the data will be discarded. The %RSD value less than 10 (ten) data will be accepted.

3.7.9 QA/QC (Quality Assurance/Quality Control)

3.7.9.1 Blank test:

This method can provide very low range measurement, in the other word, it is highly vulnerable to contamination. The treatment blank was added for every analysis in order to know the contamination level.

3.7.9.2 Equipment

Glassware and small equipment had to keep clean from contamination. All glassware were cleaned by nitric acid and only used for metal analysis.

3.7.9.3 Chemical and reagent

All chemicals and reagents were analytical grade quality. Checked the contaminant assay provided by supplier.

3.7.9.3.1 Acids

Trace level of analytical grade acids (permitted for AAS) were used. Remaining acid wasn't returned to the storage bottle.

3.7.9.3.2 Metal Standard

Commercial metal standard (CRM) is available. Keep in the freeze (4-10 °C).

3.7.9.3.3 Laboratory water

Laboratory water had no detective concentration of metal to be analyzed by the analytical method. High quality laboratory water is one of the most important factors of analysis.

Laboratory ultra-purified water was used for dilution of reagents, samples, and blank analysis. The quality of Laboratory water is related directly to the analysis result. Therefore, the laboratory water used our laboratory was produced by three steps procedures as, distillation, deionization and ultra-purified water quality is set very high-class level (EC is 0.054 μS/cm).

3.7.9.4 Calibration

Performed initial calibration with a minimum of three concentrations of standards, and choose a highest concentration at the upper end of the calibration range. It was soured that the calibration range covers the analytical concentration values. In this testing, arsenic by HVG-AAS, the calibration curve includes some nonlinear portion of curve. Calibration curve was linear and its concentration range was selected by more than three point's calibration curve. Nonlinear portion had been discarded and prepared new leaner working calibration curve. The minimum correlation of coefficient for the calibration curve was specified. In this testing, a minimum value for the correlation of coefficient was set 0.995. Each calibration point was compared to the curve and if any point was not within this criterion, identify the unsuitable sources and corrected before sample testing.

Calibration verification is essential, but initial and suitable interval confirmation is enough because calibration curve has not change so significantly. Therefore, a verification of calibration by analyzing a standard at a concentration near the midpoint of the calibration range is set, and in this testing, Certified Reference Material (CRM) was used for this verification. In this testing, the calibration verification was set by % recovery. If % recovery is out of control, identify the unsuitable sources and corrected before sample testing.

Where: $\%\text{Recovery} = \frac{\textit{found value}}{\textit{true value}} \times 100$

3.7.9.5 Duplicate samples

Duplicates were the two samples taken at the same time from one location. In this testing, the maximum range was set within 20% of relative standard deviation (%RSD).

Where: $SD = \sqrt{\sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{(n-1)}}$ and n = total number of values.

3.7.9.6 Spike samples

Spike samples were used to evaluate measurement recovery in a sample matrix, As a minimum, one spike sample were set in one testing day. Spike samples were prepared from the known sample and the standard solution that used for making calibration curve. Different concentrations of spike samples were prepared against one known sample, plot these concentration on the graph, draw fitting linier line to y-axis, then read y-intercept of this fitting line and evaluate the results obtained from these one set of spike samples. The standard of result for spike test is set 75% ≦ the original concentration of the sample ≦ 125% in this laboratory.

3.7.9.7 Quantitation limit

Quantitation limit (QL) is one of the boundary values that can quantified and all quantitative measurement result must lie within this interval. Especially, minimum quantitation limit is significant because different laboratories will produce different minimum quantitation limit even though using the same analytical procedures, instruments, and sample matrices. QL is set tentatively by measuring laboratory blanks at least 7 times. Where:

QL = SDX10

SD = standard deviation of blank samples

When tentative QL is set, measure the tentative QL concentration of laboratory standard at least 7 times. Compute %RSD and QL is finalized if the %RSD is within 10%.

3.7.9.8 MDL and LOQ

Method detection limit (MDL) is defined as the minimum concentration of a substance that can measured and reported with 99% confidence that the analyte concentration is greater than zero. It was determined from analysis of a sample in a given matrix containing the analyte.

Limit of Quantitation (LOQ), or **Lower Limit of Quantitation (LOQ)**, is the level above which quantitative results may be obtained with a specified degree of confidence.

MDL and LOQ were determined by the following procedures.

1. Selected a sample which had a concentration near the estimated MDL (take 5 ppb As)
2. Prepared and analyzed 7 portions of selected samples.
3. Calculated the standard deviation of replicate sample measurement.

$$SD = \sqrt{\sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{(n-1)}}$$ Where, x =measured results, n= number of replication

4. Calculated the MDL and LOQ by following equation

MDL= Standard Deviation of 7 replicate analysis X 3.14

LOQ= Standard Deviation of 7 replicate analysis X 10

Present LOQ of Arsenic of this laboratory is 0.5 μg/L.

3.8 Analysis of Iron

Iron of the water samples were analyzed by direct Flame (Air-Acetylene) using AAS (Varian SpectrAA-220) [69]. In flame atomic absorption spectrometry, a sample is aspirated into a flame and atomized. A light beam is directed through the flame, into a monochromator, and onto a detector that measures the amount of light absorbed by the atomized element in the flame. The amount of energy at the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample over a limited concentration range. The sample is introduced into the flame atomizer. Target element is measured its absorbance and determined concentration by using calibration curve method.

3.8.1 Health & Safety Warnings

Sample and additives were sometime acidic and corrosive. The acetylene gas was flammable. Leakage of gas was checked carefully. Acetylene gas represented an explosive hazard in the laboratory wasn't allowed to contact with copper, silver or liquid mercury.

3.8.2. Interference

3.8.2.1 Chemical interference

Many metals are determined by direct aspiration of sample into an air-acetylene flame. The most troublesome type of interference was termed ''chemical'' and results from the lack of absorption by atoms bound in molecular combination in the flame. This could occur when the flame is not hot enough to dissociate the molecules or when the dissociated atom is oxidized immediately to a compound that was not dissociated further at the flame temperature. Such interferences was reduced or eliminated by adding specific elements or compounds to the sample solution.

3.8.2.2 Background Correction

Molecular absorption and light scattering caused by solid particles in the flame can cause erroneously high absorption values resulting in positive errors. When such phenomena occur, used background correction to obtain accurate values. Any one of three types of background correction was used: continuum-source, Zeeman, or Smith-Hieftje correction.

3.8.3 Equipment

(1) Atomic Absorption Spectrophotometer (Model: Varian, SpectrAA-AA220, Australia): It consists of a light source emitting the line spectrum of an element (Hollow-Cathode Lamp), a device for vaporizing the sample, a means of isolating an absorption line, and a photoelectric detector with its associated electronic amplifying and measuring equipment. The instrument must have background correction capability.

(2) Burner: The most common type of burner is a premix, which introduces the spray into a condensing chamber for removal of large droplets. The burner may be fitted with a conventional head containing a single slot; a three-slot Boling head, which may be preferred for direct aspiration with an air-acetylene flame;

(3) Lamps: A Hollow-Cathode Lamp for Fe and D_2 lamp for Back ground correction

3.8.4 Materials

i) Ultra-pure de-ionized water was used containing electrical conductivity 0.05 μS/cm.
ii) Air: Oil and moisture free air was used throughout the process.
iii) Acetylene: Standard commercial grade acetylene was used (supplied by Linde Bangladesh)

3.8.5 Reagents

i) Stock Iron Standard Solution: 1000 ppm.
ii) Acids: Analytical grade pure quality of Concentrate HCl and HNO_3.

3.8.6 Sample preservation

Preserved samples immediately after sampling by acidifying with concentrated nitric acid (HNO_3) to pH <2. Usually 1 to 2 mL conc. HNO_3 is sufficient for short-term preservation. Commercially available high-purity acid was used. After acidifying the sample was stored in a dark cool room to prevent change in volume due to evaporation.

3.8.7 Procedure

3.8.7.1 Preparation of Working Standards

Iron standard solution was prepared of appropriate concentrations within the linear working range 0 ppm, 0.5 ppm, 1.0 ppm and 2.0 ppm, & 4.0 ppm from stock solution of Fe (1000ppm) by following way:

Table 3.3: Preparation of Standard solution of Fe

Stock Conc. (ppm)	Taken Volume (mL)	Final Volume (mL)	Dilution Times	Prepared Solution Conc. (ppm)
1000	1	100	100	10
10	0 + 2mL Conc. HCl + D/W mark upto 100	100	---	0.0 (Blank)
10	5 + 2mL Conc. HCl + D/W mark upto 100	100	20	0.5
10	10 + 2mL Conc. HCl + D/W mark upto 100	100	10	1.0
10	20 + 2mL Conc. HCl + D/W mark upto 100	100	5	2.0
10	40 + 2mL Conc. HCl + D/W mark upto 100	100	2.5	4.0

3.8.7.2 Operation AAS

Instrument and data collection system was turned on. Appropriate light source was selected and recommended electrical setting was adjusted. According to SOP proper wavelength and all other conditions were set up.

3.8.7.3 Instrument Calibration

Standard solutions for instrument calibration by diluting metal stock solutions were prepared. A blank was prepared and at least three calibration standards in the appropriate concentration range (the absorption is less than 1) for correlating element concentration and instrument response. Describing calibration curve, never use zero-intercept.
The matrix of the standard solutions was match to those of the samples as closely as possible. In most cases, this simply requires matching the acid background of the samples. In addition, added the same concentration of matrix modifier (if required for sample analysis) to the standard solutions.

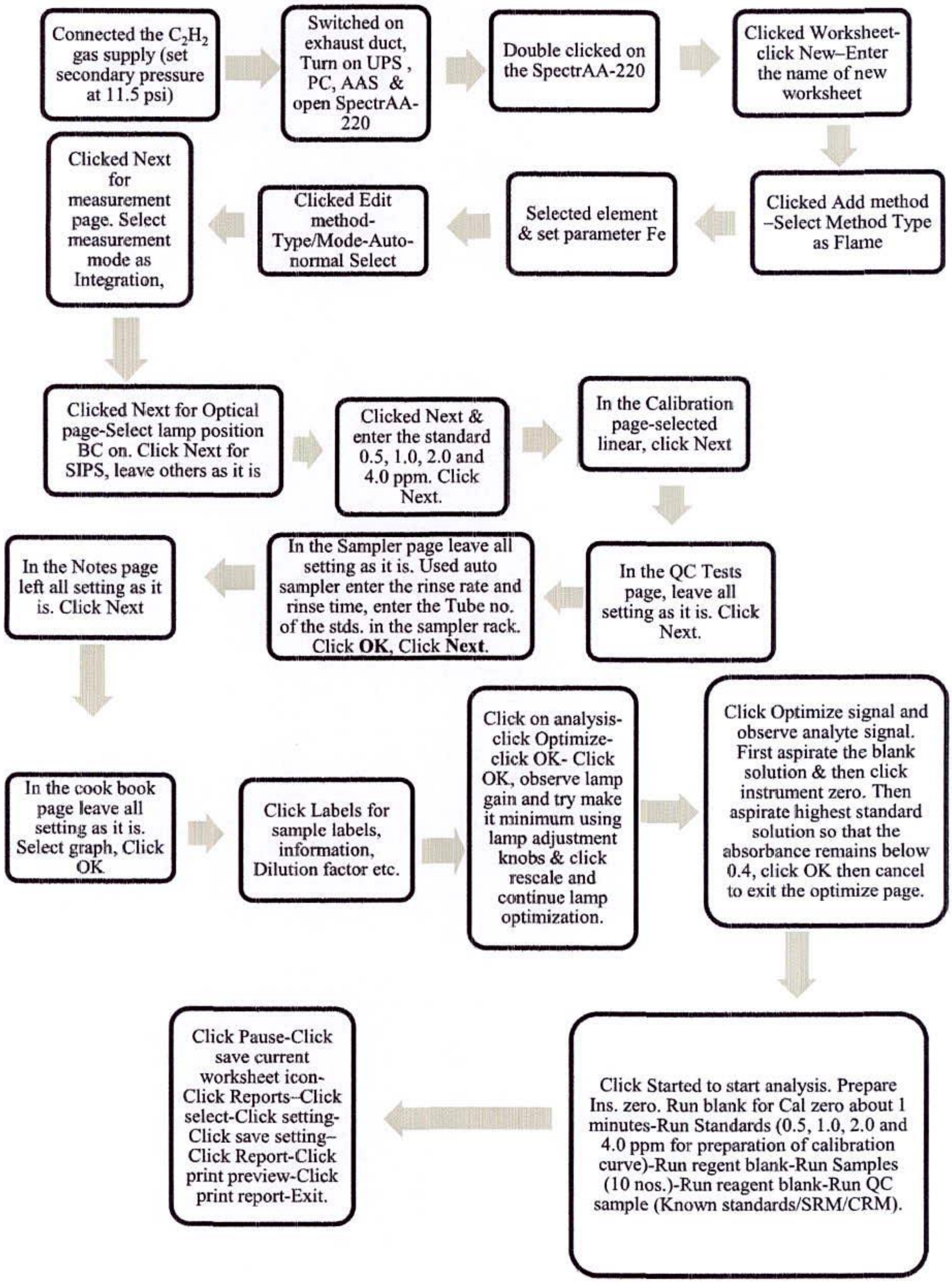
3.8.7.4 Sample Analysis

The auto sample changer (ASC) was used in the sample analysis. The position of each actual sample on the ASC Turn table accords was verified with the setting on the measurement record table (MRT) work sheet. The nebulizer was rinsed by aspirating ultra-pure de-ionized water. Blank samples were aspirated and instrument was made to zero absorbance level. Then investigated sample was aspirated and after pressing read icon concentration of the sample could be readout directly from the instrument.

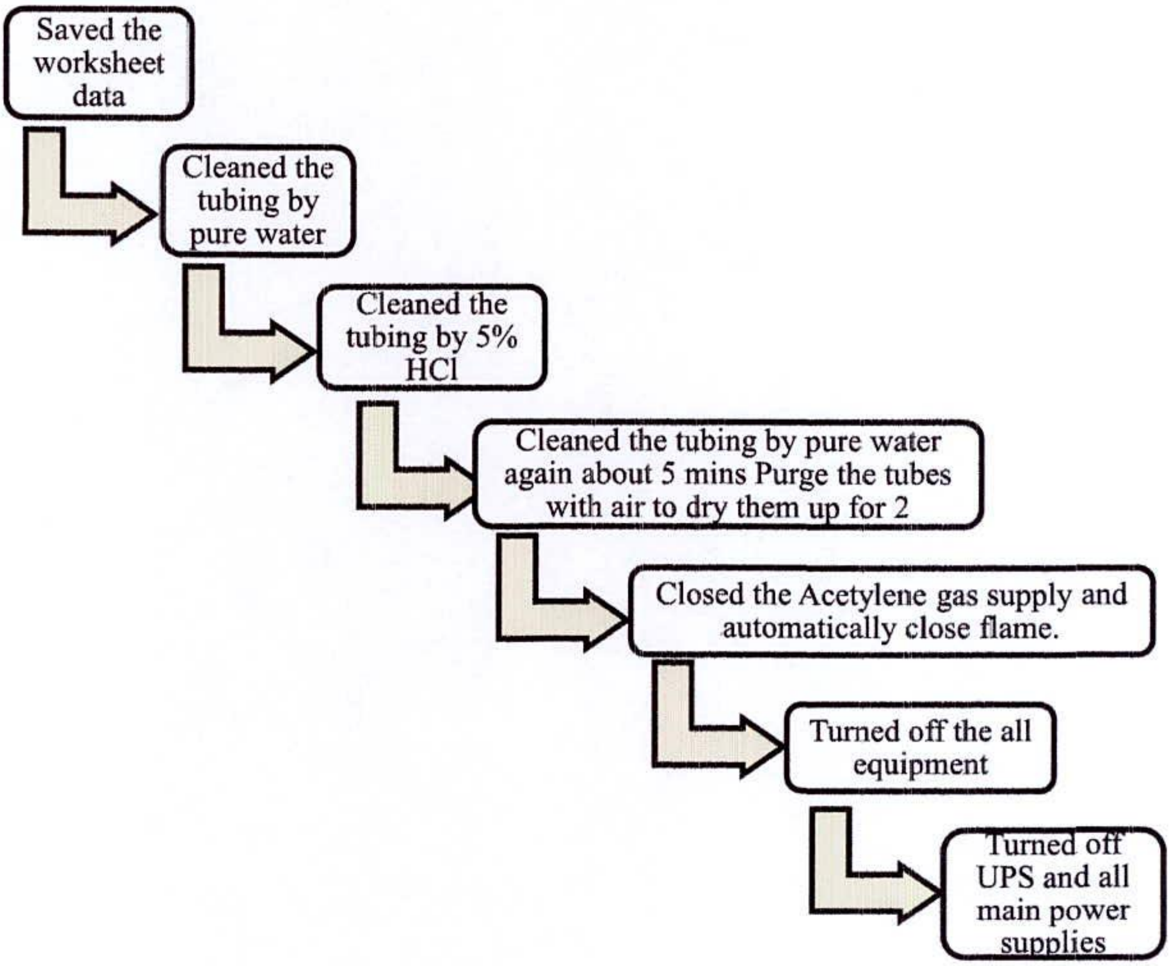
3.8.7.5 Calculation

The analytical results were directly reported in ppm (parts per million or mg/L) from the readout of the instrument. If the sample had been diluted, multiply by the appropriate dilution factor.
mg metal/L = $C \times F$; Where: C = metal concentration as read directly from the instrument or from the calibration curve, mg/L, and F = dilution factor.

Flow Chart for Fe Analysis using Varian SpectrAA-220



Flow chart for Closing AAS



3.8.7.6 Quality Control and Quality Assurance Program

QC program is as same as for Arsenic detection procedure.

3.8.7.7 Maintenance

Maintenance of the instruments was done according to SOP.

3.9 Analysis of Manganese

Same method as iron was adopted for the analysis of manganese in the water samples. In case of manganese only the working standards were changed.

3.9.1 Standard Preparation

3.9.1.1 Preparation of Intermediate Manganese Solution (10 ppm)

Dilute 1mL stock Manganese solution (from 1000 ppm) to 100 mL with de-ionized water containing 1.5 mL conc. HNO_3/L.

3.9.1.2 Preparation of Working Standards:

Prepare 0.0 ppm (Blank), 0.1 ppm, 0.2 ppm, 0.4 ppm, 0.8 ppm,1.0 ppm working standard solution by taking 0.00 mL, 1.0 mL, 2.0 mL 4.0 mL, 8.0 mL,10.0 mL from intermediate standard solution (from 10 ppm) and diluted to 100 mL volumetric flask with deionized water containing 0.15 mL conc. HNO_3 in each standard/sample. For preparation of calibration curve at least 4 standard solutions are required. Here a table shown as below

Table 3.4: Preparation of Standard solution of Mn

Stock Conc. (ppm)	Taken Volume (mL)	Final Volume (mL)	Dilution Times	Prepared Solution Conc. (ppm)
1000	1	100	100	10
10	0 + 0.15 Conc.HNO_3 + D/W mark upto 100	100	---	0.0 (Blank)
10	1 + 0.15 Conc.HNO_3 + D/W mark upto 100	100	100	0.1
10	2 + 0.15 Conc.HNO_3 + D/W mark upto 100	100	50	0.2
10	4 + 0.15 Conc.HNO_3 + D/W mark upto 100	100	25	0.4
10	8 + 0.15 Conc.HNO_3+ D/W mark upto 100	100	12.5	0.8
10	10 + 0.15 Conc.HNO_3 + D/W mark upto 100	100	10	1.0

3.9.2 Quality Control Procedures

For Quality Control (QC) a typical analytical sequence for 10 samples is the following:

Table 3.5: Quality Control Measurement

Sl No	Sequence	Sample
1.	1	Blank
2.	2-6	Calibration standards (5 nos.)
3.	7	Control reference(CRM/SRM)
4.	8	10 analytical samples
5.	9	Duplicate samples
6.	10	Spiked duplicates
7.	11	QC standard
8.	12	10 samples
9.	13	Blank

3.10 Determination of Fecal Coliform (FC)

Membrane Filtration Method [70] was refer to the determination of fecal coliform in which the culture medium was used to cultivate colony and incubation temperature of 44.5±0.2 °C for selectivity and gives 93% accuracy in differentiating between coliforms from warm blooded animals and those from other sources. Developed Color of colony was blue.

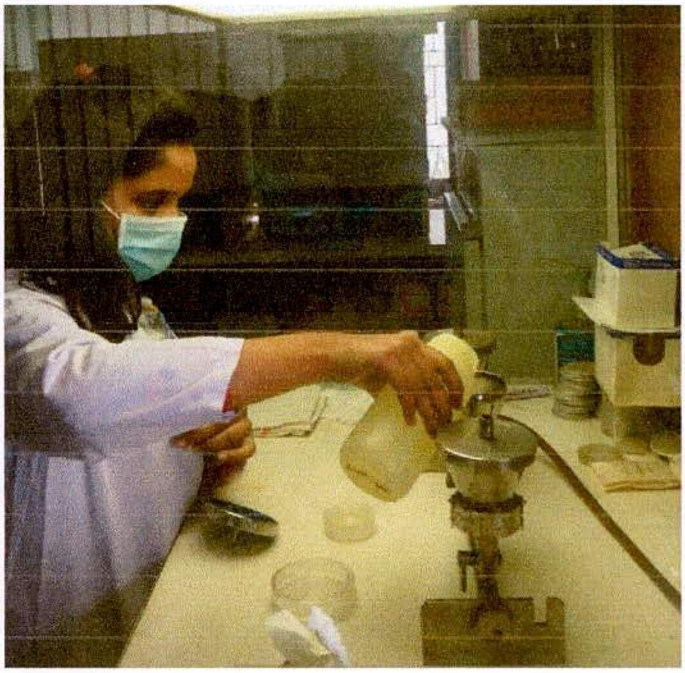


Figure 3.6: Determination of FC in incubator.

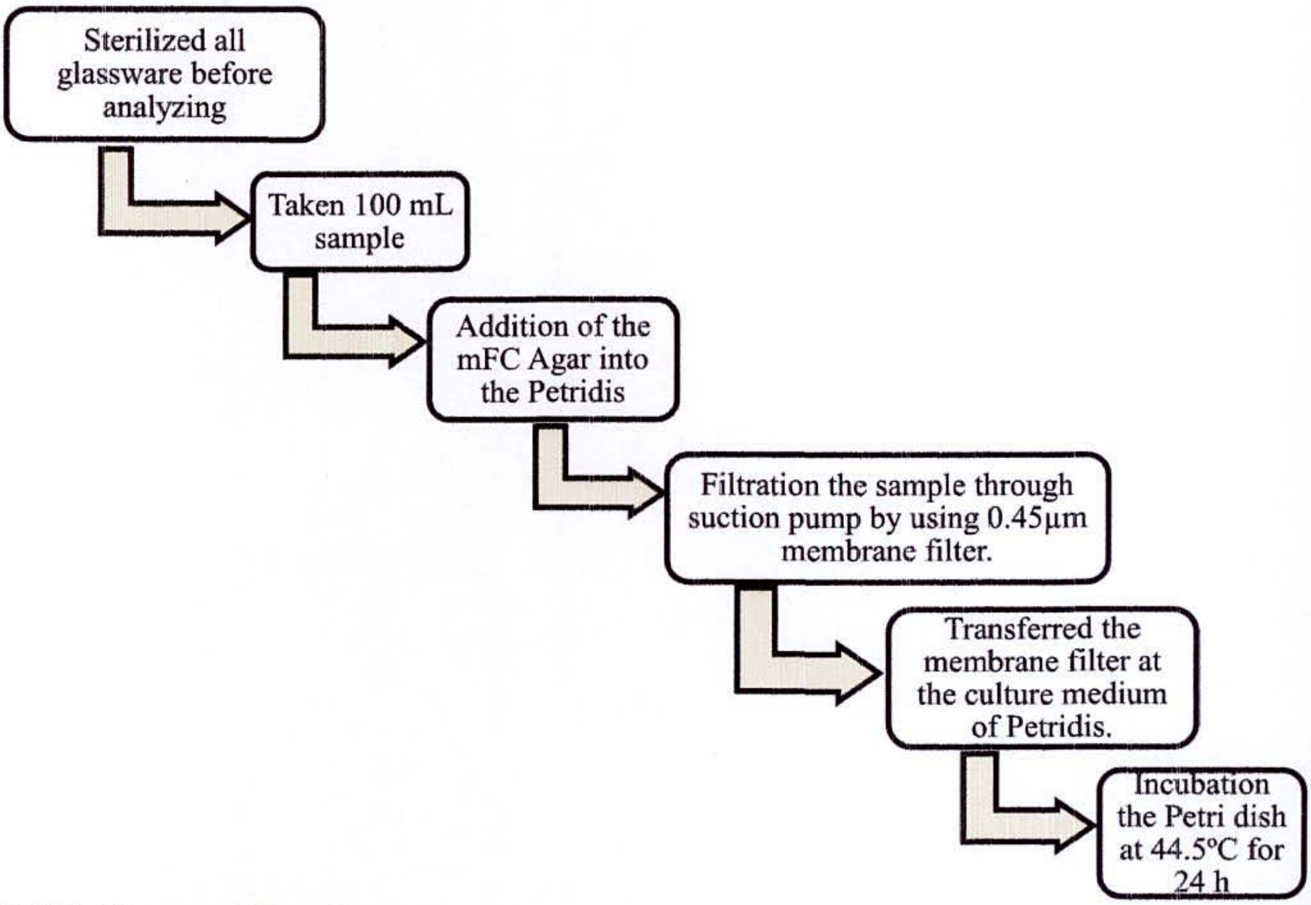
3.10.1 Apparatus

Apparatus which were used for measuring fecal coliform of water are Autoclave, Oven, Bacteriological unit, Petridis, Beaker, Cylinder, 0.45µm membrane filter, Colony counter, Forceps, Incubator, Glass rod, Conical flask, Electric Balance etc.

3.10.2 Reagents

M-FC Agar / m FC Broth Base, Sodium Chloride, Sodium hydroxide, Rosolic Acid, 1N HCl were used for measuring faecal coliform of the water samples.

Flow Chart for FC Testing Procedure



3.10.3 Storage of Samples

(1) Bacteriological test was done immediately after sampling.

(2) It was desired to conduct the test within 6-12 hours

(3) Stored the sample bellow 4 °C.

3.10.4 Preparation of mFC Agar:

52 g mFC agar was suspended in 1L purified water. To mix agar it was heated with frequent agitation and boiled until the powder dissolve completely. 10 mL of 1% solution of rosolic acid was added in 0.2 N NaOH. Heating was continued for 1 minute. pH was adjusted 7.4 with 1 N HCl, if necessary.

3.10.5 Calculation

Fecal coliforms /100 mL = (coliform colonies counted × 100) / (mL sample filtered)

3.11 Determination of Total coliform

Membrane Filtration Method [71] was refer to determination of Total coliform in which the culture medium was used to cultivate colony and incubation temperature of 36±1°C for 23±1hours. Developed Color of colony was Metallic (Golden) Red.

3.11.1 Apparatus

Apparatus which were used for measuring total coliform of water are Autoclave, Incubator, Bacteriological unit, Petri dish, Beaker, Cylinder, 0.45µm membrane filter, Colony counter, Pipette, Oven, Absorbent Pad, Forceps, Conical flask, Glass rod, Electric balance, etc.

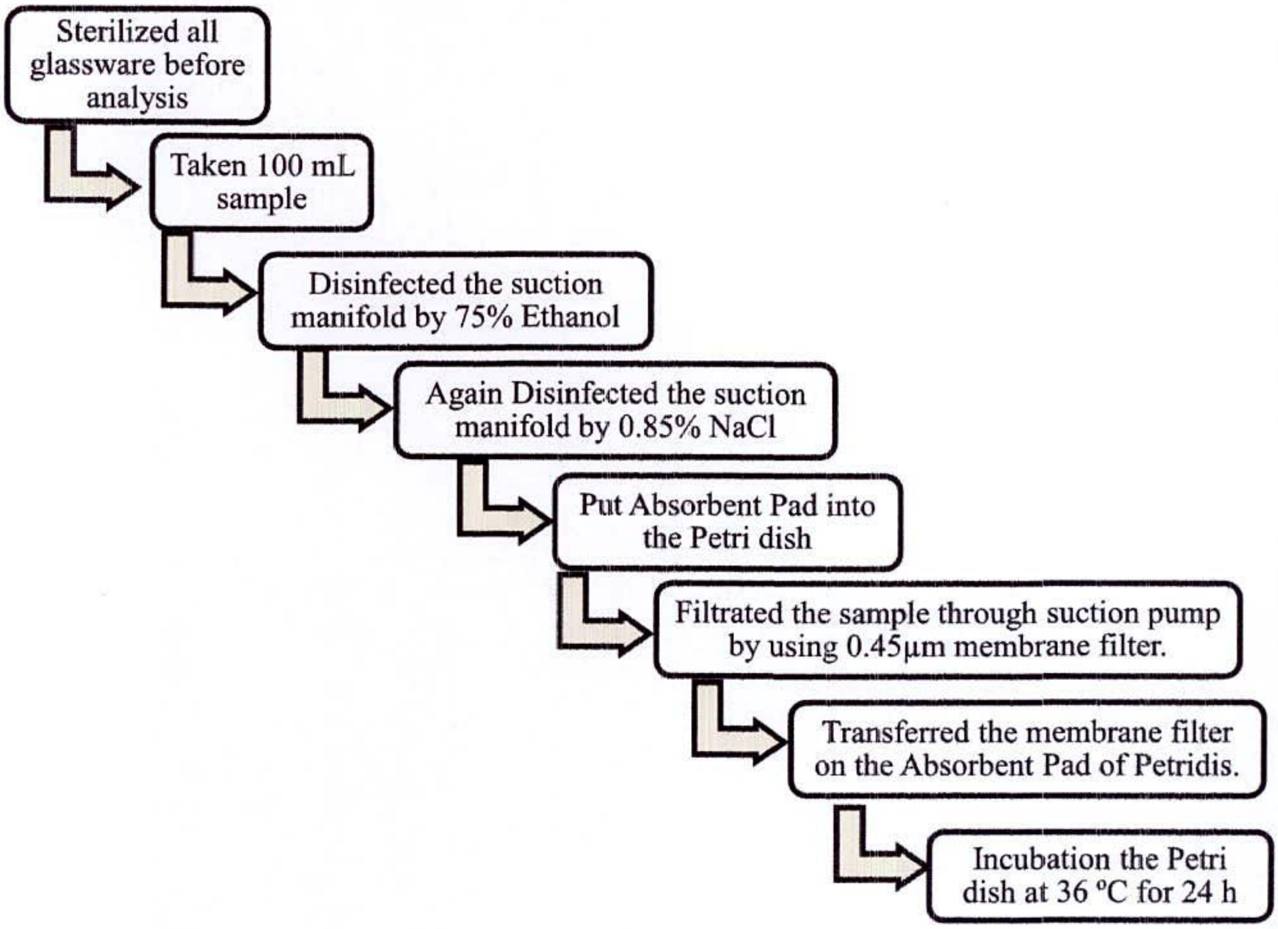
3.11.2 Reagents

M-Endo Broth, Sodium Chloride, Ethanol were used for measuring total coliform of the water samples.

3.11.3 Collection of Sample and Handling

The water sample was collected in 200 mL sterilized borosilicate glass bottles. It is secured to keep 10-20 % free space at the top of sample bottles. Residual chlorine was avoided by using sodium thiosulphate.

Flow Chart for TC Test Procedure



3.11.4 Storage of Samples

Bacteriological test was done immediately after sampling. It was desired to conduct the test within 6-12 hours. The sample was stored bellow 4°C.

3.11.5 Preparation of m-Endo Broth:

4.8 g of the powder (M-Endo) was dissolved in 100 mL purified water containing 2.0 mL of non-denatured ethanol. The solution was heated to boil but avoid overheating. After preparation, it was keep for 96 hours in refrigerator. pH value of culture media was adjusted about 7.2.

3.11.6 Calculation

Total coliforms/100 mL = (coliform colonies counted ×100) / (mL sample filtered)

3.11.7 Precaution and safety

Few compounds in mFC agar are hazardous, toxic and dangerous. So it was necessary to wear glasses and gloves during preparation of culture medium. Care was taken during cleaning bacteriological chamber by using UV light. Besides autoclave and oven was used carefully because it works in a very high temperature.

3.11.8 Waste Management

After counting the colony the petridish including filter paper and culture medium was autoclaved properly. Then the waste kept in a cotainer.

- Hands were disinfected by 75% ethanol and gloves were used before experiment.
- Suction filter was disinfected during analyses.
- Glassware and other instrument were also disinfected.

CHAPTER IV

Results and Discussion

4.1 General

The present chapter is devoted to the presentation of the findings: data and information collection and their analyses. It has been mentioned earlier in the introduction and methodology that the present research is dedicated to the investigation water quality of slum of KCC. Sample was collected from 50 different slums in several ward of KCC area. Each sampling location includes one deep TW and one household water sample. Sampling was done directly from drinking-water sources i.e., deep TW and household water were collected from stored vessels or in case of a drinking cup which they usually use for their drinking purpose.

4.2 Water Sources and Condition of Study Area

Water is one of the most important basic needs of the slum people for drinking and other household work. Various types of chronic, infectious and pathological diseases are common here. Among the diseases about ninety percent are water borne diseases. So for the improving the urban services delivery, especially in slum area it is very much necessary to ensure the environmental management of water quality situation in the study area.

KCC is the responsible authority for the water supply in this city. KCC provide piped water supply and shallow and deep tube-wells in the city. Piped water supply is generally provided from house to house and a few roadside taps for the common public use. But slum dwellers have no access to the piped water supply. They are totally dependent on deep and shallow tube well for their drinking and other purposes. A long queue for water collection is a daily phenomenon of this slum. The existing sources of water supply are not sufficient for the rapidly growing population of the slum.

4.2.1 Condition of Water Sources

Water sources in the study area are not in the same condition. Most of the sources around the slums are unhygienic as shown in Figure 4.1(A). Kitchen wastes are very common near the water sources and slum people dispose their kitchen waste by the side of the tube-wells

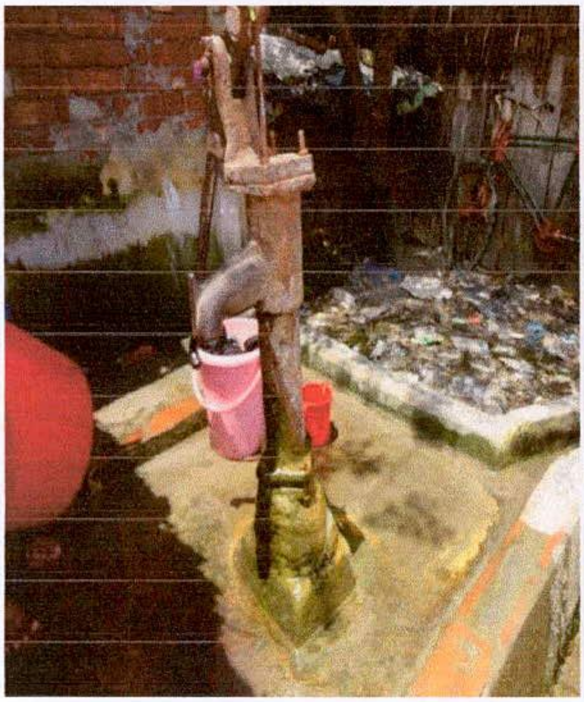


Figure 4.1(A): Unhygienic condition of deep tube-well of Kagoji Bari, 2 No custom ghat beribadh road

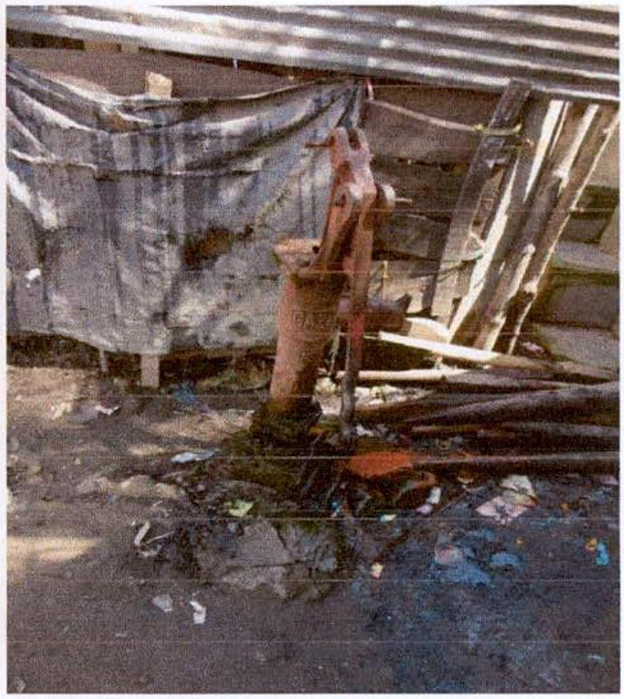


Figure 4.1(B): Deep tube-well without platform of Kagoji Bari, 2 No custom ghat beribadh road

Slum people use the same water sources for drinking, cooking, washing and bathing purpose. It was found that in most cases the worse condition of the tube-wells were caused by the presence of unhygienic latrines, open drains, broken platform and (Figure 4.1(B)) and without platform, kitchen wastes, common dustbins, bird's excreta, residence of unclaimed animals like, dogs, cats etc. besides them.. People also through other types of wastes like household waste, pet or poultry dump etc. just beside the tube-wells. Because of the lack of proper knowledge and facilities As a result the water sources lost the healthy environment.

4.2.2 Sanitation Condition around Drinking Water Sources

Proper sanitation can control many excreta related diseases. However, to improve health conditions through improved sanitation, it is necessary to have a clear understanding of the diseases that are prevalent in absence of proper sanitation and their transmission routes. These diseases are excreta-related and are caused by microorganisms. In the study area the accessibility level of sanitation facilities is poor. Most of the latrine are located near the drinking water sources (as shown in Figure 4.2). Although there is a recommendation (according to WHO health based guideline) that the latrine must be situated >10 m distance.

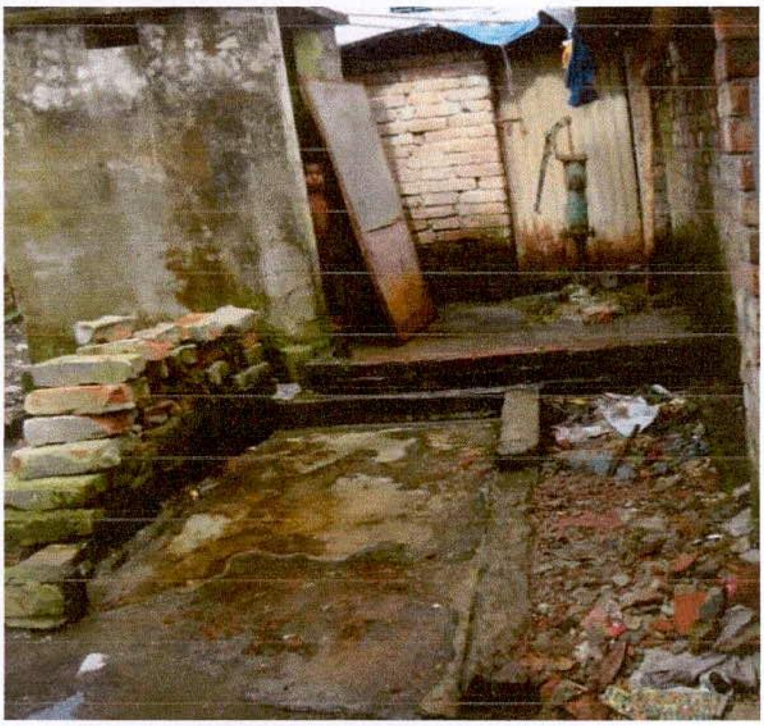


Figure 4.2: Latrine placed within 10 m at Bulbuler boshthi, Moulovipara, Khulna.

In our study we found 18 no of latrine was situated within 10 m of water sources. The number of sanitation latrine exist in the slum are not adequate in the context of the total household member. As a result a part of the slum peoples have not easy access to the sanitation facilities. The location of the sanitary latrine is not in appropriate situation. Because of close contact of unhealthy and unhygienic latrines the quality of drinking water sources affected directly or indirectly by harmful microorganism.

4.2.3 Drainage System around Drinking Water Sources

Drainage condition in the slum of the study area is miserable. It was found that Kacca, semi-paka and paka drain and sewerage line are available there. Unavailability of sufficient drainage in the desirable distance forces the people of slums to dispose waste water and sometimes solid waste here and there around the houses. Thus insufficient drainage causes the poor sanitation condition in the area. It was found that because of land space problem in the studied slums the deep TWs are close to the drain in most cases and sometimes it was very difficult to reach to the well as shown in Figure 4.3(A) and Figure 4.3(B).

Figure 4.3(A): Kacca drain and different waste around the tube-well at Mujguni Rail Crossing Road, Khalishpur.

Figure 4.3(B): Unhealthy Drainage system at No-4, Kasem nagor road, Gollamari Dakshin, Khulna.

Lack of proper maintenance of the existing drainage system and over and above disposal of solid wastes into the drains, inadequate drain sections, absence or indefinite of outlets are accounted for blocking or water logging in drainage (shown in Figure 4.4). In addition, sometime seasonal tidal effect and flat topography of land are also causing water logging. Poor drainage condition slum dwellers faces tremendous environmental hazards and fallen into so many diseases.

Figure 4.4: Water logging around tube-well at Daroga Para

4.2.4 Solid Waste Disposal

Slum dwellers have poor access to solid waste disposal because there are few dustbins beside the slum areas and these dustbins are far away from their house but they produce solid waste every day Very often most of the slums dweller disposes off their solid waste here and there or in drain nearby their houses as shown in Figure 4.5.

Figure 4.5: Disposal of solid wastes nearby drain and tube-well premises at Shekh Bari Modina Mosjid, Motlober Mor.

Accumulation of large amount of uncollected wastes produces strong offensive odor and pollutes the environment seriously. It also acts as a breeding ground for mosquitoes, flies, other insects and pathogenic microorganisms in the surrounding environment. The leachate from these degrading wastes can pollute the ground and surface water and can change the water quality

4.2.5 Housing and Socio-economic Condition of Slum Dwellers

These slum dwellers have migrated from different nearby undeveloped rural and urban areas. Most of the dwellers are engaged in different income earning activities; such as daily laborers, rickshaw and van driving, very small business, cart pulling etc. Even head of most of the household is illiterate. There are no water supplies for drinking, bathing or cooking. Slum dwellers live misery life. The living conditions of these slums are poor as shown in Figure 4.6(A and 4.6(B).

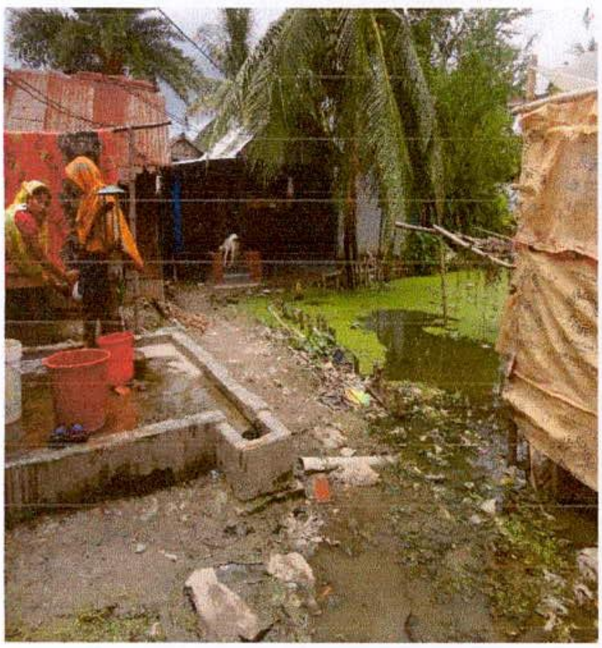


Figure 4.6 (A): Unhygienic Housing and around environment conditions of the Gabtola Slum Railway, Khalishpur

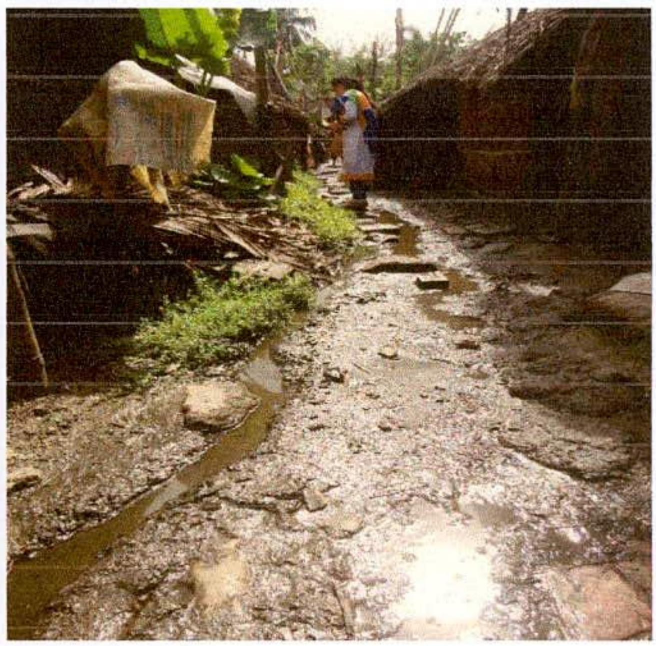


Figure 4.6 (B): Muddy and dirty living condition of Kawser bosthi, Kashipur

Many of the dwellers have to spend a lot of time to collect drinking water or money for buying water, which is unaffordable for many. Apart from this, there are few sanitation facilities. In the majority of slums, up to 20 - 100 families use one toilet and sometimes on payment, which is unaffordable for many. The sewerage facilities provided by KCC are only for 30 per cent citizens of the city and the remaining 70 per cent are deprived of these facilities. The slum dwellers are also deprived of primary health care facilities. There is no medical center for them. The child death rate is unusually high, more than 15 per cent. Most of the children suffer from malnutrition. From field, it has also been observed that children of the study area repeatedly suffer from water borne diseases, typhoid, cough, dysentery, diarrhea and measles.

4.2.6 Educational Status of the Slum Dwellers

Educational status of the slum dwellers is not so high. Most of the people are illiterate. The percentage of illiterate people is 42.19% and the people who can sign only are 20.66%. Some of them have primary level and a few have secondary level education. The percentages are 33.34 and 3.81 respectively [72]. For high rate of illiterate, they are not aware enough about the necessity of education.

4.3 Sources of Water in the Study Area

The sources of water for different purposes of the slum is mainly tube well and that of a minimum number. About 100% of the respondents said that they don't get any water supply from the KCC. Mainly they use tube well water for different purposes. Some of the use pond water for washing clothes, bathing etc. But for drinking water almost everyone collect water from tube wells (96%) [73]

And they have to walk for a certain distance to collect drinking water (Figure 4.7).

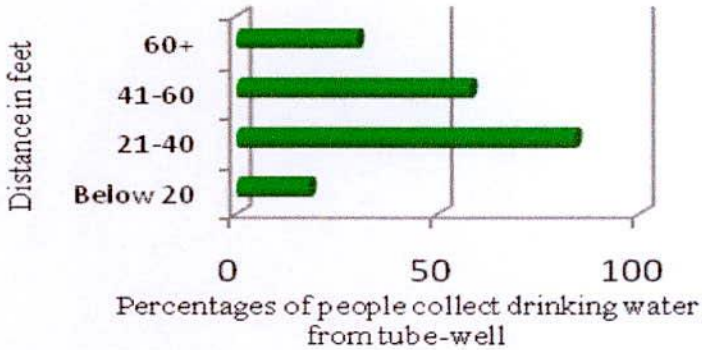


Figure: 4.7: Distance of tube wells from where people collect water [61]

4.4 Portability status of groundwater

The physical, chemical and biological quality of ground water varies in accordance with the environment through which it passes during the course of hydrological cycle and becomes a part of ground water. Pathogens as well as life threatening chemicals get to pollute the groundwater system through leaching. When such polluted ground water is sourced for human consumption, the health implications can be overwhelming. Poor sanitation practices, such as locating on-site sanitation systems close to these wells, are a sure contributing factor in the pollution of the ground water system.

Water quality standards have been developed to minimize the known chemical and microbial risks of human health. Safe drinking water does not imply risk free; it simply denotes risks are very insignificant which could not result in serious health problems [74]. The importance of doing away with microbiological contamination is the major benefit of ensuring good water quality for drinking and reducing of water-borne diseases transmitted by the fecal-oral route. Generally, improvements in microbiological water quality as well as the prevention of use of unhygienic water sources are best interventions to prevent water-borne diseases [75]. Their water quality is affected by unsafe water supply, unhygienic sanitation facilities, and poor solid waste management, unhygienic practices particularly with regard to hand washing, insecure land tenure, poor socio-economic backing, and crowded living conditions [51]. Slum dwellers use ground water as potable water but health records obtained from the Municipal Hospital showed that the communities experience periodic outbreaks of water-borne diseases like diarrhea, cholera, dysentery, etc. This occurs virtually every year. It is therefore important to investigate the possibility or otherwise of pollution of the water sourced from the wells. This will help ascertain whether or not the diseases reported at the Municipal Hospital are either directly or indirectly related to water sourced from these wells.

The standards prescribed for potable water supplies by different authorities usually give two types of norms e.g. permissible and tolerable range. Bangladesh has also set a nation standard (Bangladesh Drinking water Standard: BDS) for different physical, chemical and biological parameters level for drinking water standard. WHO has set international standard for drinking water standard which is used by the all nation. Here results of physico-chemical and bacteriological parameters.

Table 4.1 represents the mean, maximum, minimum and standard deviation of the physicochemical parameter and microbial analysis of all the sources and household water samples along with standard guideline value set by WHO and BDS. The results obtained from the analysis of water quality collected from the selected sites in KCC showed that some of the measured physical and chemical parameters were below and some were above the permissible limits of WHO and BDS standards for drinking water.

Tables 4.1: Mean, maximum, minimum and Standard Deviation of Physicochemical and bacteriological Parameter of water Samples

Parameter	Mean	Standard deviations	Max	Min	WHO (2006)	BDS (1997)
pH	8.0348	0.26487	8.55	7.4	6.5-8.5	6.5-8.5
EC (µS/cm)	929.28	455.1742	2.21 (mS/cm)	544	-	-
Cl^- (mg/L)	183.3616	180.1411	721.58	31.68	1000	1000
TDS	487.84	241.626	1176	276	500	500
Hardness (mg/L)	221	138.7958	650	50	250	600
As (mg/L)	--	--	0.02	<LOQ	0.3	0.3-1
Fe (mg/L)	--	--	0.91	<LOQ	0.5	0.1
Mn (mg/L)	--	--	0.68	<LOQ	0.01	0.05
FC(Sources)	3.36	9.349801	54	0	0	0
FC(Household)	29.41667	25.22273	<<100	0		
TC (Source)	10.44	15.37711	70	0	0	0
TC (Household)	55.54286	33.00751	<<100	8		

4.5 pH

All liquids, of which water is constituted contained free, positively charged hydrogen (H^+) ions and negatively hydroxyl ions (OH^-) in caring and related proportion. Method of expressing the concentration of ionized hydrogen which is called as the pH value. It is an indicative of the alkalinity (pH>7) and acidity (pH<7) is expressed in terms of pH units. Most natural waters are within pH range of 6.5 to 8.5 [39]. There are three main source of hydrogen ion in natural waters: 1) hydrolysis, 2) dissociation and 3) oxidation. Other source of hydrogen ions include humic and fluvic acid, volcanic gases, acid rain and short-chain organic acid present in some oil-field brines [76].

The H^+ ion in aqueous solution is controlled by chemical reactions that produce or consume hydrogen ions. In some cases these reaction may be limited if CO_2 is dissolve in water because it act as buffering agent by forming CO_3^{2-} and later as HCO_3^- then if we ad acid or base pH changes little.

$$CO_2\,(aq) + H_2O \rightleftharpoons H_2CO_3\,(aq)$$

$$H_2CO_3\,(aq) \rightleftharpoons H^+\,(aq) + HCO_3^-\,(aq)$$

$$HCO_3^-\,(aq) \rightleftharpoons H^+\,(aq) + CO_3^{2-}\,(aq)$$

Results of determination of pH values of the investigated area have been given in Table 4.2 and Figure 4.8. In the study area pH of both ground water and household water were almost same. The experimented pH values were in the range of 8.55 to 7.4. From the results it is seen that 49 Tube-wells, 98% of the total meet the BDS and WHO standard. Only one sampling station S-23, Bil slum (khora slum), Sonadangahas exceeded the WHO and BDS guideline value. Which indicates that potable water in study area is slightly alkaline but satisfy both the BDS and WHO standard. In the study area groundwater pH is suitable for drinking purposes. Various factors bring about changes the pH of water. The higher pH values observed suggests that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physico-chemical condition.

Table 4.2: pH range of the investigated TWs of different slums

Sl. No	pH Range	No. of TW	Percentage of TW	Remarks
1	6.5- 8.5	49	98%	Acceptable range of BDS and WHO standards.
2	>8.5	1	2%	Exceeds the range of WHO and BDS Standards

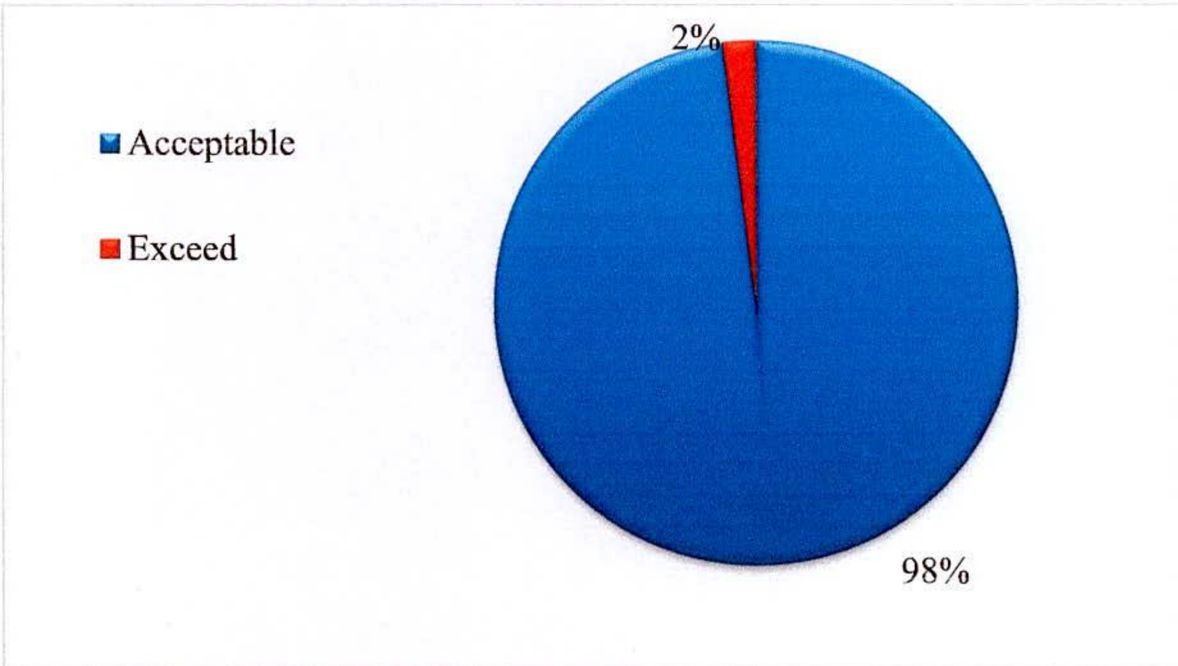


Figure 4.8: pH acceptability of water sample

4.6 Electrical Conductivity

The electrical conductivity (also called conductivity) is the measure of capacity of a substance or solution to carry an electric current. The conductivity is represented by the reciprocal value of electrical resistance in ohms relative to cubic centimeter of water at 25 °C. [75]. The electrical conductivity is a total parameter for dissolved and dissociated substances. Its value depends on the concentration and degree of dissociation of the ions as well as the temperature and migration velocity of the ion in the electric filed. The concentration of salts depends on the environment, movement and sources of ground water. The soluble salts in groundwater originate primarily from solution of rock materials and are always higher concentration than the surface water. It is said that drinking water of higher conductivity are not always safe as regular drinking it may be the cause of hyper tension, kidney failure, stone deposition in various in intestine.

EC of water of TWs was investigated and was given in Table 4.3 and Figure 4.9. It is seen Conductivity values varied within a wide range of found 2.21 ms/cm and 544 µs/cm. From the convention on the basis of EC drinking water has been categories into i) good drinking for humans (<800 µS/cm), ii) can be consumed by humans (800-2500 µS/cm) and

iii) not recommended (>2500 μS/cm). The highest and lowest EC values have been found 2.21 ms/cm and 544 μs/cm respectively.

Table 4.3: Quality of drinking water on the basis of EC

EC (μS/cm)	No. of TW	Percentage of TW	Water quality
<800	26	52	Good drinking for humans
801-2500	23	46	Can be consumed by humans
>2500	1	2	Not recommended*

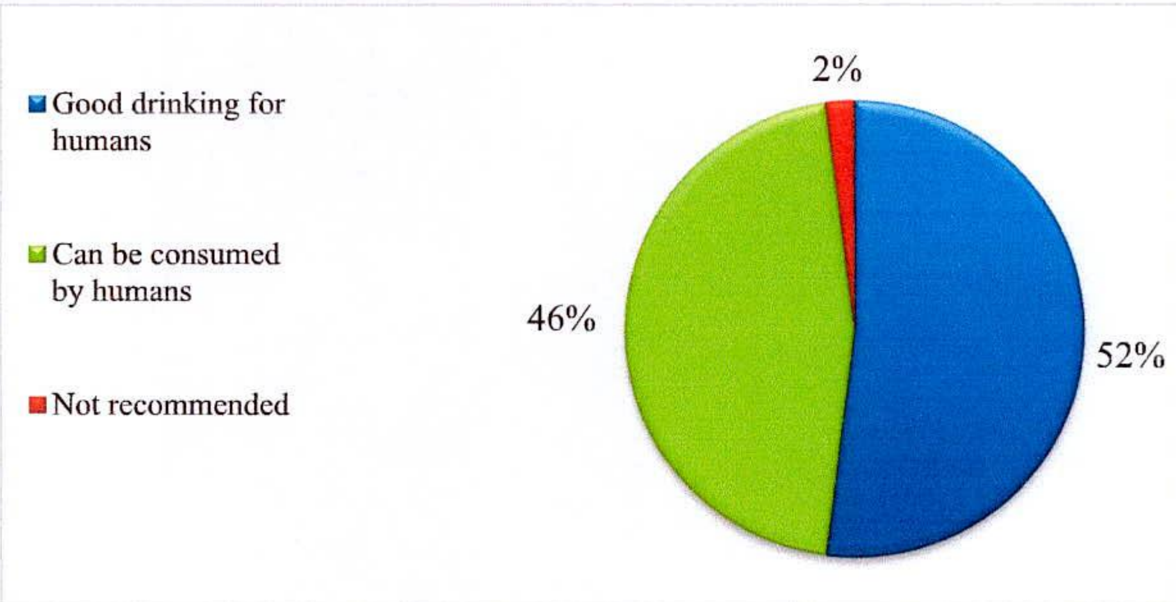


Figure 4.9: EC level of investigated area.

The highest value of EC was found in sample no. S-37 at Alam Nagar Pora Mosjid, Khaluishpur (ward no. 3) which was dug in 1994 at 1000 ft depth. About 100 people of 25 families are consuming water from this TW. Apparently according to BDS recommendation this water should not use at for drinking purposes. But from our research it has been came in front that the residence of that slum are using this water of very high EC for long time which is not safe always and they have no knowledge about it. Highest value of EC may be due to the extraction of groundwater from the shallow aquifer [40].

EC is also correlated with Ca^{2+}, Mg^{2+} and Cl^-. Higher values of EC may be explained by intrusion of different ions from sea water into the ground level. On average, 52% of total TWs supply good drinking water with EC values of <800 μS/cm. At the same time 46% of total TWs of which EC drinking water can be consumed. Only one Sample, S-37, Alam Nagar Pora Mosjid, Khaluishpur was found higher EC value, which should not be consumed by humans. But there is no valid or strong reference of this statement. According to the Water Supply (Water Quality) Regulations 2000 (SI 2000/3184 as amended) conductivity of drinking water higher than 2500 μS/cm at 20 °C are not recommended for human consumption. Higher values of EC also support the chloride content in water and has been discussed later in section 4.2.6. From investigation it can be conferred that the water of all the TWs have several dissolved minerals content.

4.7 Total Dissolved Solids

TDS refers to the sum of all the dissolved components in water. Water that contains too much dissolved matter is not suitable for drinking. The palatability of water with a TDS level of less than 600 mg/L is generally considered to be good and that for 1000 mg/L is unpalatable [77]. According to BDS and WHO standard value level of TDS in water <1200 mg/L is acceptable and that for >1200 mg/L is unacceptable for drinking. From different reports of drinking water quality by the WHO water can be classify into different qualities. Water of different category (excellent, good, fair, poor and unacceptable) was found in different slums given in table 4.4.

Table 4.4: Quality of drinking water on the level of TDS

Level of TDS (mg/L)	No. of TW	Percentage of TW	Nature of Water
<300	4	8	Excellent
301-600	36	73	Good
601-900	4	8	Fair
901-1200	6	12	Poor
>1201	-	0	Unacceptable

Quality of water on the basis of TDS of the investigated 50 different slums is tabulated in figure 4.10. From the study it was observed that 8% TWs contain excellent quality water, where 73%, 8% and 12% TWs of the total are good, fair and poor for drinking respectively. But it was significant that no sample was found unacceptable i.e. more than 1200 mg/L. A substantial number of TWs i.e., (12%) of the total TWs provide poor (TDS: 901-1200 mg/L) water for drinking where the major portion provide good water (TDS< 600 mg/L). We Found 4 TWs which has TDS more than 1000 mg/L and near to 1200 mg/L. Which cross the BDS guideline value. In the study area highest TDS value was found 1176 mg/L in S-50, Kawser bosthi, Kashipur, (ward no. 6) depth 800 ft and lowest TDS was found 281 mg/L in S-6, Rupsha Mach bazar boshti, (Ward no. 30) depth 900 ft. [Appendix A]. Higher TDS values may be due to the shallow aquifer system which may derived from soil or poor aquifer system. DTS is directly proportionally related to EC. So higher TDS values corresponds the EC values in the previous section. TDS in drinking-water may originate from natural sources, sewage, urban runoff and industrial wastewater. Concentrations of TDS in water vary considerably in different geological regions owing to differences in the solubility of minerals [76].

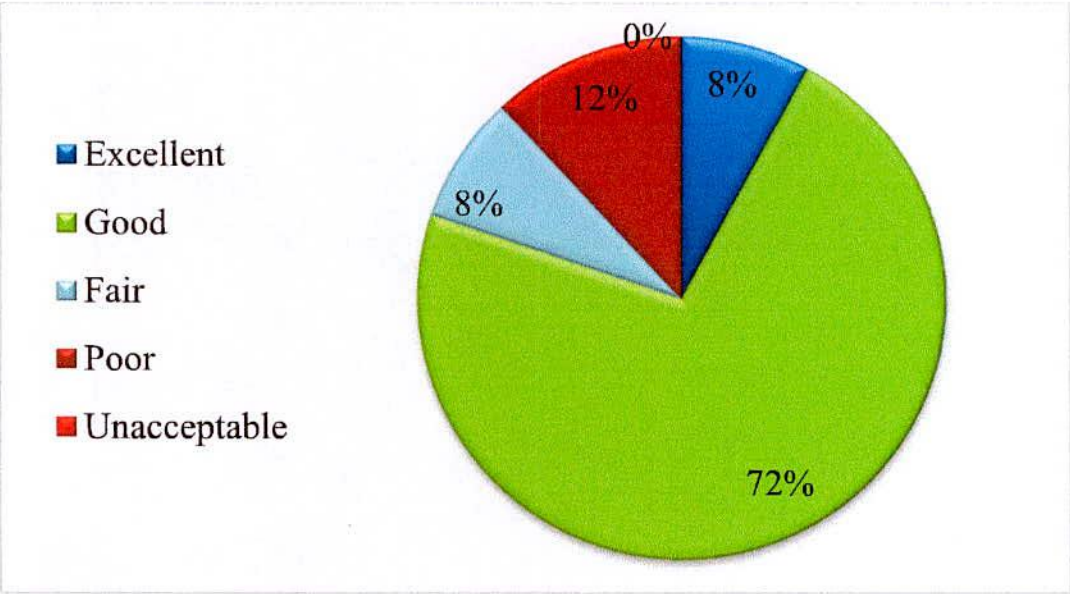


Figure 4.10: TDS rating of the investigated slum area

4.8 Hardness

Hardness results from the presence of the bivalent metallic cations, of which calcium and magnesium are the most dominant [36]. There are two types of hardness, temporary and permanent hardness respectively. Temporary hardness is caused due to the presence of bicarbonate of calcium, magnesium and other bivalent metals. This is known as carbonates hardness. Permanent hardness is caused due to the presence of sulphates and chlorides hardness constituting cations. This is also known non-carbonate hardness. Thus, total hardness is taken to comprise the calcium and magnesium concentrations expressed as mg/L CaCO3. The widespread abundance of these metals in rock formations leads often to very considerable hardness levels in surface and ground water. Hardness level have a bearing on the toxicity of some metals. In general, these toxic effects are markedly less in water with a significant degree of hardness. However it has no noticeable adverse effect on human health. The health problems such as urolithiasis, anencephaly, cancer and cardiovascular disorders may get increased due to long term usage of very hard water [79]. One of The chief disadvantages of hard waters are that they neutralize the lathering power of soap and, more important, that they can cause blockage of pipes and severely reduced boiler efficiency because of scale formation. These effects will increase as the hardness rises to and beyond 200 mg/L $CaCO_3$. Water containing hardness at concentrations below 60 mg/L is generally considered as soft; 61–120 mg/L moderately hard; 121–180 mg/L hard; and more than 180 mg/L very hard [78]. Classification of the water as per as hardness were given in table 4.5. According to classification most of the samples comes under moderate to very hard type. On the basis of this classification it has been observed that only 2% water samples are soft, 14% are moderately hard, 38 % are hard and 46% are very hard.

Table 4.5: Quality of drinking water depending on Hardness

Total Hardness (mg/L)	No. of TW	% of TW	Nature of Water Sample
0-60	1	2	Soft
61-120	7	14	Moderate
121-180	19	38	Hard
>181	23	46	Very Hard

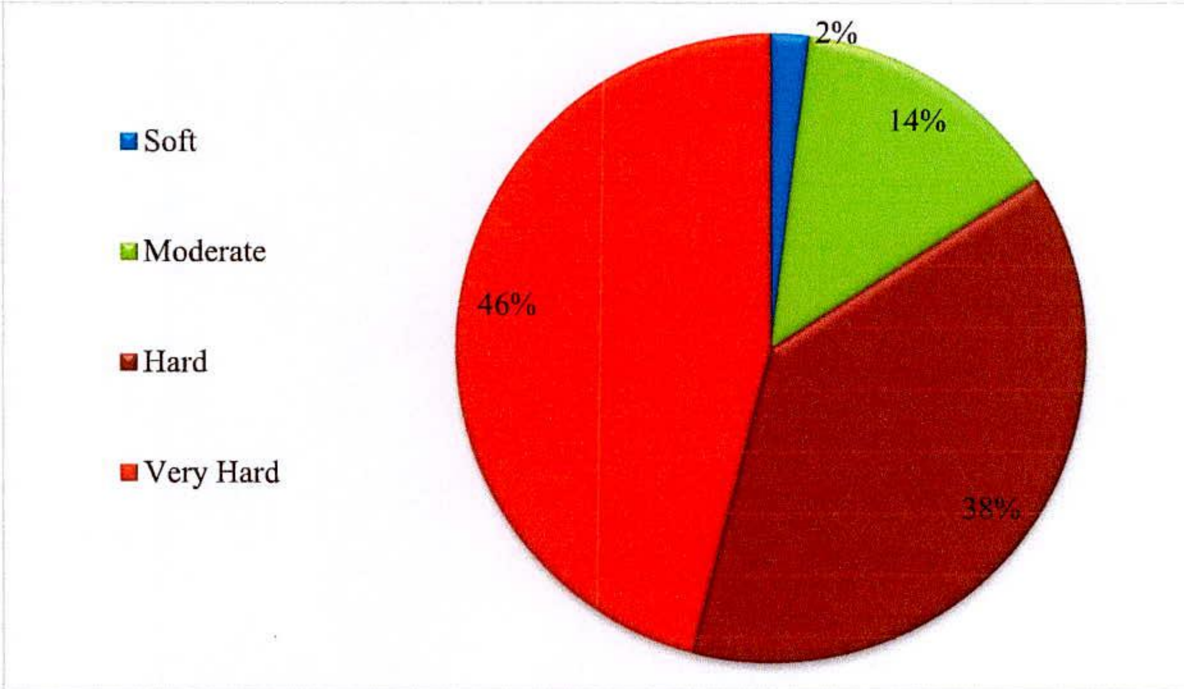


Figure 4.11: Hardness quality of sample in the investigated

Both calcium and magnesium are essential minerals and beneficial to human health in several respects. Inadequate intake of either nutrient can result in adverse health consequences. Recommended daily intakes of each element have been set at national and international levels. Individuals vary considerably in their needs for and consumption of these elements. So, on the basis of hardness as well the need of calcium and magnesium in human body the drinking water has been classified into acceptable or unacceptable. WHO International Standards for Drinking-water stated that the maximum permissible level of hardness in drinking-water is 500 mg calcium carbonate/L, based on the acceptability of water for domestic use. Also on the basis of BDS standards acceptability of hardness is 500 mg/L. Which was given in Table 4.6

Table 4.6 Acceptability of water on basis of hardness

Total Hardness (mg/L)	No of TWs	% of Acceptability	Acceptability
>500	45	90	Acceptable
<500	5	10	Unacceptable

In our investigation is was found that 5 TWs Noyabati Siddik Munshir Bari, Khalishpur, No-2 Platinum Jublee Labour Colony, Khalishpur, 3 no. Camp, Khalishpur, Alam Nagar Pora Mosjid, Khaluishpur and Kawser bosthi, Khalishpur (S- 31, S-32, S-36, S-37, S- 50) sample had hardness value more than 500 mg/L which is 10% of total TWs and hence unacceptable for slum dwellers according to the BDS and WHO standards.

4.9 Chloride

Chloride is an indication of salinity in water. It is one of the major constituents of natural water. Increase in chloride level is injurious to people suffering from diseases of heart or kidney [80]. Chloride toxicity has been observed in such cases where it is impaired with sodium [81]. When the excess chloride concentration is present with excess sodium concentration it may cause congestive heart failure. The sources include soil and rock formations, sea spray and waste discharges. Sewage contains large amounts of chloride, as do some industrial effluents. High chloride content of groundwater is likely to originate from pollution sources such as domestic effluents, fertilizers, septic tanks and from natural sources such as rainfall, the dissolution of fluid inclusions.

In this study the concentration of chloride varies from 31.68–721 mg/L. Amount of chloride in TWs are presented in table 4.7 and figure 4.12.

Table 4.7: Percentage chloride of water sample according to WHO and BDS

Chloride (mg/L)	No. of TW	% of TW	Remarks
≤250	41	82	WHO and BDS Standard
250-600	5	10	BDS Standard
>600	4	8	Exceed allowable limit

It is seen from the table that only 41 out of 50 i.e., 82% TWs provide chloride upto 250 m/L, the WHO standard for human consumption and 10 % of the total TWs exceeded the WHO standard for chloride content. From the table it is observed that although the WHO standard value for chloride is ≤250 mg/L but that for BDS value is ≤600 mg/L. Chloride concentration of water of 4 TWs i.e., 8% TWs situated in Khalishpur were very high, which exceeded the standard level of both Bangladesh and WHO, hence unsuitable for drinking purpose.

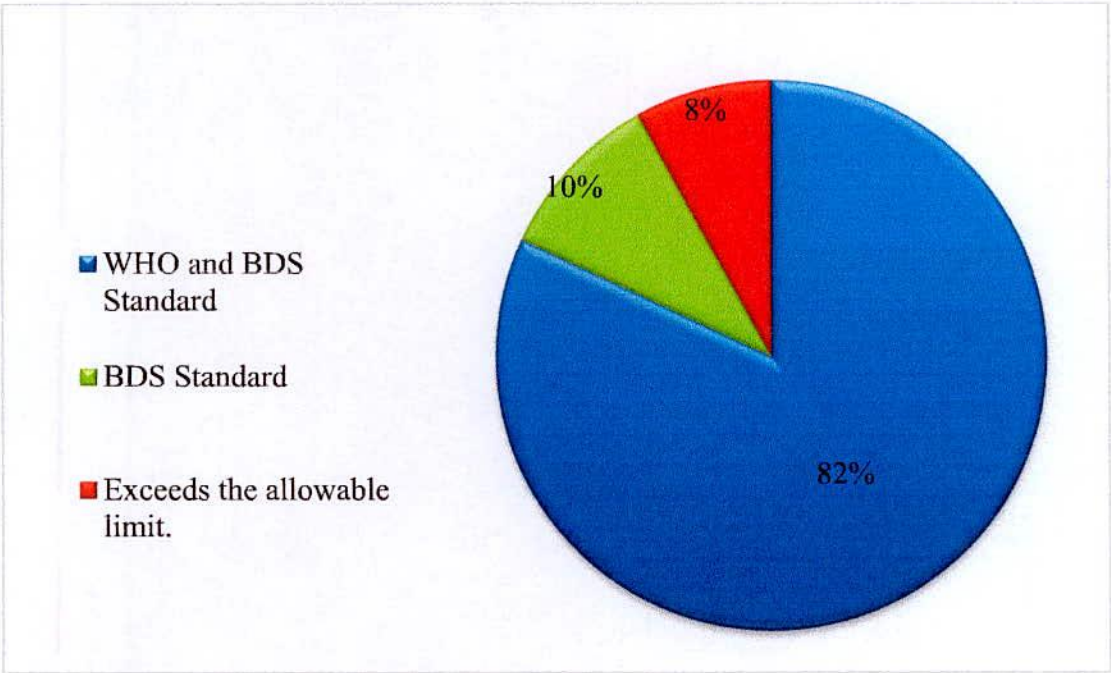


Figure 4.12: Percentage chloride of water sample

The results are quite realistic, as it is known from experience that Khulna is coastal area. A lot of salts, especially NaCl are present in dissolved state in ground water. Higher value of chloride in groundwater may be derived from evaporated salty water and seawater. From the interpretation of data (Appendices B), it can be assumed that aquifers of Khalishpur area might be influenced by marine or seawater intrusion. These three stations aquifer were contaminated by seawater intrusions. So water from these boreholes, Khalishpur water were not potable for drinking purposes. Also, Khulna city is located on the bank formation of the river partly and other sides are plain. As a result, there is stagnation of rainwater in the city area. In addition to this, there is flush back of saline water in the city area during the high tide. Consequently, some of the city areas remain wet [83].

4.10 Arsenic (As)

This element is very widely distributed throughout the earth's crust, according to the WHO Guidelines, which state that "it is introduced into water through the dissolution of minerals and ores, from industrial effluents, and from atmospheric deposition: concentrations in ground water in some areas are sometimes elevated as a result of erosion from natural sources. Very toxic to humans, some arsenical compounds are carcinogens, hence much of the concern regarding them, but there are a variety of other effects on health. The WHO states that inorganic arsenic is a documented human carcinogen, and that a relatively high incidence of skin and possibly other cancers that increase with dose and age has been observed in populations ingesting water containing high concentrations of arsenic. As is a known carcinogen (an agent producing and exciting cancer) and a toxin. Skin cancer has been associated with long-term, low-level exposure to arsenic through drinking water Thus, people living in communities where significant As concentrations were detected could, potentially, be at risk of diseases associated with long-term low-level As ingestion. As level in the study area has been revealed in table 4.8.

Table 4.8: Level of As in water according to WHO and BDS

As (mg/L)	No. of TW	Percentage of TW	Standards
<LOQ	29	58	WHO & BDS
0.001-0.01	19	38	WHO & BDS
0.011-0.05	2	4	>WHO but <BDS
>0.05	0	0	Exceed the Limit

There are 29 TWs (58% of the total provide almost arsenic free water, 19 TWs (36% of the total TWs) provide water of As content 0.001-0.01 mg/L within BDS and WHO permissible limit. This exposes that water of 48 TWs are safe from As according to both BDS and WHO. Two TWs S-4 and S-46 (2 no. customs ghat, beri badh Road, Kagoji Bari and Diyana Uttor para boundary road Doulatpur) provide water of As level higher than WHO guideline but within the BDS limit. But there is no TW in considered slum of which water is As contaminated according to both BDS and WHO guideline. Percentage of Arsenic content in water in TWs has been shown in figure 4.13.

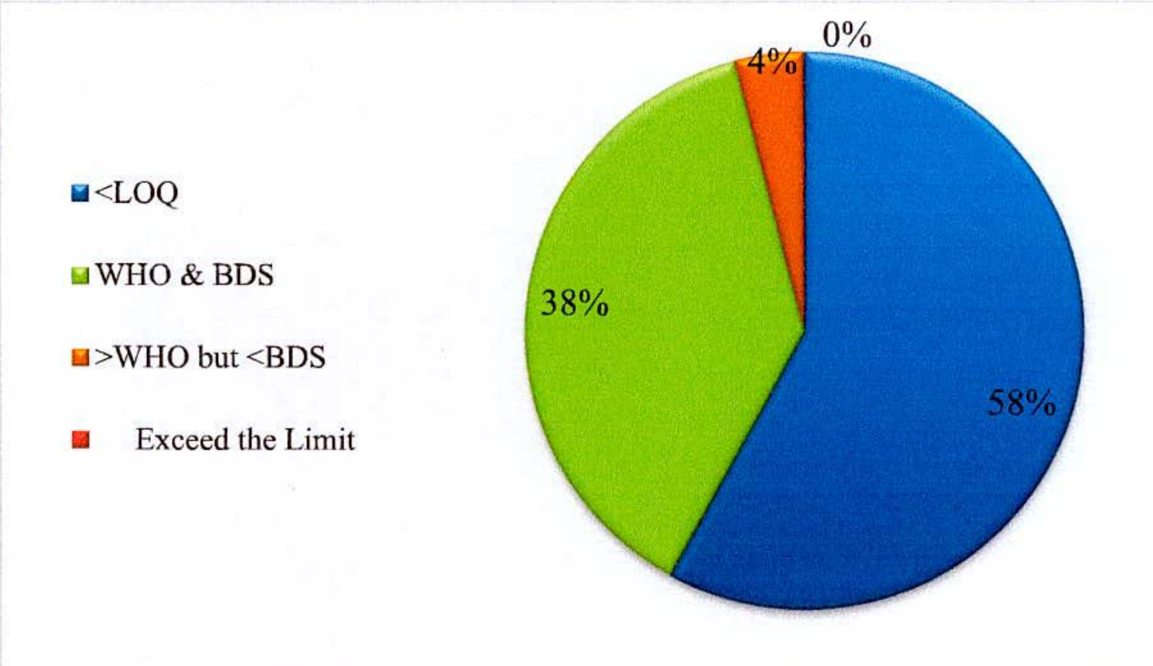


Figure 4.13: : Level of As in sample water in the investigated area

4.11 Iron (Fe)

Metals in our water supply may occur naturally or may be the result of contamination. Naturally occurring metals are dissolved in water when it comes into contact with rock or soil material. Few scientists suggested that the presence of iron in underground drinking water could be due to its percolation from granitic and metamorphosed rocks into groundwater i.e., water-rock interaction. Other sources of metal contamination are corrosion of pipes and leakage from waste disposal sites. The national hydro-chemical quality surveys conducted by the British Geological Survey (BGS) and the Department of Public Health Engineering (DPHE) have shown that in Bangladesh, large numbers of wells also exceed permissible limits for iron (Fe). According to WHO [16] taste is not usually noticeable at iron concentrations below 0.3 mg/L, although turbidity and color may develop in piped systems at levels above 0.05–0.1 mg/L. Laundry and sanitary ware will stain at iron concentrations above 0.3 mg/L. Department of National Health and Welfare

(Canada) [19] assumed that iron also promotes undesirable bacterial growth (iron bacteria) within a waterworks and distribution system, resulting in the deposition of a slimy coating on the piping. Iron content in the investigated wells has been summarized in table 4.9

Table 4.9: Level of Iron (Fe) in water sample according to WHO and BDS

Fe (mg/L)	No. of TW	Percentage of TW	Standards
<0.30	42	84	WHO Acceptable
0.30-1.0	8	16	BDS acceptable
>1.0	0	0	Exceed the Limit

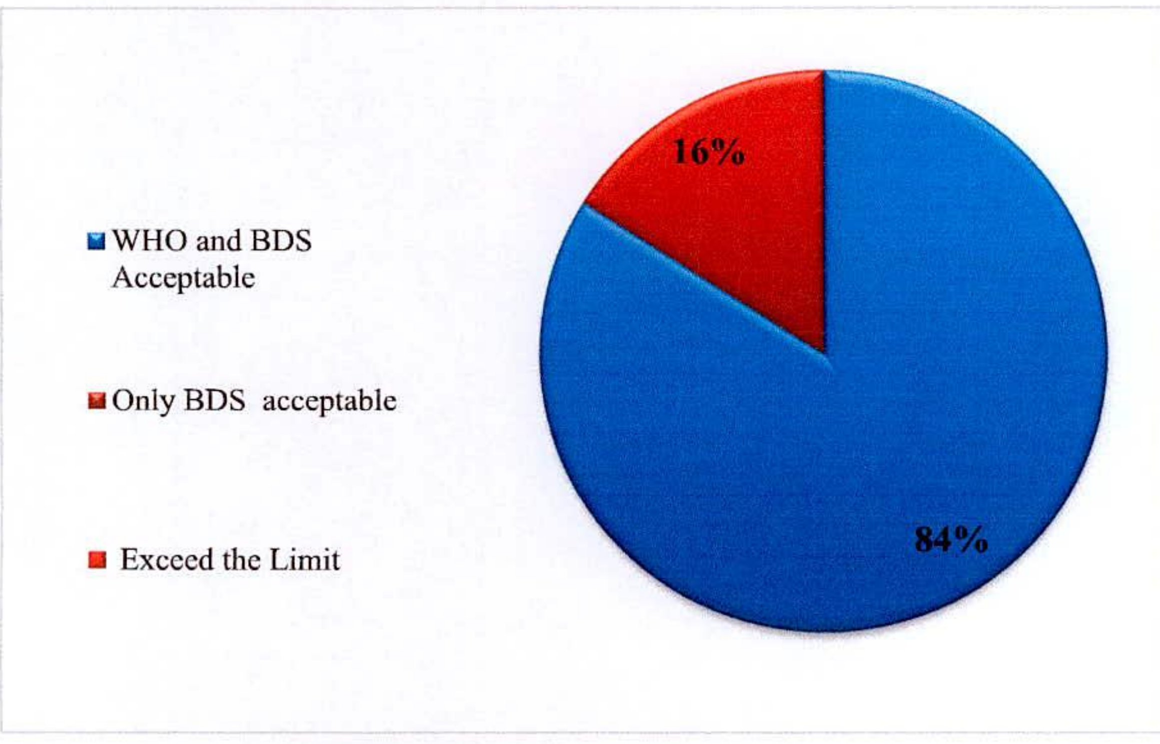


Figure 4.14: Level of Iron (Fe) in sample water

There are 42 TWs contain iron, 84% of the total provide water below the WHO standards as shown in figure 4.14 TWs (16% of total) among the sampling station follow only BDS permissible limit. Iron content 0.30-1.0 mg/L within BDS permissible limit but exceeds the

WHO guideline value. No TWs exceeded the BDS guideline values, but it is a major concern that in some TWs WHO limit is being crossed.

4.12 Manganese

Manganese is one of the most abundant metals in the earth's crust. It can occur in a number of forms, in which Mn^{2+} is dominating in environments.

Manganese is an essential element for humans, but a growing body of research suggests that exposure to high levels in drinking water can lead to adverse neurological effects [83]. Because of possible health risks, WHO has set a guideline value of 0.4 mg/L. Normally, consumers are unlikely to drink water containing manganese at this level or higher because of a strong unpleasant metallic taste. However there are recorded situations, such as in Bangladesh, where people are regularly consuming water with manganese levels above the guideline value of WHO. Concentrations below 0.05–0.1 mg/L are usually acceptable to consumers from a taste perspective but may sometimes still give rise to the deposition of black deposits in pipes.

Analysis of data obtained from the national hydro-chemical survey shown that about 42% of tube-wells have manganese concentrations exceeding the WHO health-based guideline value of 0.4 mg/L. High manganese concentrations in groundwater have been found in the central, northern, and western regions of Bangladesh; groundwater in the north-eastern region of Bangladesh contain relatively less manganese. Deeper wells (>150 m) have been found to contain relatively lower concentrations of manganese [84]. Manganese concentration in the investigated wells has been summarized in table 4.10.

Table 4.10: Quality of drinking water depending on Manganese

Mn (mg/L)	No. of TW	Percentage of TW	Standards
<0.1	47	94	BDS and WHO acceptable
0.1- 0.4	1	2	WHO acceptable
<0.4	2	4	Unacceptable

There are 47 TWs 94% of the total in study area provide water contain manganese <0.1 mg/L, are within the WHO and BDS standards shown in figure 4.15.

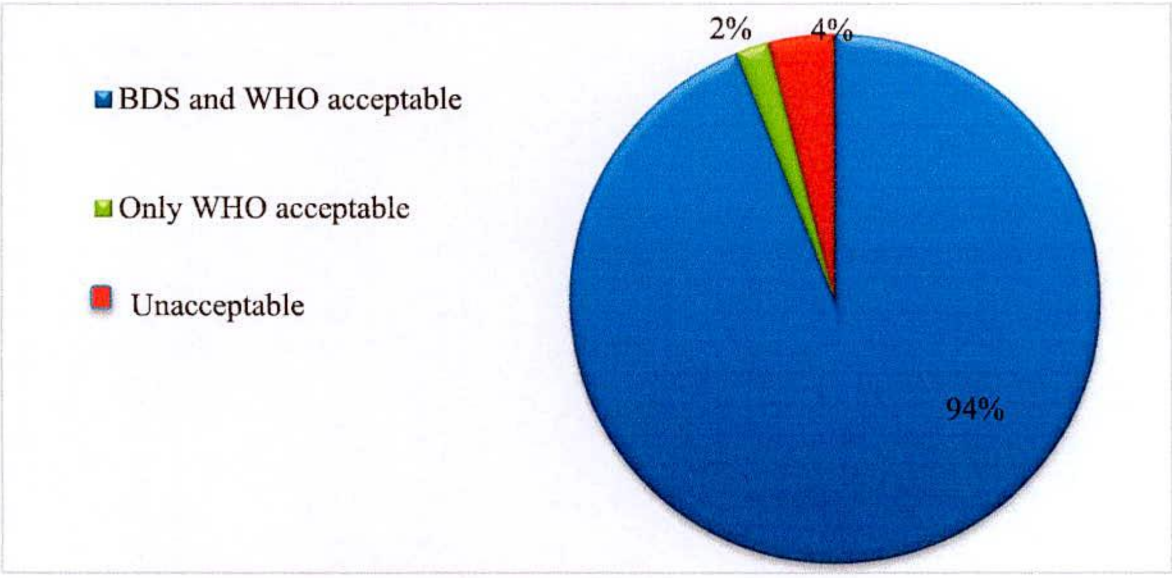


Figure 4.15: Manganese Quality of drinking water

In this investigated, there are 1 TWs (2% of the total wells) provide water of manganese concentration higher than 0.1 mg/L, it means that the water supplied of these wells exceeded the BDS standard guideline value hence unsuitable for drinking purpose but according to WHO standard (0.4 mg/L), the water may drinkable. Also we found another 2 TWs (4% of total) contain higher level of Manganese which exceed the acceptable limit of WHO. Iron and manganese often occur naturally together. Sources of manganese in groundwater are naturally occurring; for example, from weathering of manganese bearing minerals and rocks. Like iron, it is suggested that manganese is most probably produced from different ores that soluble into ground water. In other word, the presence of manganese in underground drinking water could be due to its percolation from granitic and metamorphosed rocks into groundwater i.e., water-rock interaction. Actually manganese occurs naturally in ores that may erode into ground water sources.

Iron and manganese often occur naturally in deeper wells where the groundwater may have little or no oxygen, and in areas where groundwater flows through soils rich in organic matter. Man-made sources include well casing, piping, pump parts, storage tanks, and other objects of cast iron or steel that may be in contact with water. Industrial effluent, acid-mine drainage, sewage, and landfill leachate may also contribute manganese to local groundwater. In this study we found Manganese level very insignificant, samples did not cross the WHO guideline value.

4.13 Fecal Coliform and Total Coliform

Beyond a doubt one of the most serious public health risk associated with drinking-water supplies is microbial contamination. Groundwater is usually of good microbial quality. Groundwater occurs under much of the world's surface, but there are great variations in depths at which it is found. When water sources are contaminated microbiologically, water-borne diseases can be transmitted the many pathogens that can be present in water are ingested by humans through drinking and cooking water. Drinking of unsafe water may cause intestinal infections, dysentery, hepatitis, typhoid fever, cholera, gastroenteritis, and other illnesses like abdominal cramping, vomiting, nausea, headaches, fatigue and diarrhea possibly leading to severe dehydration, malnutrition, kidney failure, and death. Safe drinking water is intended for human consumption should contain no pathogens. To determine if a given water supply is safe, the source needs to be protected and monitored regularly [85]. The use of indicator organisms, in particular the coliform group, as a means of assessing the potential presence of water-borne pathogens has been of principal importance in protecting public health [86].

TC and FC are commonly measured as indicator bacteria for drinking water quality.

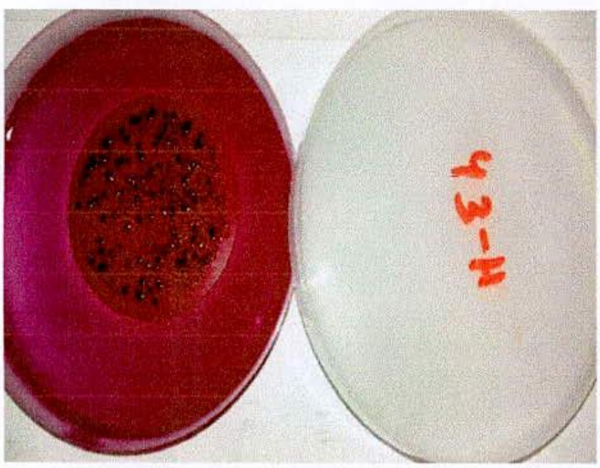


Figure 4.16(A): Higher total coliform found in Household water sample of Raligate Resir Bagan slum, ward no 02.

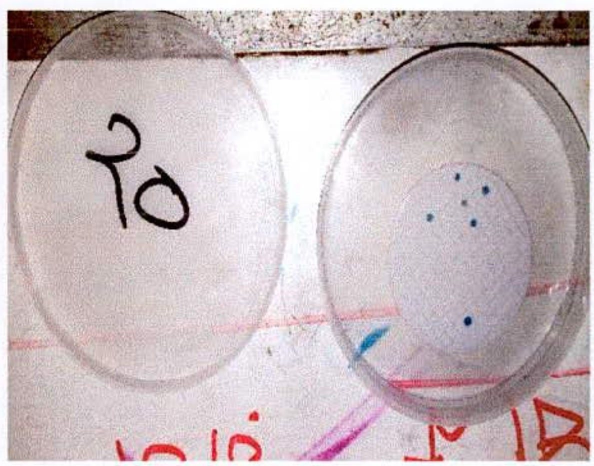


Figure 4.16(B): Fecal Coliform found in 4-no Kasem nagor road, Gollamari Dakshinward, Ward no 24.

In the investigated areas, groundwater is the principal source of drinking water. Slum dwellers use this water directly or they collect it into aluminum, plastic or mud made jar/household and use from there. Bacteriological investigations were performed as measure of drinking water quality of both sources and household water. Fecal and total coliform in the investigated drinking water sources and household stored water and type of risk is put into the table 4.11 and percentages of sources water and household water contaminated with FC and TC has been shown in the table 4.12.

Table 4.11: Quality of drinking water on basis of fecal coliform and total coliform

Category (CFU/100mL)	FC (Source)	FC (Household)	TC (Source)	TC (Household)	Type of Risk
<1	37	5	19	0	Safe
1-10	7	8	16	1	Low
11-50	5	25	13	14	Intermediate
51-100	1	9	2	20	High
>100	0	3	0	15	Very High

Table 4.12: Percentages of source and household water contaminated with fecal coliform and total coliform

Category CFU/100mL	% of FC (Source) CFU/100mL	% of FC (Household) CFU/100mL	% of TC (Source) CFU/100mL	% of TC (Household) CFU/100mL	Type of Risk
<1	74	10	36	0	Safe
1-10	14	16	32	2	Low
11-50	10	50	26	28	Intermediate
51-100	2	18	4	40	High
>100	0	6	0	30	Very High

Study results have been ordered according to the level of contamination in Figures 4.17(A), (B) and 4.18(A), (B). From the table, it is clearly seen that 74% TWs provide FC free water, where only 10% household water sample was found FC free. At the same time only 19% TWs supply TC free water, hence safe for drinking purpose but no household water sample was found TC free. Again 14% of total TWs sample and 16% of total household water samples contained FC range 1-10 CFU/100mL which is considered as low level risk and 32 %TWs and 2% of Household samples contained TC organism within this range. Potable water of intermediate risk level 11-50 CFU/100mL FC contained in 10% TWs samples and 50% household samples where TC contained in 26% TWs sample and 28% in household samples. On the other side 2% of TW's and 18% of and household samples contained FC from high risk range 51-100 CFU/100mL and also 4% TWs sample and 40% household samples were within this range. TC in this range is treacherous risk in case of human consumption. Fecal coliform higher than 50 CFU/100mL is risk for public health especially for children as well as older. Furthermore it was very much alarming that 6% FC of total household and 30% TC of total household samples contained coliform bacteria more than 100 CFU/100mL which supposed as very high risk in case of consumption. The high level of coliform count recorded in this study may be attributed to the high degree of contamination of the water sources due to unhygienic practices around and near water sources.

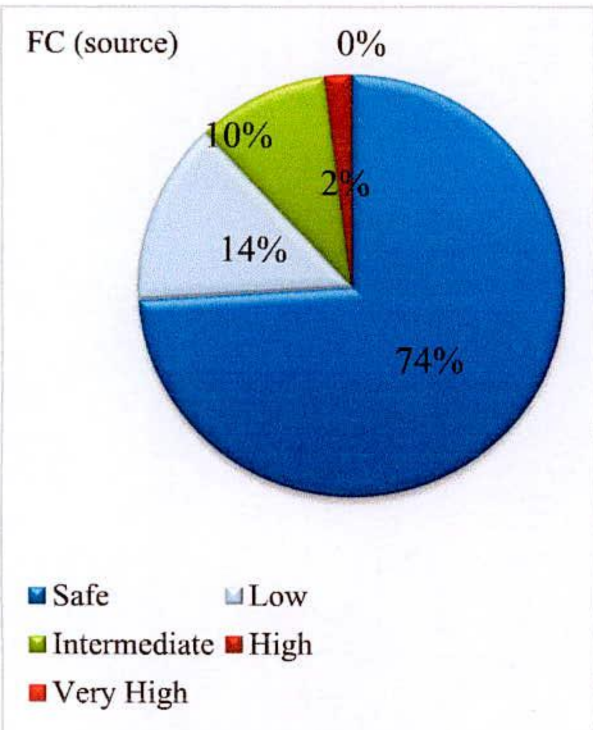


Figure 4.17(A): Percentage of FC contamination in TWs sample

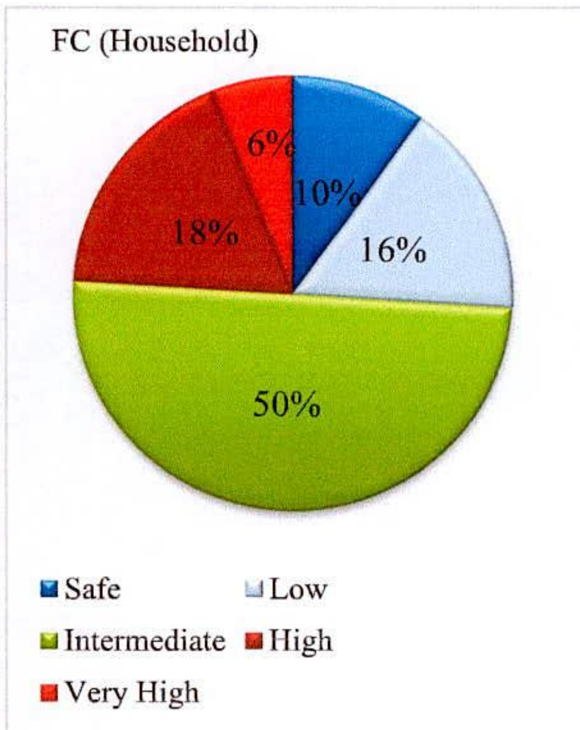
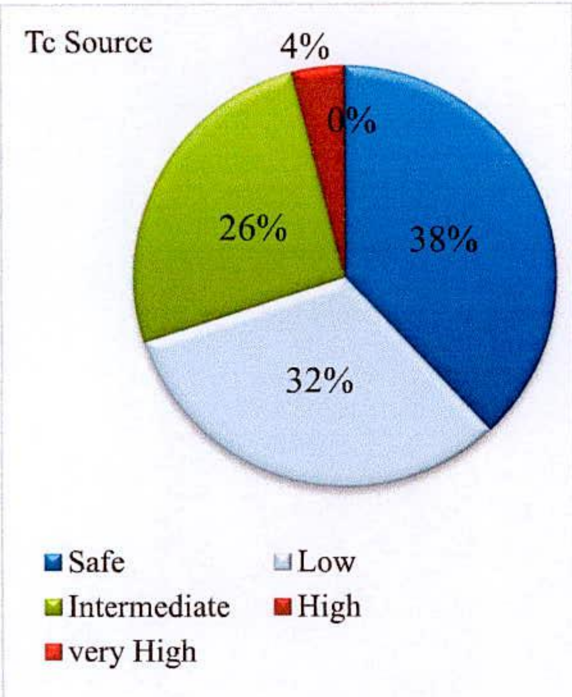


Figure 4.17(B): Percentage of FC contamination in household sample



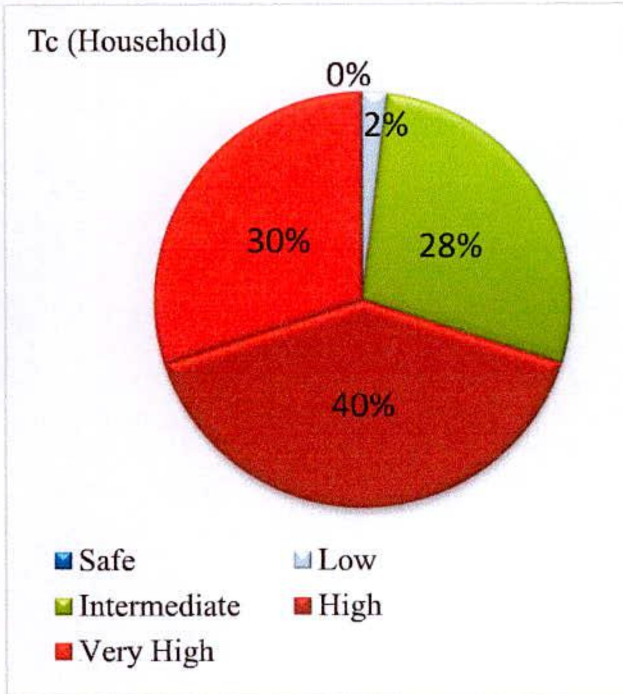


Figure 4.18(A): Percentage range of TC contamination in TWs samples

Figure 4.18(B): Percentage range of TC contamination in household samples

Sources of total and fecal coliform in groundwater can include agricultural runoff, effluent from septic systems or sewage discharges, infiltration of domestic, solid waste or animal fecal matter. Poor well maintenance and construction can also increase the risk of bacteria and other harmful organisms getting into a well water supply. Well construction defects such as insufficient well casing depth, improper sealing of the space between the well casing and the borehole, corroded or cracked well casing, and poor well seals or caps can allow sewage, surface water, or insects to carry coliform bacteria into the well. Unplugged abandoned wells (Figure 4.1(B)) can also carry coliform bacteria into deeper aquifers. However, groundwater may also easily become contaminated from sources of contaminants such as pit latrines, garbage dumps, animal sheds and cemeteries and through poorly constructed wells. And also improper water supply, insufficient health facility, water logging, and unclaimed animal as well as some cracks and leaks might be the causes of positive bacterial counts and increased water contamination in GW.

Furthermore comparing coliform contamination level of sample between TWs water and household water sources obtained that contamination level deteriorated tremendously. From figure 4.19 and 4.20 it was evidenced that coliform counts were substantially higher in household water samples than in TWs water sources. It was also noticed (Appendices C) that in many household samples coliform bacteria contained more than 100 CFU/100mL while all the water samples of TWs was found coliform less than 100 CFU/100mL. From bacteriological counts it is seen most of the household samples were in unsafe range of pollution for drinking specially by TC. None of the household water samples were found to be safe for drinking according to WHO Microbiological Guidelines (recommend TC and FC values is zero in drinking water). So it is evident from the results household water samples are highly contaminated by TC and FC than those from TWs water samples.

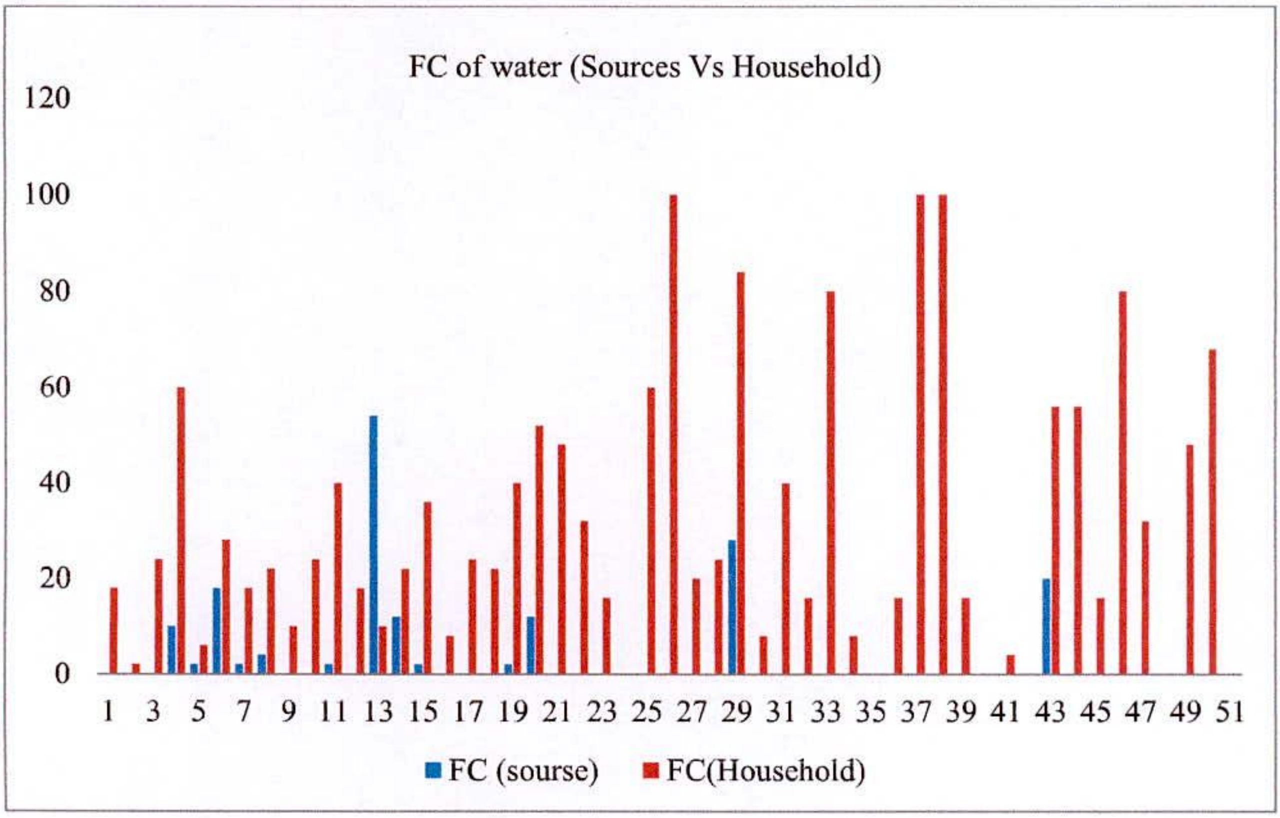


Figure.4.19: Comparison of FC in water between TWs and household samples.

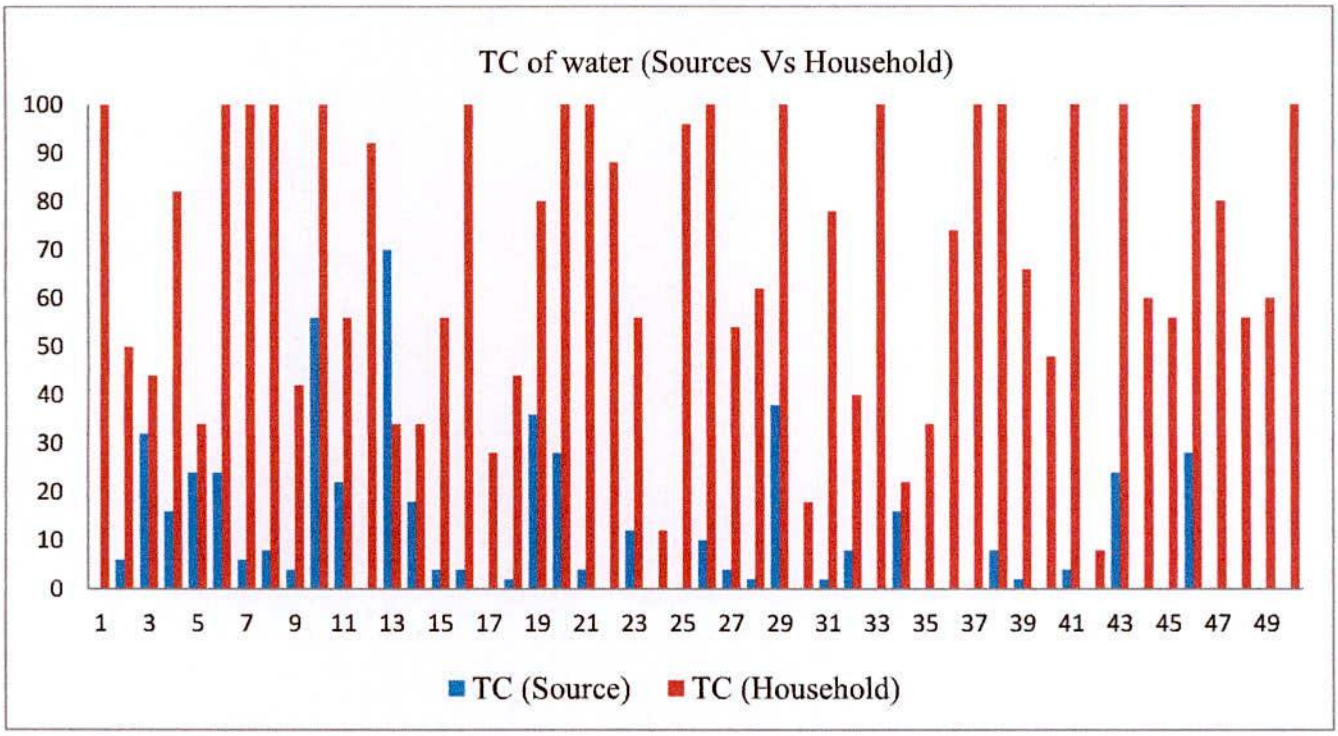


Figure 4.20: Comparison of TC in water between TWs and household samples.

According to Thomas and Cairncross [87]. The main contribution for household water contaminations were unhygienic water collection and storage activities. Selection household containers, transfer of water out of storage container by dipping increases household container than sources even clean water collected form a source can be contaminated due to unsafe hygiene practices: Water can be contaminated at the source, in the home, or during the journey in between [88]. According to a baseline assessment conducted in Bangladesh, about 8% of the respondents were found to dip their hands during water collection to remove excess water from the container. After intervention through hygiene education and motivation, only 2% respondents were found to continue with this practice; and about 74% of the respondents covered water containers during transportation, with the remaining respondents leaving the container open [89].

However, from the research is was assumed that the water at the source is only the first step. Even clean water collected from a source can be contaminated. The assessment of water handling practices in slum area observed that stored may be contaminated through unhygienic practices around water sources, human activities near water sources, unwise waste disposal, high population density, basic sanitation lacking, handling water at home with dirty kits or hands, storing water at home in open or dirty water container, dirty and muddy housing conditions (Figure 4.6), animal (rat, mice), insect, bad sanitation system.

But in slum area people are drinking water in which contain TC and FC in low or intermediate ranges habitually due to unavailability of fresh water, ignorance or of their nuisance. Interestingly, a little trouble is observed. This is may be inhabitants in this area adapted or used to this type of water and developed immunity to those amount of mentioned bacteria. It is also seen from this study that the slum dwellers who use to drink water which contain high range of bacteria often suffer various diseases like, dysentery, hepatitis, typhoid fever, cholera, gastroenteritis, abdominal cramping, vomiting, nausea, headaches, fatigue, diarrhea etc. People of this area are illiterate (as mentioned in section 4.1.5-4.1.6) or they have no any idea regarding the water quality or the reason behind the diseases talked about. At the same time they have no capacity of buying fresh/safe water or other alternatives too.

Water sources should be used with care and maintained in good condition. Water should be stored in clean vessels which are covered and regularly cleaned. Latrines should be located away from water sources and be kept clean. Proper sanitation, management, regular monitoring and maintenance of water sources should be carried out to avoid water borne diseases.

CHAPTER V

Conclusion

For the last few decades the growth of urban population is extremely high. Khulna city as well has been experiencing a regular increase in its inhabitants because of migration of peoples from various parts of the country. With the ever growing population pressure a large area of slums and unplanned housing is building up. Where absence of proper sewerage system, lack of adequate roads and drains, inadequate provision for water supply and solid waste disposal system etc. have led to the development of various environmental problems. In the present study the groundwater and household stored drinking water quality of KCC slum area has been characterized. To assess the quality of water each parameter was compared with the standard desirable limits prescribed by WHO and BDS. This study confirms that major physical and chemical parameters of GW meets the Bangladesh and WHO standard and reflect the suitability of drinking purposes from the point of view of levels of pH, EC, TDS, total hardness, Cl^-, Fe, As, Mn. The bacteriological results of TC and FC revels that the quality of maximum water sources did not meet guidelines standard for drinking water set by WHO. A number of water sample in TWs are found dipped with coliform bacteria. A water source can be contaminated through a number of routes including leaking septic tanks, duration of TW and latrine, objects falling into the well, unprotected TW, broken and cracked fence, improper solid waste disposal, water logging. At the same time dreadfully noticing point was that both TC and FC counts in household samples were higher than those of identical TWs sources. The percentage of contamination may increase after water collection and stored from safe sources because of contamination through unclean hands, unwashed uncovered dirty water containers and dippers, unhealthy and dirty housing condition, bad sanitation system, unclaimed animals and insects. All efforts to make water clean are pointless if the water is improperly stored or handled. High counts of indicator organisms in all sampled water sources of the study areas suggested the presence of pathogenic organisms that constitute a threat to anyone consuming these water sources. However, continuous assessment and monitoring is needed to in slum area of KCC for water security and public health.

Recommendation

- It is necessary to find out the source of contaminants which is due to soil types, industrialization, water chemistry and other human activities.
- Latrine should not be situated within 10 m (standard distance according to WHO health based guideline) from the tube-wells.
- Bacterial counts in all household sample water have exceeded the guidelines so it is urgent to develop basic water handling practice and disinfect the water sources properly.
- To overcome the difficulties in providing safe water and sanitation to those that lack it need more research.
- Household area and water containers should be cleaned regularly.
- Water containers should be stored in safe and cleaned places in which insects and animals like rat are unapproachable.
- Fence and Platform of the tube-wells must be well constructed and cleaned. And broken fence and platform should be repaired.
- Sewerage line, dustbin, drain, must be well constructed and also be cleaned regularly.
- Future studies are required to determine the seasonal variations in the contamination level of the water sources to develop risk-reducing water quality management systems.
- Unhygienic practices around water sources, human activities near water sources like unwise waste disposal as well as some cracks and leaks might be the causes of positive bacterial counts and increased water contamination. Proper sanitation, management, regular monitoring and maintenance of water sources should be carried out

Reference

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Appendix A

Sample. no	Sampling Location	Ward .no	caretaker Name	Death (feet)	Installation year	Famil y no.
Sample1	Moksed goli, Rupsha	22	Surjha Biswas	1200	1994	30
Sample2	Mumshi Bari, Rupsha Ghat	29	Habibur Rahaman	950	1996	15
Sample3	Sat Vai goli, Notun Bazar chor goli, Rupsha	22	Fatima Begam	850	1999	25
Sample4	2 no. customs ghat, beri badh Road, Kagoji Bari	22	Public	900	2000	85
Sample5	Motiakhali pancham goli	31	Public	950	1999	36
Sample6	Rupsha Mach bazar boshti	30	Harun Molla	900	1992	25
Sample7	Mohi barir mor, south tootpara.	28	Saifur Rahaman Khoka	900	2003	15
Sample8	Chotokhal Para, circuler Road, Tootpara.	30	Abdul Odud	800	2010	28
Sample9	Daroga Para	28	Abdul Gaffar	1200	1995	15
Sample10	Bulbuler Bosthi	28	Md. Hasibur Hossain	1000	2001	22
Sample11	Shekh Bari Modina Mosjid, Motlober Mor	27	Shekh Abdul Kader	950	1995	50
Sample12	Barek Member Bari, Khulna	27	Rustam shekh	950	1990	20
Sample13	Binodini Hospital, Halim Uukil Bosthi. Mia para	28	Khalib Ukil	900	2000	50
Sample14	Commerder Bari, Mia Para	28	Torikul Islam	950	2012	20
Sample15	Nazrul Islam sarak, Karpara, Khulna sadar	28	Liton Shekh	1000	2005	18
Sample16	Mistripara Khalpar slum, Purba Bagmara.	27	Md Shikder	900	1995	150
Sample17	Slum of Mr Jalil, Purba Bagmara, Khulna sadar	27	Jalil Ahmed	1000	1997	22
Sample18	Mushir Goli, 2 no. cross Road	24	Islamuddin Shekh	700	1978	30
Sample19	Nirala Dhighir paar	24	Golam Rabbani	1000	1990	80
Sample20	No-4, Kasem nagor road, Gollamari Dakshin	24	Hafeej Hossain Siraj	950	1998	
Sample21	Gollamari Bridge Side	24	Omed Ali	850	1995	50

Sample2 2	Gollamari Rishi Para	25	Molen dey	1000	1993	60
Sample2 3	Bil slum(khora slum), Sonadanga	17	Habibur Rahaman	850	1999	210
Sample2 4	Sonadanga slum	17	Nur Ali	850	2001	56
Sample2 5	Biswas Bari, Khalasi, Uttar Gobarchaka Main Road	18	Rabeya Biswas	800	2005	60
Sample2 6	5 no. Mach Ghat Rail colony	21	Md Jamal Hossain	1400	1995	400
Sample2 7	Greenland Abasik Rail colony	21	Parul Begam	1000	2001	120
Sample2 8	7 no. Ghat Kacha Bazar	21	Haque Mia	950	1996	90
Sample2 9	Boroi tola Railway colony	21	Nobolok Parishod	960	2007	960
Sample3 0	Joragate Monur Colony	21	Md Montu	1000	1990	350
Sample3 1	Noyabati Siddik Munshir Bari, Khalishpur	10	Public	1000	1980	100
Sample3 2	No-2 Platinum Jublee Labour Colony, Khalishpur	11	Ofan Mridha	950	2010	55
Sample3 3	Kashipur Pora Bari, Lkhalishpur	7	Forhad Hossain	1050	2000	350
Sample3 4	Rajanigandha Colony(Cricent Jute Mill) Khalishpur	8	Rafiq Sardar	1200	1980	200
Sample3 5	Camp no. 7, old Colony Khalishpur	12	Hasin Moulovi	900	1995	200
Sample3 6	3 no. Camp, Khalishpur	12	Public	950	2005	300
Sample3 7	Alam Nagar Pora Mosjid, Khaluishpur	13	Younus Molla	1000	1994	25
Sample3 8	GMB bastuhara colony	9	Md. Rahim	1000	1990	25
Sample3 9	Mujguni Rail Crossing Road	9	None	1000	1992	65
Sample4 0	Gabtola Slum Railway, Khalishpur	15	Shamim Kazi	1050	1995	250
Sample4 1	Ispahani Laboure colony	3	Mamjaj Begam	1000	1995	100
Sample4 2	Palpara, Doulotpur	3	Hamid Munshi	950	1998	
Sample4 3	Raligate Resir Bagan	2	Public	900	1999	300

Sample44	Nogor Ghat Raligate	2	Shohidul Islam	850	1998	21
Sample45	Helal colony , Doulotpur	3	Kushum Begam	950	1985	40
Sample46	Diyana Uttor para	4	Humayan Talukder	900	2000	150
Sample47	Anjuman Road Amtola	5	Public	950	2002	30
Sample48	Rishi para Doulotput	5	Public	900	Unknown	40
Sample49	Pabla teen dokaner Mor	5	Altaf Muhuri	1000	2002	28
Sample50	Kawser bosthi, Kashipur	6	caretaker Name	800	2005	30

Appendix B

Sample No.	pH	EC (μs/cm)	Cl^- (mg/L)	TDS	Hardness (mg/L)	As (mg/L)	Fe (mg/L)	Mn (mg/L)
1	7.88	953	153.54	456	260	0.002	0.03	<LOQ
2	8.03	730	124.29	369	155	0.001	0.02	<LOQ
3	7.74	1681	519.12	845	450	<LOQ	0.31	<LOQ
4	7.44	1019	221.78	532	345	0.013	0.58	0.02
5	8.09	635	77.99	327	185	<LOQ	<LOQ	<LOQ
6	8.04	594	70.67	281	165	<LOQ	0.31	<LOQ
7	8.18	544	82.86	276	125	<LOQ	0.09	<LOQ
8	8.27	551	43.86	286	105	<LOQ	0.01	<LOQ
9	8.05	664	90.17	347	145	<LOQ	0.15	<LOQ
10	8.04	630	168.16	329	165	<LOQ	<LOQ	<LOQ
11	8.17	587	90.17	306	160	<LOQ	0.01	<LOQ
12	8.15	588	70.67	311	150	<LOQ	0.02	<LOQ
13	8.1	643	80.43	338	145	<LOQ	0.01	<LOQ
14	8.12	582	68.24	303	130	<LOQ	0.04	<LOQ
15	8.13	563	48.74	307	125	<LOQ	<LOQ	<LOQ
16	8.05	638	92.61	321	175	<LOQ	0.1	<LOQ
17	8.09	658	92.61	337	180	<LOQ	0.15	<LOQ
18	8.29	564	46.3	308	110	0.006	0.01	<LOQ
19	8.27	554	41.43	289	250	<LOQ	0.03	<LOQ
20	8.3	591	68.24	312	130	<LOQ	0.23	<LOQ
21	8.34	582	58.49	309	105	0.0005	0.02	<LOQ
22	8.48	629	48.74	329	50	0.005	0.11	<LOQ
23	8.55	816	51.18	428	80	0.01	0.02	<LOQ
24	8.13	827	477.68	433	160	0	0.03	<LOQ
25	8.25	1606	153.54	837	350	0.002	0.91	0.02
26	7.99	827	155.98	436	180	0.001	0.03	<LOQ
27	8.01	826	151.11	432	210	<LOQ	0.14	0.02

28	8.05	776	136.48	404	210	0.0005	0.15	<LOQ
29	7.95	868	177.91	747	225	<LOQ	0.08	<LOQ
30	8.06	776	138.91	407	220	0.002	0.13	<LOQ
31	7.85	1540	448.44	801	510	0.00007	0.06	0.01
32	7.88	1969	625.37	1025	505	<LOQ	0.16	0.09
33	7.4	886	99.92	449	275	<LOQ	0.1	0.01
34	7.5	1279	302.21	669	300	<LOQ	0.04	0.01
35	7.96	989	226.65	516	255	<LOQ	0.32	0.01
36	7.69	1998	647.02	1032	555	<LOQ	0.48	<LOQ
37	7.68	2.21(ms/cm)	610.94	1147	650	<LOQ	0.33	<LOQ
38	8.14	914	146.23	477	200	<LOQ	0.09	<LOQ
39	8.06	1043	236.41	546	225	0.0002	0.17	<LOQ
40	7.96	910	192.53	458	250	<LOQ	0.24	<LOQ
41	8.32	611	31.68	309	130	0.008	0.17	0.02
42	7.63	1825	397.26	930	200	0.0006	0.3	0.68
43	8.22	676	60.92	350	150	0.005	0.12	0
44	7.59	725	51.18	380	140	<LOQ	0.19	0.58
45	7.58	836	63.36	424	100	0.0004	0.02	0.33
46	8.35	656	36.56	336	95	0.02	0.11	<LOQ
47	8.27	865	136.48	446	145	0.01	0.12	0.01
48	8.36	761	87.73	389	110	0.01	0.15	<LOQ
49	8.21	1130	243.71	590	200	0.008	0.14	0.01
50	7.85	2139	721.58	1176	610	0.003	0.36	<LOQ

Appendix C

Sample No.	FC (source)	FC (Household)	TC (Source)	TC (Household)
1	0	18	0	<100
2	0	2	6	50
3	0	24	32	44
4	10	60	16	82
5	2	6	24	34
6	18	28	24	<<100
7	2	18	6	<100
8	4	22	8	<100
9	0	10	4	42
10	0	24	56	<100
11	2	40	22	56
12	0	18	0	92
13	54	10	70	34
14	12	22	18	34
15	2	36	4	56
16	0	8	4	<100
17	0	24	0	28
18	0	22	2	44
19	2	40	36	80
20	12	52	28	100
21	0	48	4	<100
22	0	32	0	88
23	0	16	12	56
24	0	0	0	12
25	0	60	0	96
26	0	<<100	10	<<100
27	0	20	4	54
28	0	24	2	62
29	28	84	38	<100
30	0	8	0	18
31	0	40	2	78
32	0	16	8	40
33	0	80	0	<100
34	0	8	16	22
35	0	0	0	34
36	0	16	0	74
37	0	<<100	0	<<100
38	0	100	8	<100
39	0	16	2	66
40	0	0	0	48
41	0	4	4	<<100
42	0	0	0	8
43	20	56	24	<100
44	0	56	0	60

45	0	16	0	56
46	0	80	28	100
47	0	32	0	80
48	0	0	0	56
49	0	48	0	60
50	0	68	0	<<100