بسم الله الرحمن الرحيم

AN ANALYSIS OF HEALTH RISK ASSOCIATED WITH URBAN WATER SUPPLY IN BANGLADESH

BY

SADIK RAHMAN (085407)

MD. ASIF HOSSAIN (085430)

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT), OIC
GAZIPUR, BANGLADESH

OCTOBER 2012

AN ANALYSIS OF HEALTH RISK ASSOCIATED WITH URBAN WATER SUPPLY IN BANGLADESH

A project report submitted to the department of Civil and Environmental Engineering, Islamic University of Technology (IUT), in partial fulfillment of the requirement for the degree of

Bachelor of Science in Civil and Environmental Engineering

THESIS

CEE 4800

SUPERVISED BY

PROF. DR. REZAUL KARIM
Professor
Department of CEE
Islamic University of Technology
Gazipur.

SUBMITTED BY

SADIK RAHMAN
Student No.: 085407

MD. ASIF HOSSAIN
Student No.: 085430

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
GAZIPUR, BANGLADESH

OCTOBER 2012

Acknowledgement

All praises are for Allah (swt), by whose permission we managed to finish our work within scheduled time period. We also want to praise him for removing all odds at times of distress in working. After that, it has been a great honor to have Prof. Dr. Md. Rezaul Karim as our course supervisor whose guidance has made this work possible up to the end. He helped with his esteemed knowledge from the very beginning in understanding and applying the methods properly and patiently. The knowledge he shared and reflected will be an asset for the future with great benefit. And his cooperated contribution in spite of his busy time will remain in our minds for long.

The authors also want to thank their course supervisor for providing two valuable secondary data source of water quality parameters of Khulna City Corporation (KCC) and Jessore Pouroshova (JP) which were the nucleus of this comparative study. And lastly it was an important sharing of knowledge of health risk assessment and the Model itself which was not possible without his kind sharing and assistances.

Md. Asif Hossain　　　　Sadik Rahman

APPROVAL

This is to certify that the thesis submitted by Sadik Rahman and Md. Asif Hossain entitled as “AN ANALYSIS OF HEALTH RISK ASSOCIATED WITH URBAN WATER SUPPLY IN BANGLADESH” has been approved by the supervisor for the partial fulfillment of the requirement for the degree of Bachelor of Science in Civil and Environmental Engineering, Islamic University of Technology (IUT), Gazipur, Bangladesh in October 2012

SUPERVISOR

____

PROF. DR. REZAUL KARIM

Professor

Department of Civil and Environmental Engineering (CEE)

Islamic University of Technology (IUT)

Gazipur, Bangladesh.

Abstract

Water, a vital resource for the survival of human species, has the potential to be a destructive force with if contaminated significantly. The trend of population immigration towards large cities and rapid economic growth has led to necessity of modern, well maintained, centralized water distribution systems. However, aging of the system, overstress and poor maintenance of distribution system leads to degradation of water quality below acceptable levels within the supply network. These contaminations occurs due to various reasons including but not exclusive to failure to maintain proper disinfectant residual, low pipeline water pressure, intermittent water supply, excessive network leakages, corrosion of parts and inadequate sewage disposal. In the length of this study, two secondary data sources have been used obtain water quality parameters for two southwestern areas of Bangladesh, Khulna City Corporation (KCC) and Jessore Pourashava (JP) to establish the water quality situation in these areas and to deduce the probable flaws in the supply network that is affecting specific types of contaminations.

The quantitative assessment was done by probabilistic comparison among physical, chemical and microbial parameters like – turbidity, color, pH, conductivity, TDS, Total Coliform, E. Coli etc.   Quantitative Health Risk Assessment (QHRA) model was used to evaluate present scenario of disease burden based on microbial parameters. This assessment was also compared between KCC and JP to identify severity of disease proneness.

It was observed that among 96 sample data from JP and 138 sample data from KCC, all show acceptable level of turbidity in terms of Bangladeshi standards. But for color parameter, 77% of KCC samples and 27% of JP samples exceeded limit. For chemical parameters, all samples from JP was acceptable for pH, Electrical Conductivity, Chloride, TDS and 7% and 32% samples exceeded limit for hardness and alkalinity as $CaCO_3$ respectively. For T.C. and E.coli, 83% and 79% samples exceeded allowable limit respectively. In KCC, above 70% samples exceed allowable limit for Electrical Conductivity, and for chloride and TDS, 24% and 15% samples, respectively, exceeded allowable limit. For T.C. and E.coli, 100% and 77% samples correspondingly are beyond

permissible limits. From the QHRA analysis it is seen that the disease burden due to the high values of microbial parameters exceed the guideline value (GV) which signifies that the water quality of these two water supply networks are not in good condition.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1 GENERAL

Since the dawn of time, perhaps it is water which has been considered the most critical natural resource for the survival of human species. Human health conditions are dependent to the highest degree on the availability of safe drinking water; and as of today, it still remains a crucial public health property. One of the primary goals of WHO and its member states is that "All people, whatever their stage of development and their social and economic conditions, have the right to have access to an adequate supply of safe drinking water."(WHO 2006). Although one name of water is "life" in a well known Bengali proverb, this same resource becomes a source of destruction if significantly contaminated physically, biologically or chemically. Estimated 80 percent of all diseases and over one third of deaths in developing countries are caused by the consumption of contaminated water, and on an average as much as one tenth of each person's productive time is sacrificed to water-related diseases (UNCED, 1992). Over 60% of the communicable diseases are due to poor environmental health conditions arising from unsafe and inadequate water supply and poor hygienic and sanitation practices (Abebe Ls; 1986). Water, therefore has the vital effect of either being the preserver of life, or the taker of life.

Quality of drinking water in Bangladesh remains in a very threatening position. Acute problems are arising, caused by continuing trend of population migration to larger cities and unprecedented economic growth. The study area of Khulna City Corporation (KCC) and Jessore Pourashava (JP) is located in the southwest of Bangladesh. Both areas have been suffering from inadequate supply of safe drinking water often associated with water quality problems.

This study intends to use health risk assessment and contaminant parameters assessment of the two selected areas carried out in two different papers as secondary data sources and carry out a comparative analysis between condition of the two areas in terms of health risk and contaminant levels present. This study was undertaken as part of the under-graduate program of the Department of Civil and Environmental Engineering of Islamic University of Technology (IUT).

1.2 OBJECTIVES

This study intends to carry out the following objectives:

- Analysis of the physical, chemical and microbial quality of piped water supply of Khulna City Corporation (KCC) and Jessore Pouroshova (JP).
- Evaluation of health risk associated with microbial contamination of piped water supply using QHRA Model.
- Development of guidelines to promote sustainable drinking water quality management to meet the drinking water standard.

1.3 SCOPE OF THE STUDY

The guidelines of drinking water quality in managing drinking water quality of JP and in KCC area are followed. The governing remedial action and the necessary remedial actions that should be taken are also studied in the scope of this thesis. To achieve the above discussed the following objectives the following steps were carried out:

- ✓ Comparative analysis between water quality parameters of KCC and JP.
- ✓ Health risk analysis based on the data found from secondary sources
- ✓ Determining/ hypothesizing the causes of water quality deterioration of KCC and JP.
- ✓ Recommending a guideline to improve the quality of supply water of KCC and JP.

1.4 Study Area

The study area of Khulna City Corporation (KCC) is located in the southwest Bangladesh. The city along with its surrounding is bounded by the longitude 89°28′ to 89°37′ East and latitude 22°46′ to 22°58′ North. The Bhairab on northern side, Rupsa River in the middle part and Pasur on the southern side flows along eastern margin of the city and Mayur on the northern side and Hatia River on the southern side flow along the western side of the city.

The study area of Jessore Pourashava (JP) is located in the southwest Bangladesh. The city along with its surrounding is bounded by the longitude 89°20′ East and latitude 23°17′ North. The Bhairab River flows alongside the city. The Jessore City area is the study area.

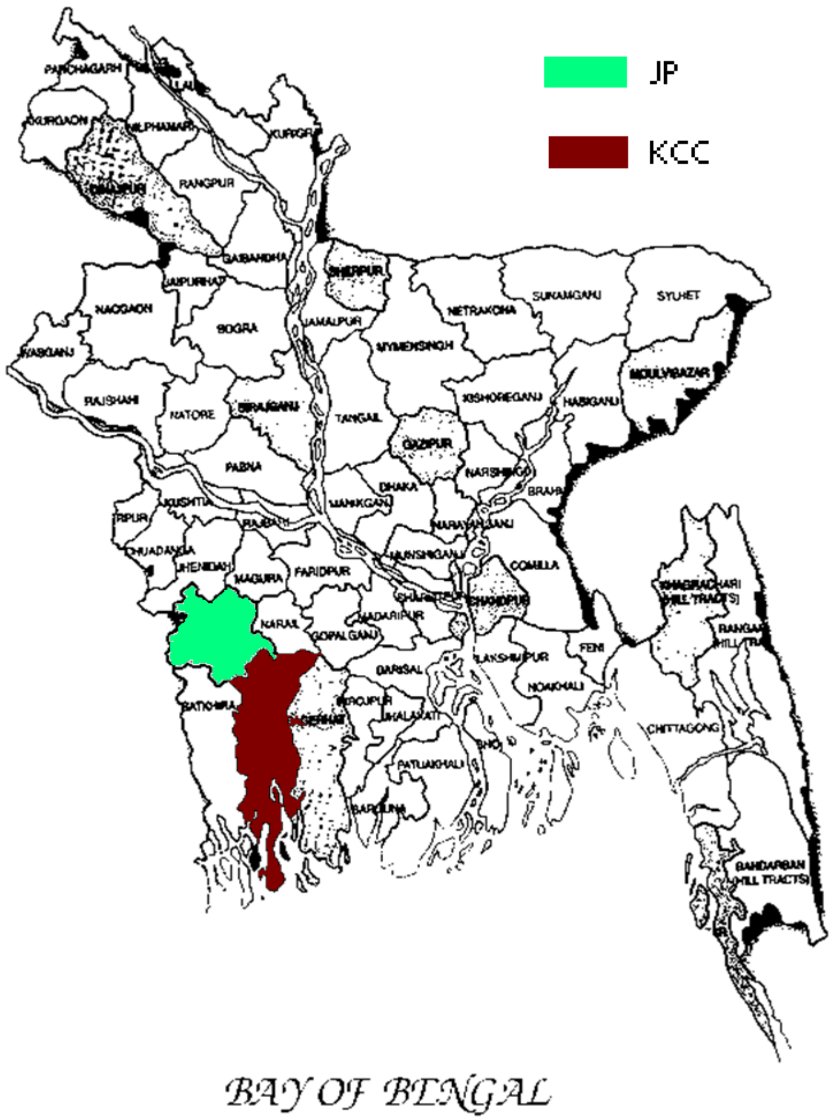


Figure 1.1: Geographical location of KCC and JP

1.5 Limitations of the Study

The assessment was done based on the secondary data from two studies which is one of the main limitations of our assessment. Unavailability of the primary data from main water extraction point and the data of supply network results in the failure of comparative analysis between the level of contamination that existed at the extraction point and the contamination that took place within the network.

CHAPTER TWO

LITERATURE REVIEW

2.1 GENERAL

Water has been used since antiquity as a symbol by which to express devotion and purity. With two thirds of the earth's surface covered by water and the human body consisting of 75 percent of it, it is evidently clear that water is one of the prime elements necessary for life on earth. About 11 per cent of the global population remains without access to an improved source of drinking water. Such sources include household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater collections. Since it is not yet possible to measure water quality globally, dimensions of safety, reliability and sustainability may actually be slowing progress.The people of developed countries has easily access to pure and sufficient water where in developing countries, in fact, many people do not have connections. A lot of effort is made in the world to change this situation, but has it been effective and is the situation really changing? That is question of utmost significance.

The area of Jessore Pouroshova and Khulna City Corporation are two well populated town and city areas where water demand was always very important to fulfill. But the common characteristic of these urban areas is the lack of accessibility to suitable quantity and quality of water.Unplanned and improper withdrawal of water is the main cause of shortage of water in KCC. These shortages have become more acute when pumps are installed haphazardly. In some of the cases the supply system suffers a gross water loss from old AC pipes, poor system control and excessive consumer wastage. And in JP water supply system, which are made of AC (Asbestos Cement) pipes planted all over the city during British Colony, still existing in the present time period, are used for water supply to the consumers and the contaminated water of those pipes is also used for drinking purposes by the city dwellers. Sometimes, the consumers suffer from frustration because of the inadequate storage capacity of the system and the intermittent supply.

The water quality of these two areas is affected with some contaminations which are responsible for water borne disease along with other disease burden. These are occurring due to various reasons but mainly of distribution systems. The health risks due to these problems are causing a large number of diseases every year which degrades the quality of health and sanitation of the area which is one of the main criteria for development. So the present stage of these two zonal water quality is in need to quantify for following reasons:

1. To know the water quality comparison between these two main towns of South west of Bangladesh which are very important for both economy and historical reasons.
2. To know the variations of distribution of data within these two areas for water quality so that it can be easily predictable about the source of contamination.
3. Also to determine the averages of the water quality parameters to know the mostly median values for particular parameter.
4. To know the health risk associated with different parameters which are the possible reasons for lots of communicable and non communicable diseases which are threat to the good quality health environment.

Major objective of the study is to investigate the extent of bacterial contamination in the piped water supply and to assess the comparison of parameters of drinking water and investigate the possible causes that influence their of these two areas.

Table 2.1: Water supply networks at a glance

	Khulna City Corporation	Jessore Pourashava
Total Area	59.57 km^2	25.72 km^2
Population of Area	8,55,650	1,78,273
Average consumption	125 l/c/d	140-150 l/c/d
Source of water	Ground Water	Ground Water
Production type	Intermittent	Intermittent
UFW	36.36%	28.2%
Pumping hour	5.3 hr/day	12 hr/day
Treatment method	None	None
Producing Tube Wells	73	18

2.2 *Piped water supply network in developing countries*

There are a number of possibilities which may be responsible for contamination of the supplied water, including but not restricted to failure to disinfect water completely in the first place, maintain proper disinfection residual, low pipe line water pressure; excessive network leakages, corrosion of parts, inadequate sewage disposal etc. Intermittent service of water encourages stagnancy of water and growth of microorganisms. In presence of pipe leakages, negative hydraulic pressure can draw pathogens from fecally contaminated material surrounding water pipes.

Water quality of water leaving from treatment plant may be acceptable in immediate vicinity. But a number of physical, chemical and biological transformations can happen as it travels through a distribution system. Evidence exists to suggest that distribution networks contribute to decreased water quality. For example, in La Plata, Argentina, intestinal parasites were detected in tap water sampled from four regional zones, but no parasites were detected from samples taken in the immediate vicinity of the plant (Basualdo et al, 2000). Similarly, in Mexico City, bacteriological contamination increased by 26% from the point of treatment to the consumer's tap. (Gaytan et al. 1997). Finally, in a Trinidadian community, 80% of house-hold tap water samples tested positive for total coliform, while no samples from the treated reservoir tested positive. (Agard et al. 2002).

Disinfectant residual is necessary in supplied water especially in developing countries due to the high risk of recontamination during distribution. For example, In Pietermaritzburg, South Africa, coliforms were found to be associated with low chlorine residual; as distance from the water plant increased, the level of free chlorine decreased with resulting coliform increase (Bailey & Thompson 1995)

In general, developing countries maintain higher concentrations of residual than the estimated 0.2mg/l maintained by developed countries' water supplies (Geldreich 1996). For instance, in Pietermaritzburg, South Africa, a free chlorine residual of 0.4mg/l was necessary to control bacterial growth (Bailey & Thompson 1995). In Johannesburg, South Africa, it was determined that a residual chlorine concentration of 0.3mg/l was necessary to reach the furthest points in the distribution system and therefore a free chlorine concentration of at least 0.8mg/l was administered at the plant (Geldenhuys 1995).

Intermittent water supply has become the norm, rather than the exception in many developing countries (Kumar 1998). In Africa and Asia, it is estimated that more than one third and one half of urban water supplies, respectively, operate intermittently (WHO & UNICEF 2000). A sporadic water supply means that, for the majority of the time that water is not provided to households, pressure in the system is drastically reduced and stagnant water remaining in the pipelines draws surrounding contaminants into the potable supply (Gadgil 1998; del Carmen Gordo Mun˜ oz 1998; Ford 1999; Merminet al.1999). Observations reinforce the notion that continual water supply is safer against contamination compared to intermittent water supply. In samples of four different Indian zones, nearly all (90–100%) samples were negative for fecal coliforms during continuous service, while only 24–73% were negative during intermittent supply (Kelkar et al.2001).

Corrosion is an inevitable result of aging process. Evidence suggests that in many regions of the world, corrosion is taking place due to aging. Chowdhury and colleagues (2002) found that, in one Bangladeshi zone, approximately 20% of the piping from early last century was corroded and leaking and over 50% of sluice valves and fittings were badly rusted. High concentration of metal precipitates solubilized in water is serious threat for consumers in terms of chemical contamination (Wagner 1994). Corrosion has the potential to contribute to degrading microbial quality of water. Even inert materials such as rubber-based materials provide bacteria with organic nutrients resulting in enhancement of microbial growth (Agard et al. 2002). Due to corrosion, miniature pitted cavities or tubercles develop on the inner surface of the walls of the distribution system, roughening the smooth surface and providing sites for bacteria to attach and grow (Besner et al.2002). These tubercles provide microenvironments for the growth of biofilms, which are thin layers of anaerobic and aerobic microorganisms adhering to the inner surface of the pipe wall (Geldreich 1996). Biofilm formation has the potential to possibly ‘hide’ pathogens by protecting them from disinfectants (Geldreich 1996).

2.3 WATER SUPPLY SYSTEM IN KCC AND JP

It has been reported that, Khulna WASA has 73 large production tube-wells which are used to supply ninety million liters of water through pipelines for the subscribers in Khulna city. Residents of Khulna city are suffering from serious water crisis as Khulna Water and Sewerage Authority (KWASA) is currently supplying only ninety million liters of water against the daily demand of 240 million liters (The Daily Star, 2011). There are only five overhead tanks in the city but two are not active. The total system has been developed over many years and has been constructed using relatively small diameter pipes. The existing system is old and poorly maintained, resulting in substantial leakage and low quality of water. A survey shows that even households connected to the piped network enjoy only intermittent water supply (5.3 hours per day), and 74% of households find the supplied quantity insufficient. As for water quality, 59% of the surveyed households perceived the supplied water to be dirty and 55% rated the service standards very poor or poor. Many unconnected households rely on shared public taps and spend a daily average of 90 minutes fetching water, imposing a particular burden on women who tend to manage water for the whole family (ADB 2011). Authority of KCC currently recovers its operating costs through the holding tax, connection fees for new services and a flat monthly charge based on the size of service connection.

During the Spring and Summer season, the G.W.L. levels down and to lift up and store that water 5 overhead tanks are used in that time period and water is distributed all over the city from those tanks. Among the pipes of different diameters, 100 mm diameter pipes are used mostly of the places. Then 200 mm dia, 150 mm dia and 250 mm dia pipes are used respectively according to the length of their usage.

Jessore Pourashava is a town in the southwestern parts of the country towards the border of India though the Benapole road. In 2001, its total population was about 178,273 composed of approximately 35,749 households. Jessore’s water supply and sanitation services remain grossly inadequate to meet the requirement of its population. Its present water supply system has 18 working production tube wells (with 7 expected to survive for longer periods), 6 overhead tanks (5 in use), nearly 106 kms of transmission and distribution pipelines, and 8,015 piped water connections (International Development Project Consult, Inc., 2006).

2.4 Drinking Water Standards:

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

The World Health Organization (WHO) had been in the forefront in developing water quality standards. The WHO standards for drinking water first published in 1958 were revised in 1963, 1968 and 1971. Bangladesh developed the first Water Quality Standards in 1976 based on the WHO 1971 International Drinking Water Standards (Islam 2011).

Table 2.2: Drinking Water Standards

Water Quality Parameters	Units	Bangladesh Standards	WHO Standard, 1993
pH	---	6.5-8.5	---
Color	Pt.Co. Unit	15	15
Alkalinity	mg/L as $CaCO_3$	400	---
Hardness	mg/L as $CaCO_3$	200-500	---
Chloride	mg/L	150-600*	250
Turbidity	NTU	10	5
Total Dissolved Solids(TDS)	mg/L	1000	1000
Electric Conductivity	µs/cm	600-1000	---
Fecal Coliform	No./100 ml	0	0
Total Coliform	No./100 ml	0	0
Iron	mg/L	0.3-1.0	---

*For Costal Area in Bangladesh Chloride value 1000 mg/l.

2.5 Water Related Diseases

Different microbial entities due to fecal contamination are the reasons for different disease burden among which some are very important to know for the disinfection.

Table 2.3: The diseases caused by different Parameters

Cause	Diseases
Rotavirus	• ***Gastroenteritis*** (inflammation of the stomach and intestines), ***watery diarrhea***, often with vomiting, fever, and abdominal pain. • In babies and young children, it can lead to ***dehydration*** (loss of body fluids). • Rotavirus is the leading cause of ***severe diarrhea in infants and young children*** worldwide. Globally, it causes more than a half a million deaths each year in children younger than 5 years of age.
Cryptosporidium	• It usually causes a mild to severe infection of the ***gastrointestinal system***, • Including ***watery diarrhea***, ***fever***, ***abdominal cramps, nausea, and vomiting.***
Enterotoxin E.coli (ETEC)	• ***Non-inflammatory Diarrheas, cholera-like illness***, common bacterial cause of acute ***diarrhoea in children*** in the developing world, • Most common cause of ***travelers' diarrhoea*** in persons who visit the developing world.

CHAPTER THREE

METHODOLOGY

3.1 Methodology

This study intends to compare between samples of KCC water supply network and JP water supply network. For this purpose secondary data sources has been used from two studies which had been previously performed in those two locations. Therefore all the physical, chemical and microbial parameters data used in this study are not derived experimentally but are obtained from secondary sources, undertaken in the first place by Maminul Islam in KCC area and Abid Azad Nobel in JP area.

For comparison purpose data were then arranged in decreasing order of magnitude and the probability P of each event being equaled to or exceeded is calculated by the plotting position formula

$$\mathbf{P} = \frac{m}{N+1}$$

Where m = order number of the event and N = total number of events in the data.

3.2 WATER QUALITY PARAMETERS:

There are various parameters related to the quality of supply water. They can be classified as physical, chemical and microbial Parameters and the comparison was done between JP and KCC based on these parameters.

Physical Parameters

- Turbidity
- Color

Chemical Parameters

- pH
- Alkalinity
- Total Hardness
- Electric Conductivity
- TDS
- Chloride (Cl^-)

Microbial Parameters

- TC
- E.coli

3.3 Quantitative Health Risk Assessment

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

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

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

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

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

Figure 3.1: DALY interpretation

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

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 INTRODUCTION

In this chapter test results are included and discussed briefly. Total 96 sample data are being used for JP area from 9 wards that were tested in the Environmental Engineering Laboratory of KUET. A no. of 10 different parameters is available and used for comparison. Total 138 numbers of sample data are being used from 23 wards of KCC Area that were tested in the Environmental Engineering Laboratory of KUET. All the graphs are drawn with the average value of the different parameters of the samples for all wards.

4.2 Physical water quality

The physical water quality, turbidity and color, of the JP and KCC supply water were compared. The maximum, minimum and average test results of each parameter are presented in the table below. It reveals from results that turbidity value for all sample is within the allowable limit of 10 NTU according to BDS when the color values exceeds the limit of 15 Pt.Co unit in most cases.

Table 4.1: Summary of Physical Parameters of JP and KCC water supply

Parameter	Unit	Max		Min.		Average		BDS	WHO GV	% exceeding BDS value	
		JP	KCC	JP	KCC	JP	KCC			JP	KCC
Turbidity	NTU	9.90	3.60	0.60	0.9	2.60	2.09	10	5	0	0
Color	Pt.Co. unit	147	89	0	0	16.50	34.50	15	15	27	77

4.2.1 Turbidity

Turbidity occurs in most surface waters due to the presence of suspended clay, silt, finely divided organic and inorganic matters, plankton (algae) and micro-organisms. The suspended particles that cause turbidity range in size from colloidal dimensions (approximately 10 mm) to diameters of the order of 0.1 mm.

The current standard method for measurement of turbidity employs the principles of nephelometry and measures the scattering of light from particles. Results are expressed in Nephelometric Turbidity Unit (NTU).

According to BDS values, the turbidity value should lie within 10 NTU and according to WHO guideline values, the maximum limit of turbidity should be 5 NTU.

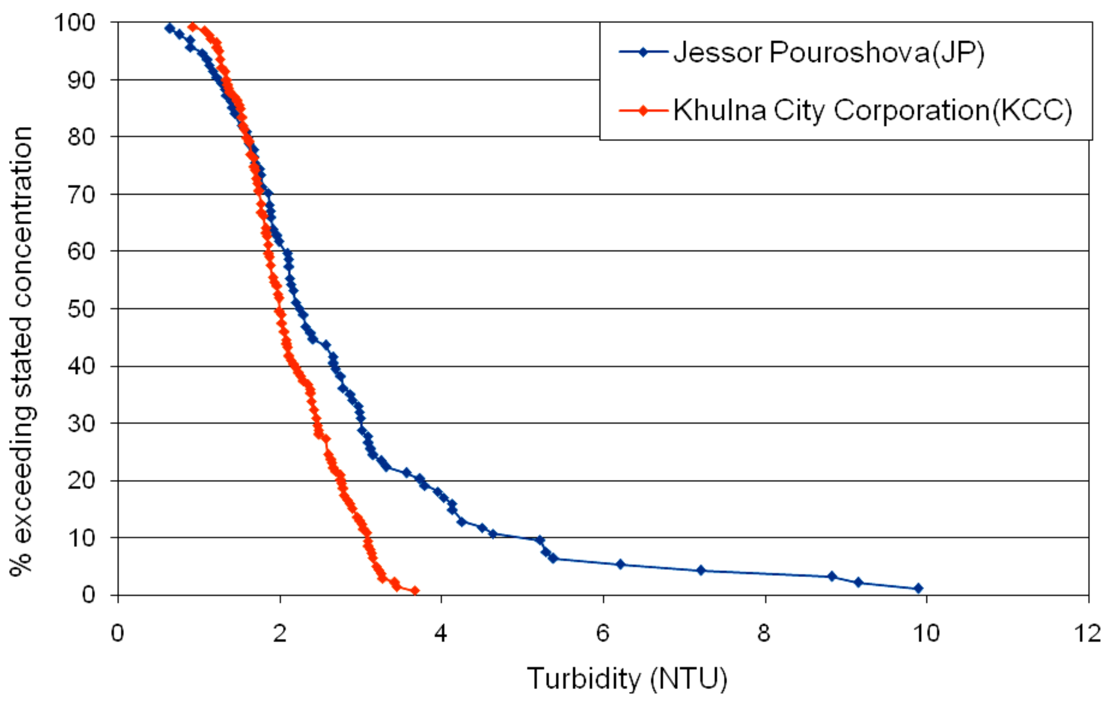


Figure 4.1: Comparison of Turbidity (NTU) in two municipalities supply water

The turbidity is important because it affects the acceptability of water to consumers. All the Turbidity results of the water samples tested are within the Bangladeshi allowable range. As may be inferred from the graph, the range of minimum values for turbidity for both JP and KCC is very close, with lowest of 0.64 NTU and 0.92 NTU for JP and KCC respectively. But it may be observed that range is much more restricted in KCC supplies with maximum value of 3.66 NTU, whereas the maximum value for JP area goes as high as 9.89 NTU. From the probabilistic distribution graph we can see that about 20%-30% of the samples from JP have very high turbidity compared to samples from KCC, albeit within the allowable limit. Possible reasons for this may be leakages in the distribution network. As was already mentioned, the supply system of JP is intermittent and this can lead to negative pressure in the pipeline resulting in entry of turbid contaminated water in the system. Another noticeable fact about the distribution of JP samples is that a few samples deviate much further in their values compared to the rest, statistically approximately about 10%. This clearly indicates a much weaker and leakage existent distribution system in JP compared to KCC, as such a percentage such as 10% of contaminated samples cannot be the result of a weakness in treatment plant, rather they indicate point source pollution i.e., leakages.

Turbidity is also affected by corrosion. It was determined that, in Mexico City, owing to the 'softness' of the water supplied, pipes were susceptible to corrosion (Gaytan et al. 1997). Later on, it will be observed from the distribution of pH, alkalinity and hardness of the samples of KCC and JP that, KCC has much higher concentrations in the mentioned parameters. Therefore, KCC distribution network is much less susceptible to corrosion. Due to the increased amount of precipitates in the water from corrosion, the amount of particulate matter (and thus turbidity) increases (Juhna and Klavins 2001).

4.2.2 Color

Color in water is primarily due to the presence of colored organic substances (primarily humic substances), metals such as Fe, Mn or highly colored industrial wastes (e.g. from pulp, paper and textile industries). The visibly colored water is not aesthetically acceptable. Color caused by suspended matters is defined as “apparent color”. It can be removed by centrifugation or filtration. Color caused by dissolved matters is defined as “true color”.

Color of 15 Pt.Co. Units (PCU) can be detected easily by the consumers. According to both Bangladesh standard values and WHO guideline values for drinking purpose, the standard color is 15 PCU.

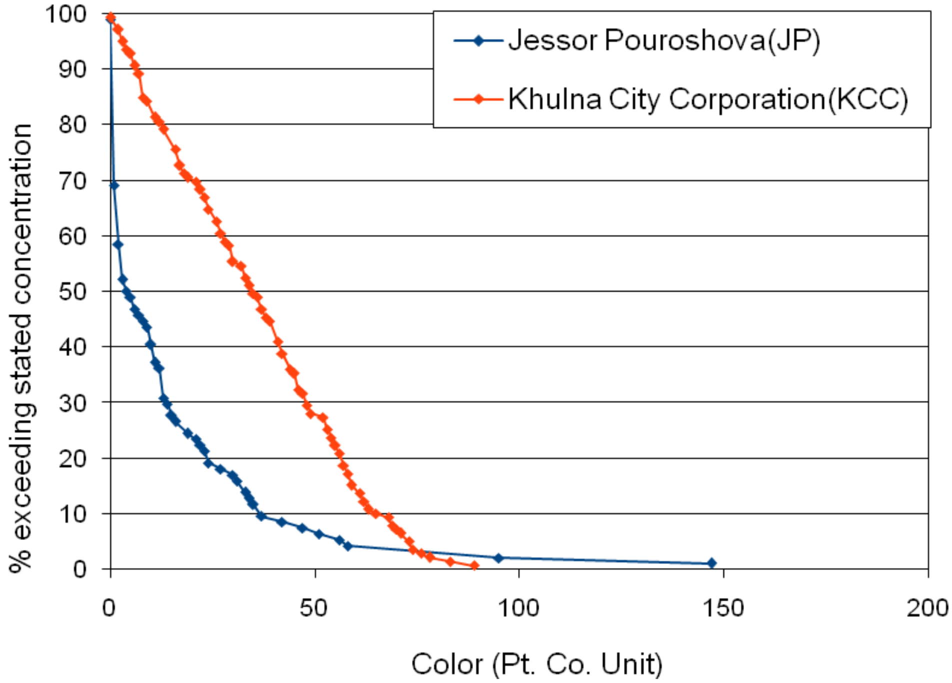


Figure 4.2: Comparison of Color Concentration (PCU) in two municipalities supply water

As can be observed from the graph that significant number of samples are above the acceptable range for color and therefore aesthetically unappealing. In general, KCC samples for this parameter are higher in color concentration than JP samples. After contact with organic debris such as leaves, conifer needles, weeds, or wood, water picks up tannins, humic acid, and humates and takes on yellowish-brown hues. Iron oxides cause reddish water (Peavy, Rowe & Tchobanoglous 1985). So, reasons due to which KCC might have higher values is that, the KCC water distribution network is much longer than JP distribution network, 226.43 km as opposed to 138 km in JP. In Bangladesh, it was observed that system pressure dropped at short distances away from overhead tanks and pump houses, with some areas even experiencing zero pressure (Chowdhury et al. 1999, 2002). Thus we may conclude that the drop of pressure in the longer KCC pipeline lead to introduction of more contaminants that imparts color compared a shorter network of JP, where drop in water pressure is lower.

While color is not usually considered unsanitary or unsafe, the organic compounds causing color may exert a chlorine demand and thereby seriously reduce the effectiveness of chlorine as a disinfectant. Additionally, some compounds of naturally occurring organic acids and chlorine are either known to be, or are suspected of being, carcinogens (cancer-causing agents) (Peavy, Rowe & Tchobanoglous 1985).

Specifically, two samples of JP deviate in quality very far from the other samples. The most probable explanation for this would be severe leakage in the distribution network near the collection spots of those samples, along with presence of negative pressure at those points.

4.3 Chemical water quality

Some important chemical parameters of water samples from JP and KCC supply water were tested. The summary of the test results is presented in the table below. It reveals from the result that some of the important parameters like conductivity and hardness for KCC cross the allowable limit while other parameters like chloride, TDS, pH are mostly within allowable limit. Few parameters like electric conductivity are less than the minimum of allowable limits. Alkalinity for both JP and KCC exceeds the allowable limit.

Table 4.2: Summary of test results of chemical parameters of JP and KCC water supply

Parameters	Unit	Max		Min.		Average		BDS	WHO GV	% exceeding BDS value	
		JP	KCC	JP	KCC	JP	KCC			JP	KCC
pH	mg/l	8.45	8.49	6.79	7.09	7.2	7.95	6.5-8.5		0	0
Electric Conductivity	µs/cm	809	2611	230	648	443.1	1231	600-1000		0	70
Chloride	mg/l	495	750	16.25	160	145.9	479	150-600*	250	0	24
Hardness	mg/l as $CaCo_3$	789	1628	109	202	354.4	756	200-500		7	73
Alkalinity	mg/l as $CaCo_3$	910	1560	108	180	447.6	685	400		32	73
TDS	mg/l	403	1687	120	259	211.3	769	1000	1000	0	15

4.3.1 pH

The pH is of major importance in determining the corroding capability of water. In general, the lower the pH, the higher is the level of corrosion. However, pH is only one of a variety of factors affecting corrosion.

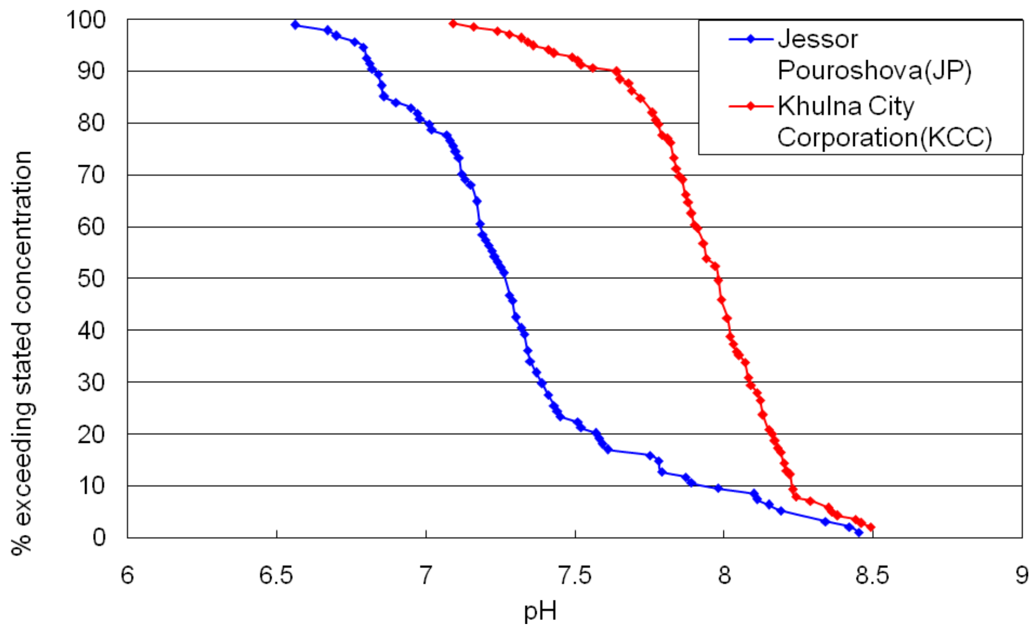


Figure 4.3: Comparison of pH in two municipalities' supply water

All the pH values of the water samples tested are within the allowable limit. The maximum value of pH is 8.49 for KCC and 8.45 for JP and the minimum one is 7.09 for KCC and 6.79 for JP. The average pH value for KCC is 7.95 and JP is 7.17. Average value shows that most of the value of pH is within 7.50 to 8.00, therefore also not likely to cause corrosion by virtue of low pH of water. For pH value the supply water of KCC area and JP is acceptable.

Comparing the values for two areas, we can observe that in general, the samples of KCC have much higher pH values than JP sample pH values. This can be attributed to KCC being adjacent to the coast, and it is a known fact that sea water has slightly higher pH value. JP is situated at a distance from the coast and therefore, the pH range is comparatively lower.

pH usually has no direct impact on water consumers. However, it is one of the most crucial operational water quality parameters. Careful pH control is absolutely necessary at every stage of water treatment to ascertain acceptable water clarification and disinfection. For effective disinfection with chlorine, the pH should preferably be less than 8.

The pH of the water that enters the distribution system should be controlled in order to minimize the corrosion of water mains and pipes in household water systems. Failure to do so can result in the contamination of drinking water and in adverse effects on its odor, taste and appearance.

The optimum pH varies for different supplies as per the composition of the water and the nature of the construction materials used in the distribution system, but is tends to be in the range 6.5–9.5.

4.3.2 Electric Conductivity

Electrical conductivity is the property of a substance which enables it to serve as a channel or medium for electricity. The basic unit of measurement of electrical conductivity is micro-Siemens per centimeter (µS/cm) or deciSiemens per meter (dS/m). The sample's electrical conductivity can be converted to TDS. Salty water conducts electricity more readily than purer water. Therefore, electrical conductivity is routinely used to measure salinity. The types of salts (ions) causing the salinity usually are chlorides, sulfates, carbonates, sodium, magnesium, calcium and potassium (Environment Australia, July 2002).

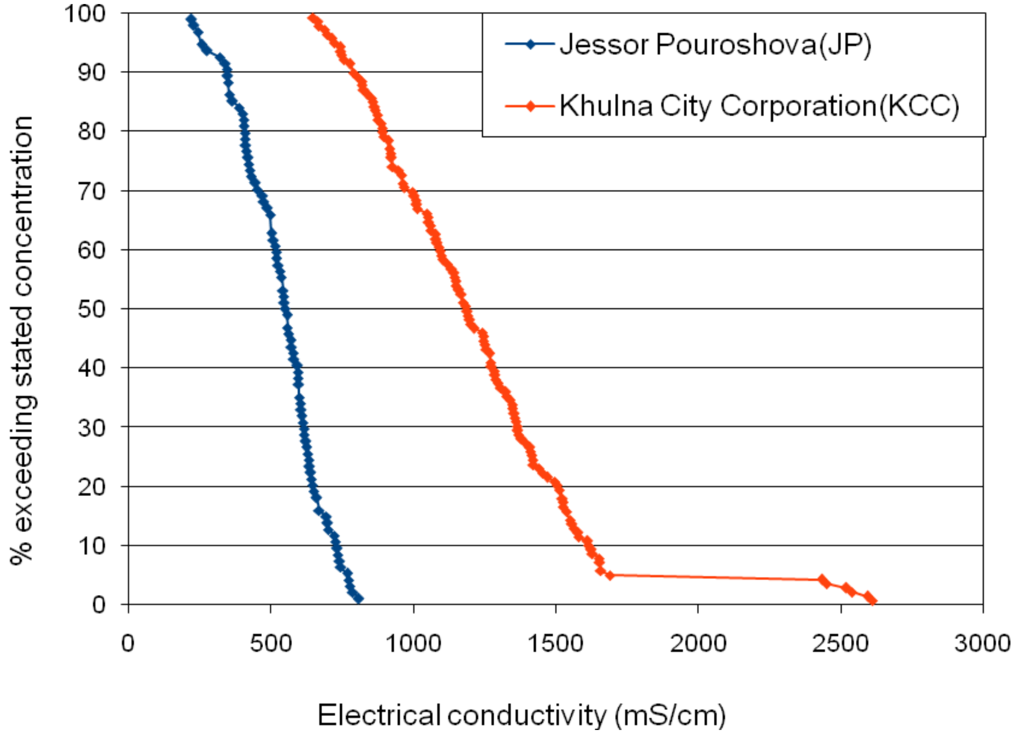


Figure 4.4: Comparison of EC (µS/cm) in two municipalities supply water

For KCC, Most of the average values of electric conductivity are above 1000 µS/cm which is not acceptable for drinking water. Few values are less than the Bangladeshi standards (600-1000 µS/cm). Therefore, in the most cases the electric conductance values of supply water of KWASA are above allowable limit guided by BD and WHO standard. So the supply water is not acceptable for drinking purpose in terms of conductivity.

For JP, all samples are within the maximum permissible limit 1000 µS/cm. Therefore, water supplied in JP may be declared safe for drinking as far as this parameter is concerned.

As the distribution graphs clearly illustrate, water supply of KCC network has much higher conductivity in general compared to JP water supply. Once again, this may be attributed to KCC using water supply sources that are located closer to coastal areas, and therefore saline in nature resulting in higher conductivity than is acceptable.

4.3.3 Chloride

Chloride increases the electrical conductivity of water and thus increases its corrosivity. In metal pipes, chloride reacts with metal ions to form soluble salts, thus increasing levels of metals in drinking-water.

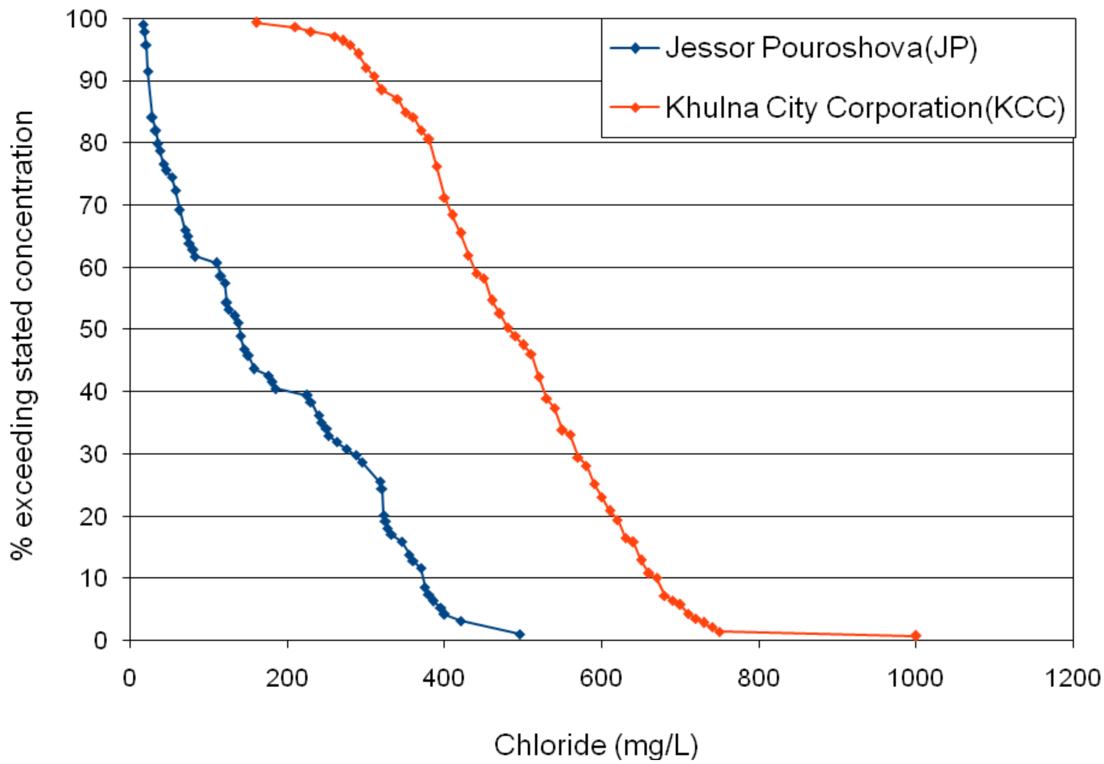


Figure 4.5: Comparison of Chloride concentration (mg/L) in two municipalities' water supply

All the average test results of Chloride show acceptable value of chlorine contamination for KCC area. The highest average value of chloride is 750mg/l which is acceptable for coastal area like Jessore city. All other values are within 250mg/l to below or just around 500 mg/l which is the range of BD standard. So, it can be said that supply water of JP is acceptable in the context of chloride contamination.

The graphs of distribution of sample chloride values of JP and KCC, clearly shows that KCC water in general has much higher levels of chloride than JP water, as should be expected since it is a coastal region, and JP is further away from the coast. It could mean corrosive effect for cast iron pipes for KCC area, but since the network is constructed of GI, PVC and AC, this problem is not likely to occur. Significant amount of residual chlorine would also ensure the prevention of regrowth of microorganisms within the distribution network.

However, in case of JP, about 50% of the sample has chlorine concentration below the minimum expected 150mg/L. Too low chlorine in the supply water can result in regrowth of pathogenic micro-organism since there is no disinfectant to counter it. In that respect, about half of the connections in JP are at risk.

4.3.4 Hardness

Hard waters are generally considered to be those waters that require considerable amount of soap to produce a foam or leather and that also produce scale in hot water pipes, heaters, boilers and other units in which the temperature of water is increased materially. Hardness is caused by multivalent metallic cation. The principal hardness causing cations are the divalent calcium and magnesium, strontium, ferrous ion and manganese ions.

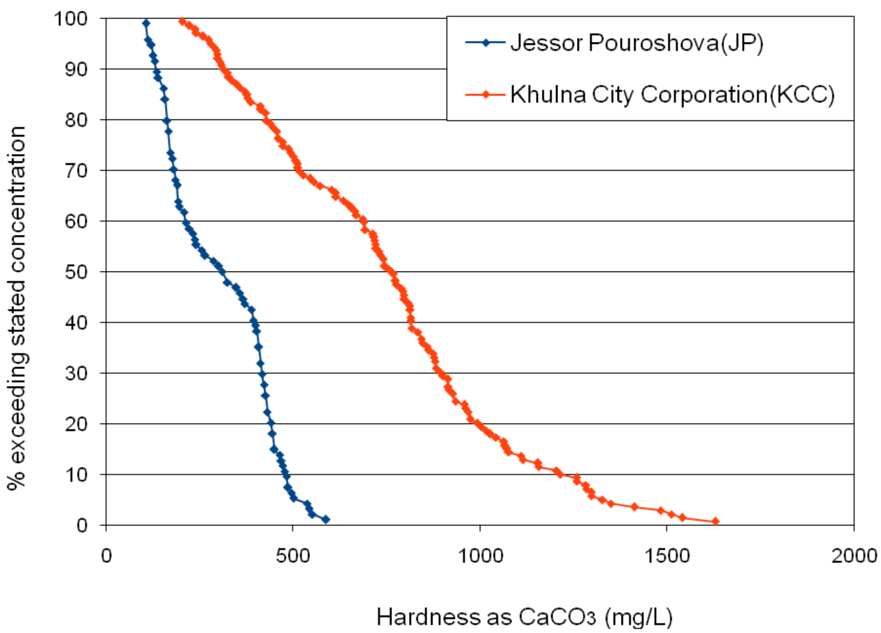


Figure 4.6: Comparison of Hardness of water as $CaCO_3$ (mg/L) in two municipalities' water supply

The test results of total hardness shows that most of the values for KCC exceed the allowable limit of hardness for drinking water quality. Average value for KCC is 756 mg/l as which is well above the Bangladeshi limit. Only 6 wards of KCC area shows acceptable limit of hardness for drinking purpose. So the quality of piped water of KWASA is not acceptable according to hardness. On the other hand, only a small percentage of samples of JP exceed the allowable limit for hardness. So JP water is acceptable in terms of hardness.

There seems to be a very considerable difference between the distribution of the KCC sample values and JP sample values. The KCC values are much higher even for samples that are lower in the magnitude among the samples. As distribution progresses towards higher percentiles, the deviation of concentrations of hardness becomes even more pronounced and contrasting. This could be due to the presence of coastal water in KCC.

Also, significant portion of KCC water supply network is constructed of Asbestos Cement pipes. Cement based materials such as concrete and asbestos cement may leach calcium-containing products and asbestos fibers into the water (Wagner 1994). This may be another potential reason for the hardness of water of KCC supply network.

4.3.5 Alkalinity

The alkalinity of water is a measure of its capacity to neutralize acids. The alkalinity of water due to salts of weak acids and strong bases and such substances act as buffers to resist a drop in pH resulting from acid addition. Alkalinity is thus a measure of buffer capacity.

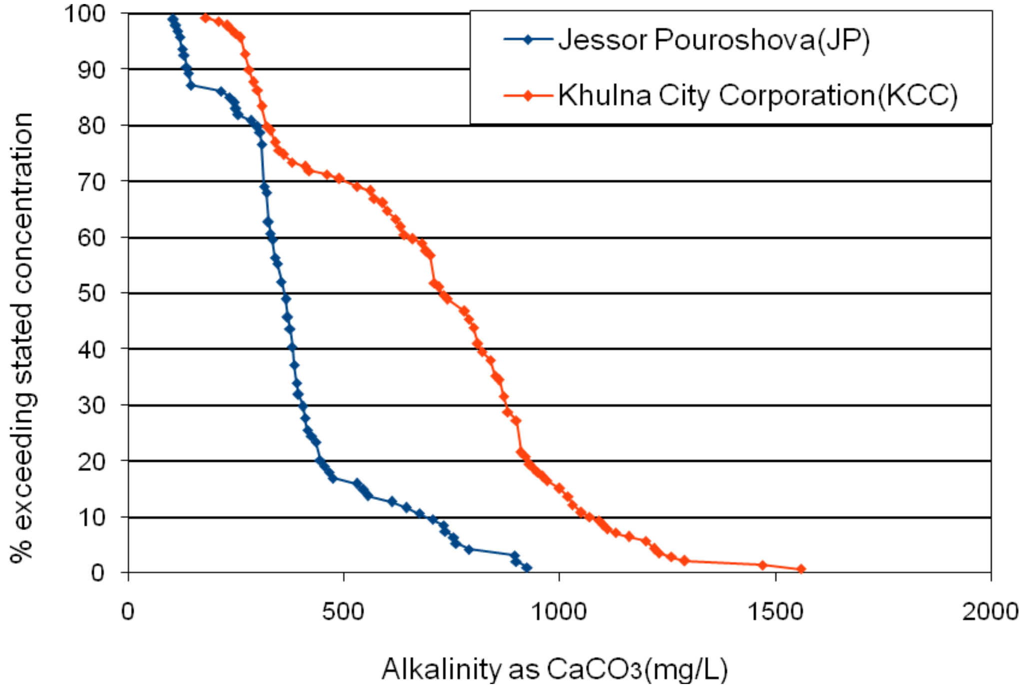


Figure 4.7: Comparison of Alkalinity as $CaCO_3$ (mg/L) in two municipalities' water supply

From the test results and graph it is shown that alkalinity is lower where hardness is lower and higher where hardness is higher. It indicates that the supply water consists of higher bicarbonate, carbonates and hydroxides.

Alkalinity has an average of 447.6 mg/l for JP samples which is not pleasant for the consumers. For KCC, the water is harder at 685 mg/L as $CaCO_3$, which is also not acceptable as drinking water. But these levels have the advantage of preventing pipeline corrosion. The reason which may be held responsible for higher levels of alkalinity is that the source of water for KCC is sea water.

4.3.6 Total Dissolved Solid (TDS)

Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulfate, and nitrate anions. Certain components of TDS, such as chlorides, sulfates, magnesium, calcium, and carbonates, affect corrosion or encrustation in water-distribution systems. High TDS levels (>500 mg/liter) result in excessive scaling in water pipes, water heaters, boilers, and household appliances such as kettles and steam irons. Such scaling can shorten the service life of these appliances.

Reliable data on possible health effects associated with the ingestion of TDS in drinking water are not available. The results of early epidemiological studies suggest that even low concentrations of TDS in drinking-water may have beneficial effects, although adverse effects have been seen being reported in a few investigations.

Water containing TDS concentrations below 1000 mg/liter is usually acceptable to the consumers. However, the presence of high levels of TDS in water may be objectionable to consumers owing to the resulting taste and to excessive scaling in water pipes, heaters, boilers, and household appliances. Water with extremely low concentrations of TDS may also be unacceptable to consumers because of its flat, insipid taste; it is also often corrosive to water-supply systems.

Table 4.3: Water classification depending on TDS

Depending on TDS, water is often classed as follows:

Water Quality	TDS (mg/l)
Excellent	<300
Good	300-600
Fair	600-900
Poor	900-1200
Unacceptable	>1200

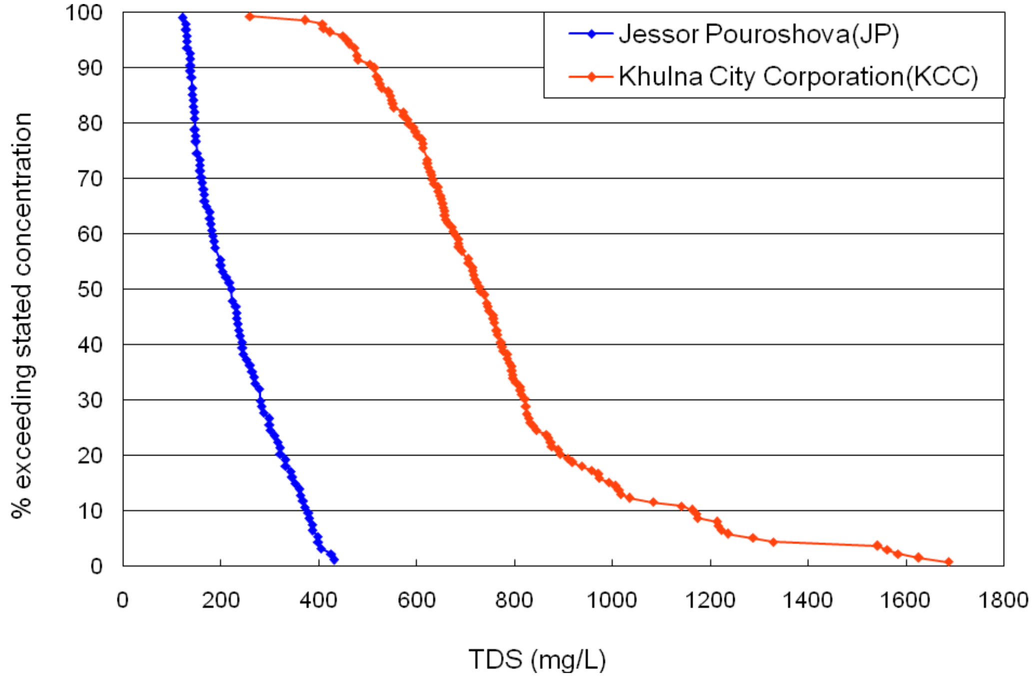


Figure 4.8: Comparison of TDS (mg/L) in two municipalities' water

For KCC, most of the value lies between 400-1000 mg/l which indicates that the water quality is good to fair enough to be consumed. As some values exceed 1000 mg/l then they are categorized as unacceptable. JP supply is with TDS in the range of 150-420 mg/L, much lower than KCC supply. As may be observed from the graph, in general TDS values of water supplied by KCC are much higher throughout than JP. This could have been due to that TDS is mainly constituted of same salts that increased the hardness, and KCC water supply has higher values in this regard as the water is from coastal region, with its source water containing high amounts of TDS. At least 20% of the samples deviate very far from the noticeable trend, which may indicate old AC pipelines that causes point sources of pollution by introducing high TDS.

4.4 Bacteriological water quality

The principal risk associated with the drinking water is the spread of infectious water-borne diseases related to the fecal contamination. In this thesis, the TC and E. coli concentrations of JP and KCC are compared. The summary of test results for all these coliforms in JP and KCC water is given in the table below. It was observed that the presence of TC and E. coli in most of the water samples indicating high risk of spreading water borne diseases by JP and KCC water supply.

Table 4.4: Summary of Bacteriological Parameters of JP and KCC water supply

Parameter	Unit	Max		Min.		BDS	WHO GV	% exceeding BDS	
		JP	KCC	JP	KCC			JP	KCC
Total Coliform	No./100 ml	86	28	0.0	2	0	0	83	100
E. coli	No./100 ml	48	18	0	0	0	0	79	77

4.4.1 Total Coliform (TC)

The most common and widespread danger associated with natural water bodies such as rivers and streams, is contamination by sewage, other wastes or human and animal excrement. Fecal pollution of water may introduce a variety of intestinal pathogens e.g., bacterial, viral or parasitic.

The allowable limit for Total Coliform concentration is zero in per 100 ml. All the test values from KCC show much higher values than the allowable one. So the water is unacceptable for consumption in that area in that respect. As for JP, 83% of the samples show contamination above allowable limit. Therefore, water in JP is also largely of unacceptable quality.

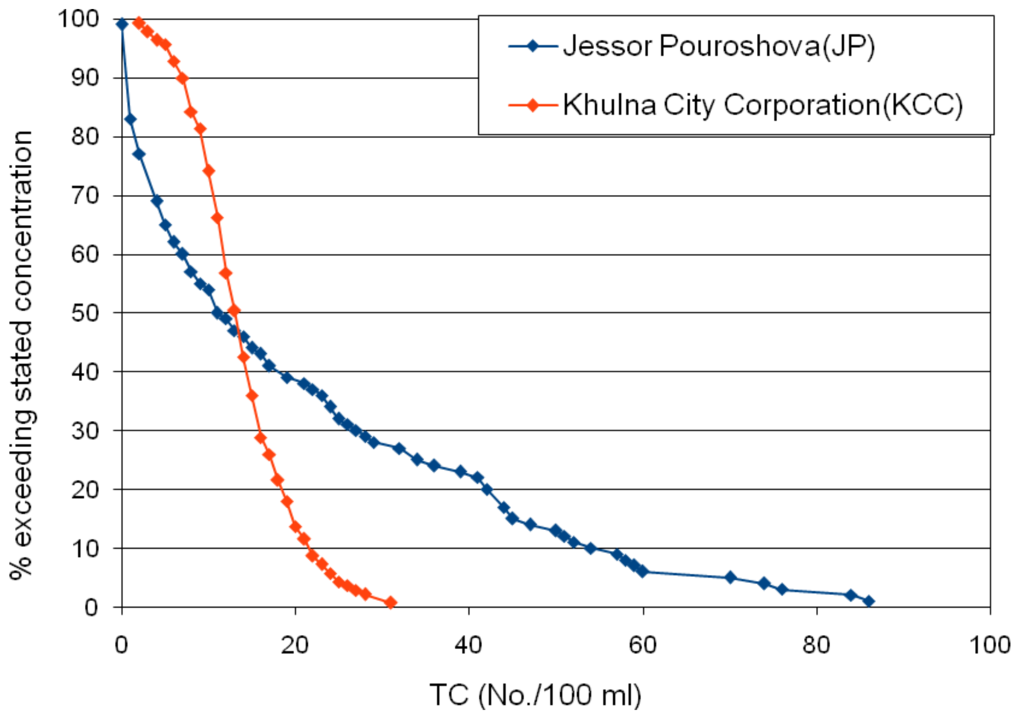


Figure 4.9: Comparison of Total Coliform (No. /100 ml) concentration in two municipalities' water supply

The Distribution of TC values for samples from the two areas illustrates a sharp contrast between two areas. The TC values for KCC samples are distributed mostly over much smaller range (about 5-20 No. /100 ml) compared to JP samples which are distributed almost evenly in larger range (5-60 No. /100 ml). One possible reason for this may be that, in KCC distribution network, the contamination takes place in some central location of the network. Therefore, contamination level occurs within a very similar and small range throughout the network. Also, since the discharge at central locations would be high, relative contamination concentration gets effectively lowered.

Compared to KCC samples, JP samples have contamination levels spread out over a large range. The shape of the distribution curve illustrates that at least 50% of the samples have lower TC values compared to lower 50 percentile samples of KCC samples. However, the other 50% deviates much further in magnitude. This is possible if the contamination does not occur at a central location, rather they are local contaminations with varying magnitudes. Therefore, we may conclude, the KCC network has leakages in central locations, whereas JP network has higher number of leakages at localized sections of the network.

Due to the increased amount of precipitates in the water from corrosion, the amount of particulate matter (and thus turbidity) increases (Juhna & Klavins 2001). As a result microbes may attach and aggregate onto these particles and be protected from disinfection (Besner et al. 2002), rendering a disinfection residual less effective. It is worth mentioning that we had previously observed about 50% of JP samples to have significantly higher turbidity compared to KCC samples. This may be another contributory factor for high levels of contamination in JP network.

Since Bangladesh has poor sanitary conditions in general and high risk of recontamination during distribution, it is very important that a disinfectant residual be present. Generally, residual chlorine levels decline as the distances from the plant increase (Egorov et al. 2002). In Pietermaritzburg, South Africa, coliforms were found to be associated with low chlorine residual; as distance from the water plant increased, the level of free chlorine decreased with resulting coliform increase (Bailey & Thompson 1995). This could be another factor affecting the level of contamination in the two different networks. Since, KCC much higher level of chlorine in its water supply compared to JP, as we previously observed in the chlorine concentrations in the samples, the chance for recontamination to take place or regeneration of microorganism in stagnant water is much less in KCC supply. The sample concentration distribution seems consistent with this.

4.4.2 E.coli

Escherichia Coli normally inhabits the intestinal track of man and other warm-blooded animal and is excreted in large numbers with the feces.

The presence of such organisms indicates fecal pollution and therefore the presence of intestinal pathogens. Thus the coliform group is of great importance in the microbial quality analysis of supply water.

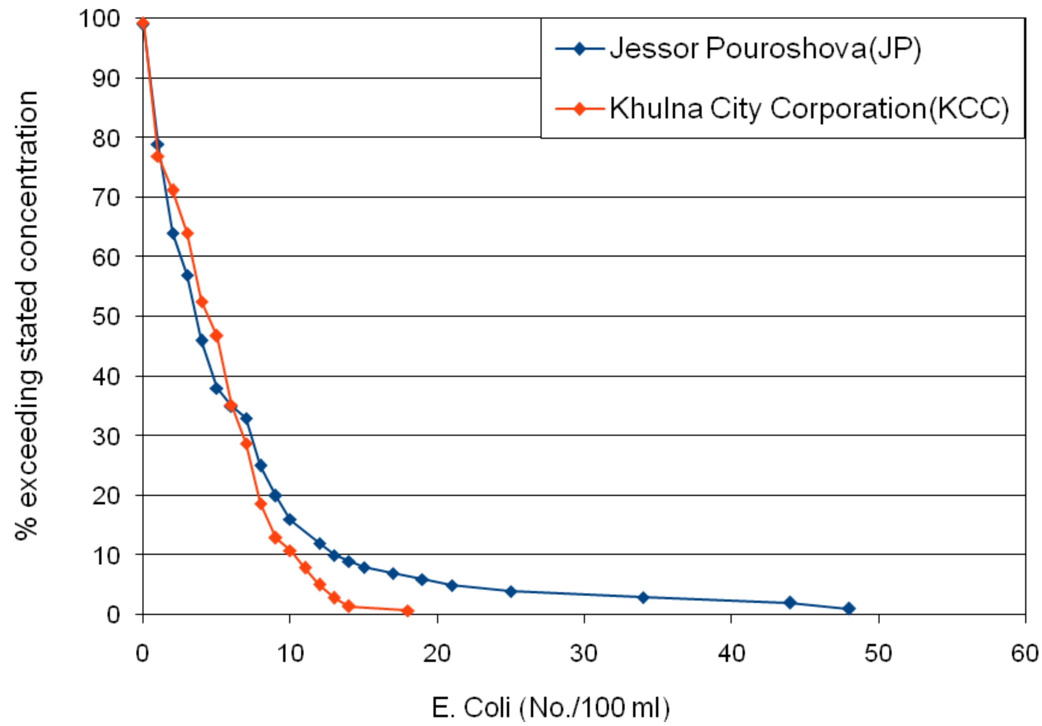


Figure 4.10: Comparison of Concentration of E. coli contamination (No. /100ml) in two municipalities waters

The major risk involved in using supply water is that of infectious disease related to fecal contamination. Hence, the microbial examination of drinking water emphasizes assessment of the hygienic quality of supply. In these two studies, E.coli concentration is found to exceed allowable limit for the vast majority of samples. So the supply water of both areas is mostly unacceptable for drinking and may cause adverse effects on health.

From the above shown graphs we can see that, there are large numbers of E. coli bacteria or coliforms present in the water which can cause many dangerous intestinal diseases. So, these values would be used in the QHRA Model to calculate the risk associated and numbers of life in danger.

As may be observed from the concentration distribution, the JP water supply and KCC water supply is on even grounds regarding this parameter up to the highest 10% of sample concentrations. Then for this 10%, the concentration of contaminant in JP rises very high compared to concentration of KCC samples. This could only be attributed to point source of pollution, leakage in pipes, highly corroded and deteriorated supply network structure etc.

4.5 Health Risk Assessment

The bacteriological test results of KCC and JP supplied water reveals the presence of E. coli in substantial numbers. These microbial indicator E. coli from test results are put into the QHRA Model (Haward et al, 2006) and hence associated disease burdens are assessed for JP and KCC water supply and compared based on their parametric concentration.

4.5.1 Assessment of Health Burden

Table 4.5: Value output from QHRA Model for Jessore Pouroshova (JP)

Compare values and results	Log additional µDALY/person•year			Additional µDALY/person•year			Comment
	95%ile	5%ile	Median	95%ile	5%ile	Median	
Scenario total burden	#NUM!	#NUM!	2.8	#NUM!	#NUM!	589.02	***Result***
Total; TTC 95% <1 GV; As 50 µg/L GV			2.4			234.43	*Compare value*
Scenario viral burden	3.4	0.9	2.7	2,385.24	7.36	551.84	***Result***
Viral; TTC 95% <1 GV			1.7			46.99	*Compare value*
Scenario bacterial burden	3.6	-0.5	1.6	3,807.80	0.30	36.85	***Result***
Bacterial; TTC 95% <1 GV			0.4			2.27	*Compare value*
Scenario protozoal burden	1.1	-2.7	-0.8	13.25	0.00	0.16	***Result***
Protozoal; TTC 95% <1 GV			-1.9			0.01	*Compare value*
Scenario arsenical burden	#NUM!	#NUM!	-0.8	#NUM!	#NUM!	0.16	***Result***
Arsenical; 10 µg/L As GV			1.5			33.46	*Compare value*
Arsenical; 50 µg/L As GV			2.3			185.17	*Compare value*
WHO 1µDPY reference GV			0.0			1.00	*Compare value*

Table 4.6: Value output from QHRA Model for Khulna City Corporation (KCC)

Compare values and results	Log additional µDALY/person•year 95%ile	5%ile	Median	Additional µDALY/person•year 95%ile	5%ile	Median	Comment
Scenario total burden	#NUM!	#NUM!	2.8	#NUM!	#NUM!	589.02	***Result***
Total; TTC 95% <1 GV; As 50 µg/L GV			2.4			234.43	*Compare value*
Scenario viral burden	3.4	1.7	2.7	2,306.43	47.22	551.84	***Result***
Viral; TTC 95% <1 GV			1.7			46.99	*Compare value*
Scenario bacterial burden	2.8	0.4	1.6	584.33	2.28	36.85	***Result***
Bacterial; TTC 95% <1 GV			0.4			2.27	*Compare value*
Scenario protozoal burden	0.3	-1.9	-0.8	2.14	0.01	0.16	***Result***
Protozoal; TTC 95% <1 GV			-1.9			0.01	*Compare value*
Scenario arsenical burden	#NUM!	#NUM!	-0.8	#NUM!	#NUM!	0.16	***Result***
Arsenical; 10 µg/L As GV			1.5			33.46	*Compare value*
Arsenical; 50 µg/L As GV			2.3			185.17	*Compare value*
WHO 1µDPY reference GV			0.0			1.00	*Compare value*

Table 4.7: Graphical output from QHRA Model-(KCC)

Disease Burden	Total Burden (KCC)	UCL(KCC)	MCL(KCC)	LCL(KCC)
		Log Additional µDaly/person year		
Viral	2.8	3.4	2.7	1.7
Bacterial		2.8	1.5	0.4
Protozoan		0.3	-0.9	-1.9

Legends: UCL- Upper confidence level, MCL- Median Confidence level,

LCL- Lower Confidence level

The total burden due to E.Coli is 2.8 DPY and the tolerance value is 2.4DPY. Hence the total burden due to E.Coli in KCC water is over the tolerable range.

The viral burden for E.Coli of 95% ile with <1GV (guiding value) it varies 1.77 DPY to 3.4 DPY that is tolerable loss of healthy life per million over a year whereas the acceptable tolerance value is 1.7 DPY. Hence the viral burden due to E.Coli in KCC water is beyond over the tolerable range.

The bacterial burden for E.Coli of 95%ile with <1GV (guididing value) is ranging from 0.4 DPY to2.8 DPY whereas the minimum tolerable limit is 0.40 DPY. Here it also appears that bacterial burden due to E.Coli in KCC water is beyond over the tolerable range.

The protozoal burden for E.Coli of 95%ile with <1 GV (guididing value) is ranging from –1.9 DALYs to .3 DPY whereas the minimum tolerable limit is –1.9 DPY. Here it also appears that protozoall burden due to E.Coli in KCC water is beyond over the tolerable range.

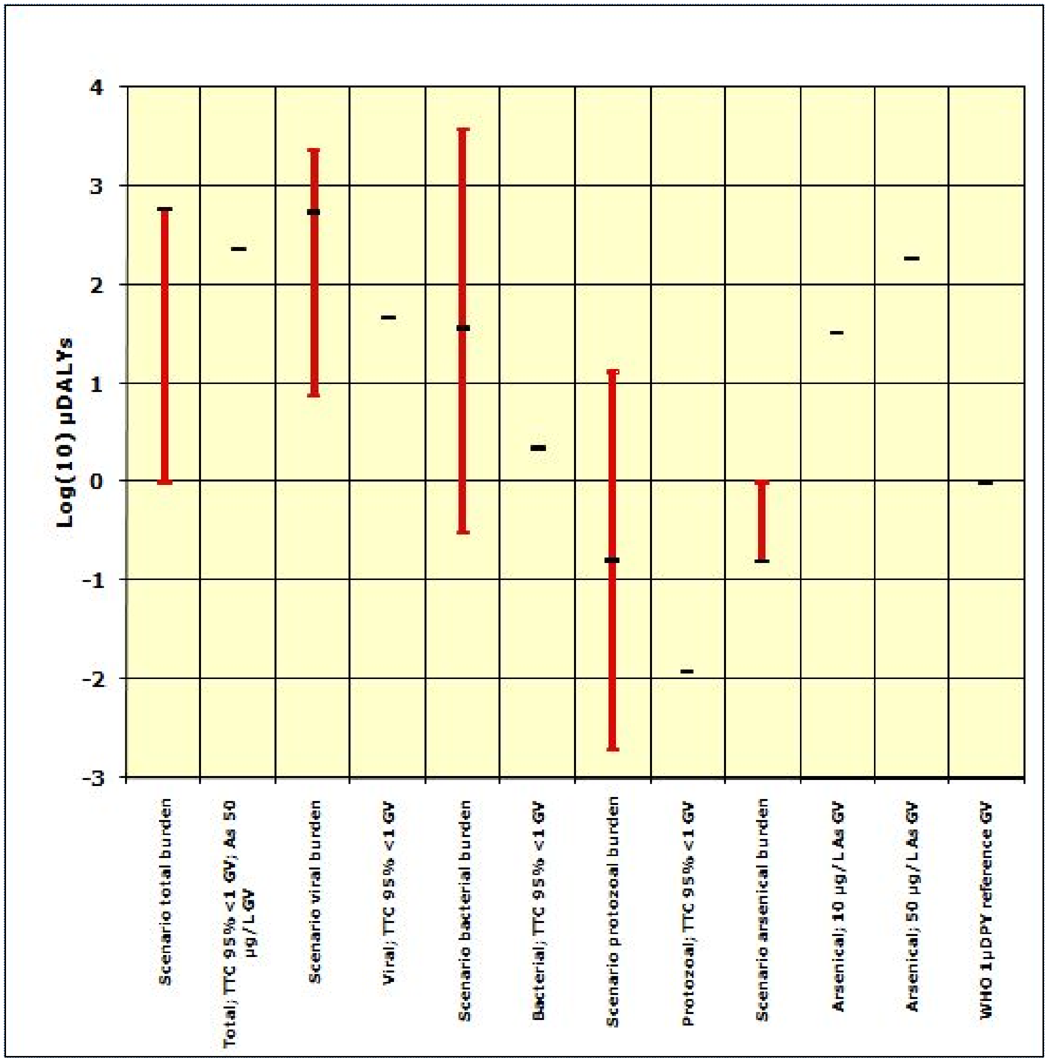


Figure 4.11: Graphical output from QHRA Model (KCC)

Table 4.8: Graphical output from QHRA Model (JP)

Disease Burden	Total Burden (JP)	UCL(JP)	MCL(JP)	LCL(JP)
		Log Additional µDaly/person year		
Viral	2.8	3.4	2.7	0.9
Bacterial		3.6	1.6	-0.5
Protozoan		1.1	-0.8	-2.7

Legends: UCL- Upper confidence level, MCL- Median Confidence level, LCL- Lower Confidence level

The total burden due to E.Coli is 2.8 DPY and the tolerance value is 2.4DPY. Hence the total burden due to E.Coli in JP water is over the tolerable range.

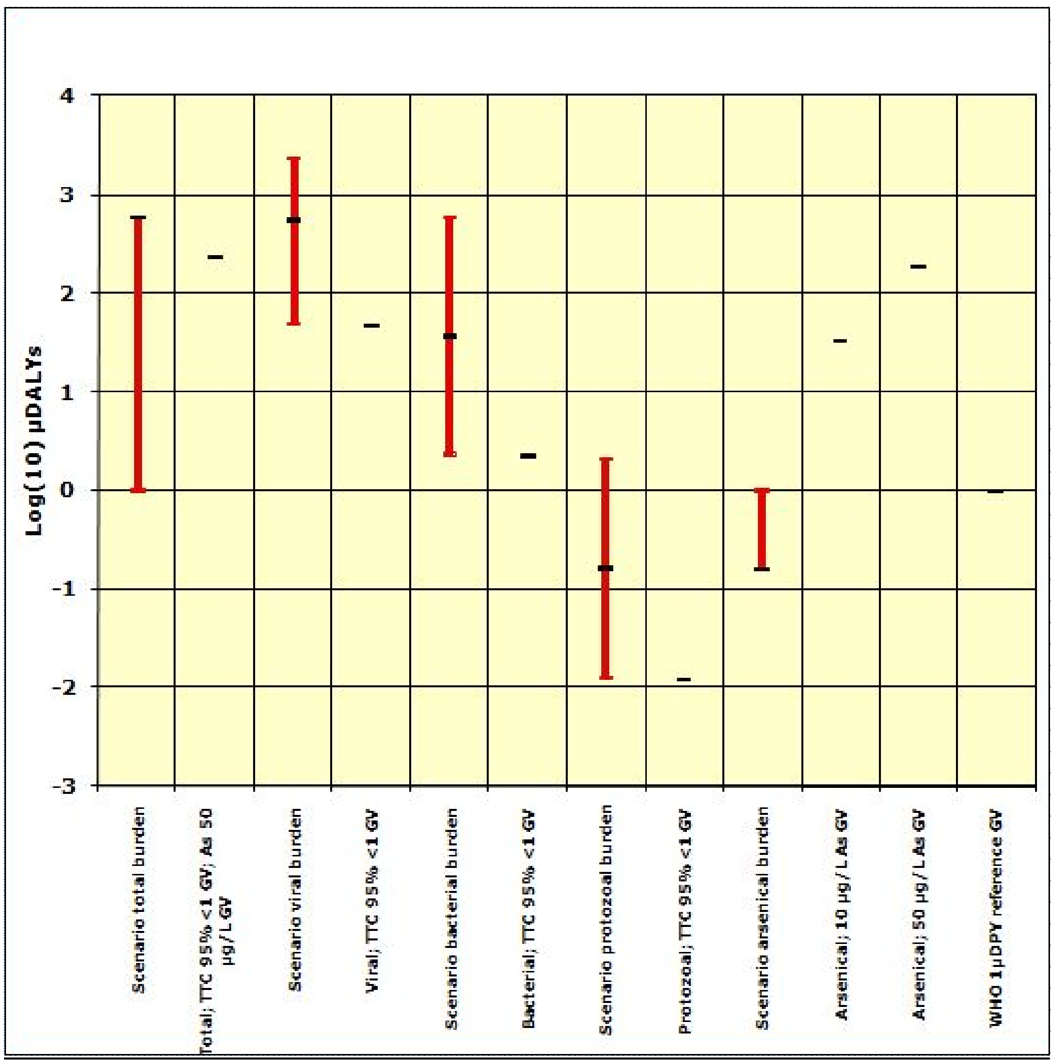


Figure 4.12: Graphical output from QHRA Model (JP)

The viral burden for E.Coli of 95% ile with <1GV (guididing value) it varies 0.9 DPY to 3.4 DPY that is tolerable loss of healthy life per million over a year whereas the acceptable tolerance value is 1.7 DPY. Hence the viral burden due to E.Coli in KCC water is beyond over the tolerable range.

The bacterial burden for E.Coli of 95%ile with <1GV (guididing value) is ranging from -0.5 DPY to3.6 DPY whereas the minimum tolerable limit is 0.40 DPY. Here it also appears that bacterial burden due to E.Coli in KCC water is beyond the tolerable range.
The protozoal burden for E.Coli of 95%ile with <1 GV (guididing value) is ranging from –2.7 DALYs to 1.1 DPY whereas the minimum tolerable limit is –1.9 DPY. Here it also appears that protozoall burden due to E.Coli in KCC water is beyond the tolerable range.

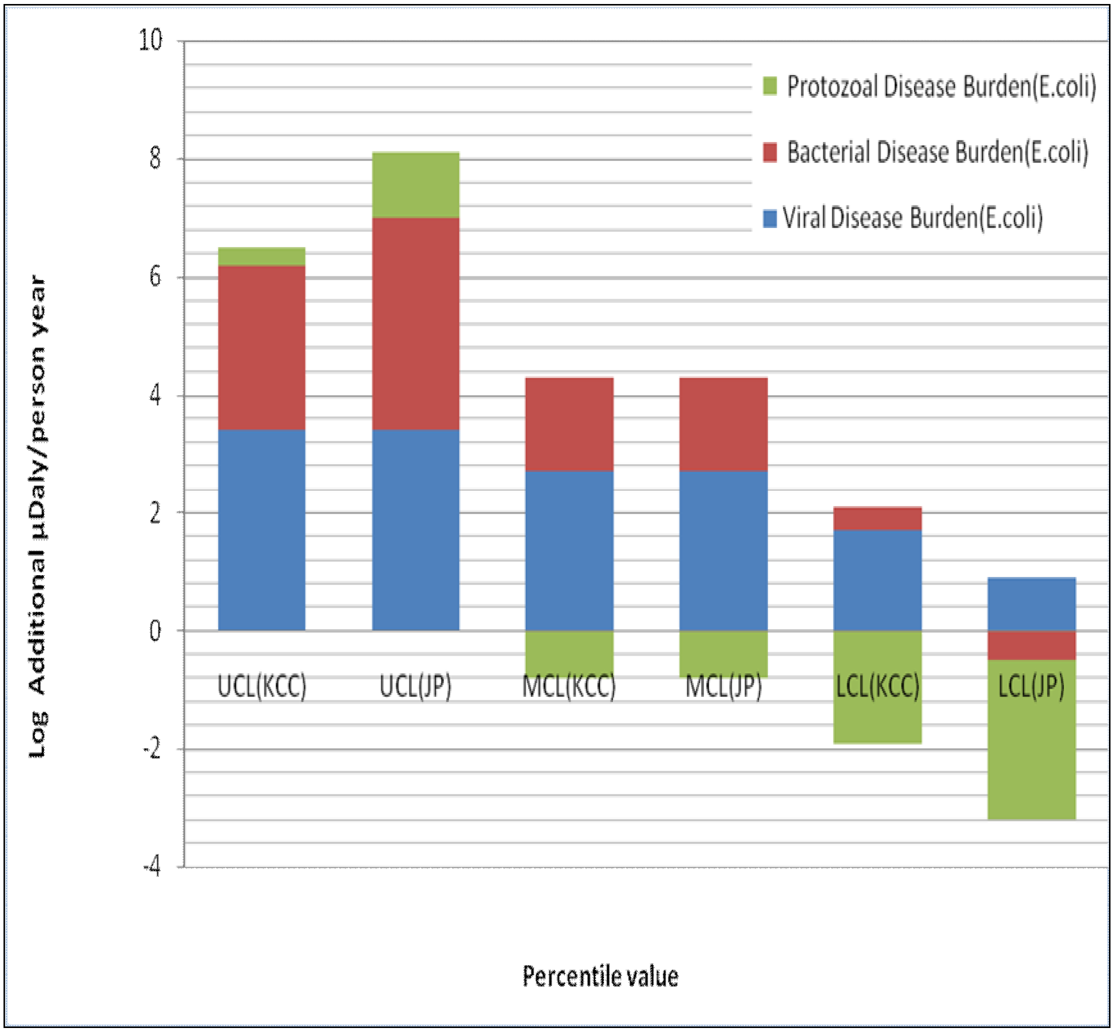
Table 4.9: Comparison of Disease Burden due to E.coli input

Comparison of Disease Burden **due to E.coli input** **(** in μDPY**)**							
Disease Burden	UCL-KCC	UCL-JP	MCL-KCC	MCL-JP	LCL-KCC	LCL-JP	WHO GV (μDPY)
Viral	3.4	3.4	2.7	2.7	1.7	0.9	1.7
Bacterial	2.8	3.6	1.6	1.6	0.4	-0.5	0.4
Protozoan	0.3	1.1	-0.8	-0.8	-1.9	-2.7	-1.9

Legends: UCL- Upper confidence level, MCL- Median Confidence level, LCL- Lower Confidence level

This is a comparison shown between KCC and JP of E.coli values in Log format. Comparison shows us JP has viral concentration in 95%ile value of 0.9 -3.4μDPY where as KCC has value of 1.7 – 3.4 μDPY which is quite same. But in bacterial concentration JP has higher value 3.6 μDPY where KCC has 2.8μDPY which is 1.28 times large. In protozoan concentration it is seen that JP has 1.1 μDPY and KCC has 0.3 μDPY which is also quite high by 3.66 times. In Median value comparison both the concentrations are quite same.

But the 5%ile values are quite variable. The viral concentration for JP is 0.9 μDPY where as KCC has 1.7 μDPY which means KCC has only 5% values, less than 1.7μDPY and JP has also 5%ile values, less than 0.9μDPY. We also see some negative values in 5%ile and Median values for Protozoan case.



Legends: UCL- Upper confidence level, MCL- Median Confidence level, LCL- Lower Confidence level

Figure 4.13: Comparison between KCC and JP

CHAPTER FIVE

CONCLUSIONS

AND

RECOMMENDATIONS

5.1 CONCLUSION

The crucial role of water in the protection of public is well recognized. Health problems surface due to inadequacies in water supplies. The developing countries are in a much more vulnerable position in this regard. Even though larger percentage of population in today's world receives coverage under water supply system, the same cannot be said about the quality of water.

The following conclusions may be made from the study undertaken:

- People in both areas are suffering from poor quality of water supply, especially in terms of microbial parameters.

- The measured value of pH, turbidity, chloride, TDS is mostly within the permissible range. Color, Hardness and conductivity value of most samples were significantly higher than permissible values.

- Simply supplying safe water at the entry of supply network would not necessarily ensure delivery of safe water as the distribution system itself is responsible for causing significant amount of pollution.

- KCC is comparatively in a much better position compared to JP in terms of safety of potable water. KCC samples show comparatively higher pH, TDS, alkalinity, chlorides etc. However, they are all within the permissible range. On the other hand, JP water samples boast higher turbidity and micro-organic contamination, which is much more dangerous for public health.

5.2 PROPOSED GUIDELINES

Some suggestions that could possibly contribute towards an improved quality of water supply:

- Continuous water supply should be provided in place of intermittent as well as critical monitoring constantly to ensure no negative pressure occurs in the pipeline.
- All existing distribution pipe should be abandoned as it has been the primary source of water contamination. New distribution pipe must be used with good clean treated surface water or clean pumped ground water.
- All service connections must be replaced. It will be very important not to allow the existing distribution to be connected in any way to the newly replaced distribution system. Continuous monitoring facilities should be in place in the distribution system in order to protect those facilities. The authority should also conduct regular monitoring program to prevent possible contamination of water along its distribution network by cross connections, cross contamination by leaking pipes, improper domestic storage etc.
- Proper disinfection should be done and disinfection residual should be maintained.
- Both routine sampling for microbial quality and real-time (and possibly online) monitoring of parameters linked to microbial quality at selected locations throughout the storage and distribution system should be performed.
- Realistic residual concentrations to be maintained to at least inactivate the least resistant microorganisms such as E. coli that are used as the main indicators of water safety (Payment, 1999).
- Asbestos cement pipe should be replaced regardless, not for health reasons but because its strength deteriorates with time. Likewise GI pipe needs replacement every 10 years due to corrosion.

- Waste should be collected properly and sanitation system should be improved.
- Illegal connections should be identified and closed down and meter should be provided to document water usage and tariff should be increased to a desired extent.
- Public awareness can also play an important role to help prevent such problems. The situation may aggravate in near future if the authority does not pay attention and take immediate actions to restore water quality in the distribution system.

5.3 RECOMMENDATIONS

Based on this study the following points may be considered for improving future surveys/analysis:

- When data is collected about samples in a particular area, water quality parameters may be studied /measured at the extraction source of that supply distribution network.
- Detailed information may be collected on the elements of the construction of that network, as well as the age of various components of that network, so that this information might be used to correlate the contamination as a function of network construction material and network age.
- Seasonal variation could have been carried out.

REFERENCES

Agard, L., Alexander, C., Green, S., Jackson, M., Patel, S. & Adesiyum, A 2002 Microbial quality of water supply to an urban community in Trinidad. J. Food Prot. 65(8), 1297 – 1303.

Abebe Ls. (1986). Hygienic water quality; its relation to health and the testing aspects in tropical conditions, Department of Civil Engineering, Tempe ere University, Finland.

ADB. (2011). Proposed Loan and Technical Assistance Grant People's Republic of Bangladesh: Khulna Water Supply Project.

Amanullah, Q., The daily star – August 14, 2011, Khulna city people suffer from acute water crisis.

Basualdo, J., Pezzani, B., De Luca, M., Cordoba, A. & Apezteguia, M.2000 Screening the municipal water system of La Plata, Argentina, for human intestinal parasites. Int. J. Hyg. Environ. Health203 (2), 177–182.

Besner, M.C., Gauthier, V., Servais, P. & Camper, A. 2002 Explaining the occurrence of coliforms in distribution systems. J. Am. Wat. Wks Assoc. 94(8), 95-109

Bailey, I. W. & Thompson, P. 1995 Monitoring water quality after disinfection. Wat. Suppl. 13(2), 33-48.

Chowdhury, M. A. I., Ahmed, M. F. & Gaaffar, M. A. 2002 Management of nonrevenue water in four cities of Bangladesh. J. Am. Wat. Wks Assoc. 94(8), 64-75.

Craun, G. F. & Calderon, R. L. 2001 Waterborne disease outbreaks caused by distribution system deficiencies. J. Am. Wat. Wks Assoc. 93(9), 64-75.

Doyle, J., E., J., D., G., E., *Escherichia Coli* in Diarrheal Disease

Egorov, A., Ford, T., Tereschenko, A., Drizhd, N., Segedevich, I. & Fourman, V. 2002 Deterioration of drinking water quality in the distribution system and gastrointestinal morbidity in a Russian City. Int. J. Environ. Health Res. 12(3), 221-233.

Ford, T. E. 1999 Microbiological safety of drinking water: United States and global perspectives. Environ. Health Perspect. 107(Supp. 1), 191-206.

Gadgil, A. 1998 Drinking water in developing countries. Ann. Rev. Energy Environ. 23, 253-286.

Gaytam, M., Castro, T., Bonilla, P., Lugo, A. & Vilaclara, G. 1997 Preliminary study of selected drinking water samples in Mexico City. Rev. Int. Contamin Ambient 13(2), 73-78.

Geldenhuys, J. 1995 Chloramination to preserve microbiological quality: experience at Rand Water. Wat. Suppl. 13(2), 313-316.

Geldreich, E. 1996 Microbiological Quality of Water Supply in Distribution Systems. CRC Lewis Publishers, Boca Raton, Florida.

International Development Project Consult, Inc., 2006. Bangladesh: Secondary Towns Water Supply and Sanitation Sector Project (Jessore Pourashava).

Islam, A. K. M. M., (2011). Health risk Associated with Urban Water Supply: A case study of KCC Area.

Juhna, T. & Klavins, M. 2001 Water-quality changes in Latvia and Riga 1980-2000: possibilities and problems. Ambio 30(4-5), 306-314.

Kelkar, P. S., Talkhande, A. V., Joshi, M. W. & Andey, S.P. 2001. Water quality assessment in distribution system under intermittent and continuous modes of water supply. J. Indian Wat. Wks Assoc. 33(1), 39-44.

Kumar, A. 1998 Technologies to improve efficiency in distribution system with intermittent supplies. Wat. Suppl. 16(1-2), 577-579.

Peavy, H. S., Rowe, D. R., Tchobanoglous Environmental Engineering, International Edition 1985.

Sack, R., B., The discovery of cholera - like enterotoxins produced by *Escherichia coli* causing secretory diarrhea in humans.

UNCED (1992), Protection of the Quality and Supply of Freshwater Resources: Application of Integrated Approaches to the Development, Management and Use of Water Resources. The United Nations Conference on Environment and Development. Chapter 18, Agenda 21.

Waterwatch Australia Steering Committee 2002 Environment Australia, July 2002, Module 4 - physical and chemical parameters

WHO. (2006). Guidelines for Drinking Water Quality (3rd edition), World Health Organization, Geneva, Switzerland.

WHO & UNICEF 2000 Global Water Supply and Sanitation Assessment 2000 Report. Iseman Creative, Washington, D.C.

Appendix - A

Color Concentration (Pt. Co. Unit) in water for KCC:

Ward no unit	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
9	70	36	65	42	69	78
10	55	13	52	9	24	61
11	7	36	11	29	47	39
12	42	47	39	45	52	57
13	7	13	6	9	16	7
14	57	74	48	76	71	59
15	0	23	16	24	19	7
16	22	23	24	21	16	35
17	53	0	68	13	56	73
18	7	2	5	6	9	16
19	3	2	3	5	12	0
20	5	30	13	39	44	61
21	39	17	41	32	34	54
22	29	58	21	52	47	73
23	36	38	41	29	34	59
24	48	33	62	41	71	39
25	26	42	23	45	56	58
26	68	46	63	55	89	83
27	17	32	8	45	56	27
28	4	28	2	37	58	26
29	27	33	32	29	42	53
30	12	7	22	13	18	9
31	54	37	62	45	49	26

Appendix - B

Turbidity Concentration (NTU) in water for KCC:

Ward no unit	VALUE 1	VALUE 2	VALUE 3	VALUE 4	VALUE 5	VALUE 6
9	2.75	3.44	2.96	3.66	3.25	3.07
10	2.23	2.09	2.74	2.45	2.66	2.25
11	1.28	1.69	1.62	1.53	1.67	2.01
12	1.97	1.74	2.05	1.86	1.77	2.02
13	3.27	2.78	3.13	2.99	2.86	3.03
14	3.01	2.79	3.09	2.89	3.11	3.14
15	2.29	1.98	2.38	1.88	1.96	1.99
16	1.32	0.92	1.26	1.06	1.36	1.12
17	1.24	1.55	1.26	1.63	1.72	1.55
18	2.76	2.34	2.56	2.39	3.08	2.83
19	1.83	1.76	2.02	1.84	1.88	1.72
20	1.22	2.48	1.35	2.42	2.38	2.09
21	1.67	2.08	1.79	1.87	1.84	1.98
22	1.54	3.19	1.43	2.89	2.59	2.78
23	2.64	1.24	2.56	1.32	1.69	1.34
24	2.42	2.07	2.45	2.17	2.56	2.37
25	2.13	2.47	2.19	2.56	2.69	2.63
26	1.7	2.01	1.68	1.92	1.96	1.74
27	1.14	1.87	1.21	1.76	1.91	1.59
28	1.51	1.79	1.62	1.74	1.85	1.82
29	1.88	2.05	1.79	1.98	1.85	2.11
30	1.53	1.47	1.49	1.51	1.62	1.38
31	2.39	3.14	2.46	3.07	3.42	3.22

Appendix - C

pH of water samples for KCC:

Ward no unit	VALUE 1	VALUE 2	VALUE 3	VALUE 4	VALUE 5	VALUE 6
9	8.05	8.22	8.16	8.12	8.19	8.01
10	7.64	7.99	7.69	7.9	7.78	7.88
11	8.29	8.01	8.22	8.07	8.02	7.97
12	8.29	8.44	8.24	8.49	8.36	8.04
13	8.07	7.79	7.98	7.83	7.94	8.13
14	7.28	7.86	7.41	7.72	7.82	7.97
15	7.87	7.72	7.82	7.84	7.94	7.56
16	7.93	7.83	7.88	7.84	7.64	8.03
17	8.2	8.01	8.16	7.91	8.22	8.11
18	7.99	8.23	8.09	8.18	8.12	8.03
19	8.19	7.98	8.11	7.86	7.93	7.98
20	7.93	7.78	7.88	7.69	8.01	7.77
21	7.91	8.17	7.82	8.22	8.13	7.98
22	7.36	7.16	7.43	7.09	7.24	7.65
23	7.91	7.97	7.86	7.89	8.08	7.78
24	7.76	7.52	7.83	7.51	7.68	7.89
25	7.76	8.13	7.72	8.08	8.02	8.19
26	8.09	7.87	7.99	7.82	7.85	7.72
27	8.12	7.86	8.2	7.91	7.98	7.81
28	8.01	8.13	8.05	8.21	8.15	7.99
29	7.99	8.12	7.97	8.07	7.89	7.93
30	8.46	8.23	8.49	8.17	8.49	8.38
31	8.07	7.34	8.35	7.49	7.32	7.68

Appendix – D

Conductivity (μS/cm) of water samples for KCC:

Ward no unit	VALUE 1	VALUE 2	VALUE 3	VALUE 4	VALUE 5	VALUE 6
9	1284	1538	1089	1628	1454	1503
10	1513	1369	1418	1394	1245	1287
11	1246	1658	1149	1613	1691	1268
12	967	1213	1003	1159	887	1084
13	958	1009	923	1143	1168	1416
14	874	1047	912	1101	1189	997
15	1268	1338	1199	1307	1346	1076
16	1360	1564	1412	1611	1556	1578
17	1190	1550	1119	1523	1469	1079
18	863	858	917	892	747	963
19	1439	1256	1408	1324	1513	1496
20	1296	1060	1363	1095	1251	1422
21	1134	1052	1168	1097	1273	1286
22	2520	2540	2449	2432	2611	2593
23	920	912	958	873	865	1061
24	1354	1524	1272	1538	1653	1184
25	1624	1325	1579	1348	1367	1654
26	778	819	743	789	818	923
27	667	698	721	648	665	713
28	757	778	825	746	688	803
29	1243	1357	1198	1379	1654	1525
30	948	853	1011	895	835	1148
31	1054	891	1013	927	1173	1146

Appendix - E

Chloride concentration (mg/L) of water samples for KCC:

Ward no unit	VALUE 1	VALUE 2	VALUE 3	VALUE 4	VALUE 5	VALUE 6
9	1000	700	520	410	380	490
10	470	450	590	620	480	520
11	360	400	430	560	540	320
12	280	310	420	390	430	470
13	380	430	460	530	650	620
14	310	370	340	410	520	420
15	390	360	320	380	420	290
16	400	460	400	420	390	480
17	530	640	490	670	690	560
18	650	570	570	590	510	640
19	620	640	600	680	650	510
20	300	300	310	390	230	340
21	440	470	560	410	380	430
22	580	630	540	620	600	670
23	260	160	340	290	280	210
24	580	590	560	600	720	750
25	610	670	560	580	540	710
26	450	400	420	510	510	670
27	500	450	540	520	410	580
28	450	550	500	540	360	390
29	460	380	510	390	350	270
30	390	450	370	380	290	520
31	610	660	640	700	740	730

Appendix – F

Hardness of water as $CaCO_3$ (mg/L) of KCC:

Ward no unit	VALUE 1	VALUE 2	VALUE 3	VALUE 4	VALUE 5	VALUE 6
9	833	1204	792	1258	1282	1063
10	913	1108	934	1071	1154	1213
11	878	992	811	1026	1348	1283
12	814	914	876	959	733	1065
13	278	289	411	376	324	356
14	487	545	512	507	471	613
15	413	385	456	429	378	369
16	500	426	473	446	511	572
17	1297	926	1326	1001	1412	1156
18	833	915	807	882	664	516
19	741	797	768	775	812	669
20	333	296	241	308	298	273
21	313	348	295	327	456	438
22	1296	1481	1257	1539	1628	1511
23	259	222	304	238	202	426
24	861	1113	816	1076	926	957
25	973	813	968	843	773	719
26	648	814	614	845	757	689
27	741	913	692	901	1042	716
28	556	713	526	689	812	459
29	789	893	729	858	968	1015
30	656	603	686	634	493	721
31	744	878	768	796	717	873

Appendix – G

Alkalinity of water as $CaCO_3$ (mg/L) of KCC:

Ward no unit	VALUE 1	VALUE 2	VALUE 3	VALUE 4	VALUE 5	VALUE 6
9	800	600	840	590	620	970
10	740	810	720	860	800	630
11	720	600	680	700	620	590
12	810	930	780	900	840	860
13	310	360	280	320	270	490
14	380	310	350	300	420	560
15	270	260	290	270	210	340
16	280	240	230	250	290	300
17	700	700	660	730	820	940
18	900	700	860	640	790	920
19	1200	1000	1290	960	1470	1560
20	280	260	310	340	330	180
21	330	360	300	310	260	530
22	900	800	860	870	790	1030
23	260	300	310	270	460	330
24	560	870	490	820	680	410
25	840	1110	780	1100	1260	1220
26	800	1000	850	920	1230	740
27	1200	900	1160	900	710	1090
28	700	700	740	690	630	570
29	1020	870	1130	700	880	1070
30	900	900	880	900	1020	1050
31	840	950	870	910	970	1030

Appendix - H

TDS concentration (mg/L) of water of KCC:

Ward no unit	VALUE 1	VALUE 2	VALUE 3	VALUE 4	VALUE 5	VALUE 6
9	1235	765	1214	796	971	1626
10	716	774	738	793	672	643
11	673	657	691	685	1013	874
12	573	649	552	611	479	758
13	473	503	409	458	612	823
14	513	602	477	656	524	821
15	623	547	654	542	776	516
16	704	803	745	821	642	686
17	1174	1542	1216	1584	1162	1035
18	844	813	831	869	824	972
19	714	765	757	795	829	908
20	658	521	622	545	784	893
21	678	593	634	609	772	756
22	1171	1288	1141	1329	1687	1562
23	449	461	407	421	259	513
24	612	629	581	633	473	612
25	837	918	794	957	1222	1083
26	758	789	729	747	876	621
27	648	572	597	551	718	823
28	738	812	785	763	992	1016
29	628	706	584	743	370	528
30	728	662	713	691	865	1007
31	684	811	653	889	722	937

Appendix – I

Concentration of TC (No./100 ml) in water of KCC:

Ward no unit	VALUE 1	VALUE 2	VALUE 3	VALUE 4	VALUE 5	VALUE 6
9	8	11	11	10	15	21
10	14	11	14	9	20	11
11	12	18	13	16	6	8
12	26	13	24	19	13	7
13	10	7	9	4	5	2
14	19	15	10	13	12	31
15	21	18	18	15	9	17
16	17	14	19	11	6	10
17	9	13	10	12	15	9
18	12	17	13	6	7	9
19	20	10	24	22	14	17
20	10	7	9	7	2	5
21	14	15	11	11	13	10
22	18	15	12	13	5	11
23	13	12	16	10	11	28
24	23	13	10	14	7	3
25	15	6	14	11	14	8
26	15	9	17	12	11	20
27	9	5	10	8	9	16
28	16	27	19	23	12	28
29	11	21	21	14	3	7
30	18	7	17	13	15	11
31	15	19	12	22	19	25

Appendix – J

Concentration of E.coli (No./100 ml) in water of KCC:

Ward no unit	VALUE 1	VALUE 2	VALUE 3	VALUE 4	VALUE 5	VALUE 6
9	4	0	2	0	3	7
10	2	6	0	5	6	0
11	0	1	0	0	5	4
12	0	4	1	6	5	8
13	0	3	2	3	0	5
14	2	8	0	7	11	10
15	10	6	14	5	8	12
16	5	3	7	5	0	7
17	0	6	1	7	6	0
18	8	0	5	5	0	6
19	13	4	18	13	2	7
20	3	1	3	0	0	2
21	0	7	0	1	5	0
22	0	9	3	11	7	5
23	8	2	5	4	7	12
24	5	0	4	6	3	0
25	3	0	1	3	11	5
26	5	0	0	4	7	12
27	3	1	0	0	3	7
28	2	8	9	8	4	10
29	2	7	3	7	0	0
30	3	1	7	3	3	2
31	5	9	6	11	8	10

Appendix – K

Color Concentration (Pt. Co. Unit) in water for JP:

Sample No.	Value 1	Value 2	Value 3
1	0	1	10
2	3	0	5
3	5	1	51
4	1	4	0
5	0	1	33
6	9	8	0
7	0	1	0
8	1	0	0
9	0	0	0
10	0	1	0
11	2	2	0
12	7	1	2
13	0	0	147
14	2	9	0
15	0	0	0
16	3	2	16
17	0	0	15
18	12	22	0
19	47	34	56
20	1	0	0
21	12	10	42
22	14	12	58
23	37	31	23
24	31	30	35
25	12	10	58
26	0	1	27
27	16	6	95
28	23	12	0
29	9	2	35
30	19	11	24
31	14	13	21

Appendix – L

Turbidity Concentration (NTU) of water in JP:

Sample No.	Value 1	Value 2	Value 3
1	1.68	1.89	1.52
2	1.88	1.76	1.98
3	2.12	2.24	2.38
4	4.13	3.95	5.22
5	4.12	3.15	4.25
6	2.41	1.43	1.22
7	1.67	1.85	1.69
8	2.16	2.29	2.09
9	2.56	2.87	2.75
10	0.89	0.64	1.6
11	1.32	1.17	1.85
12	2.11	2.13	2.65
13	1.1	1.04	1.27
14	2.11	2.31	1.43
15	2.19	2.29	2.56
16	1.34	1.78	0.75
17	1.75	1.12	0.88
18	3.79	4.02	4.5
19	5.38	5.29	6.21
20	1.89	1.91	1.96
21	1.58	1.76	1.61
22	5.22	4.63	7.2
23	3.09	3.12	3.25
24	2.68	2.66	3
25	2.78	2.89	3.56
26	2.16	2.1	3
27	1.87	1.98	1.41
28	3.01	3.31	2.75
29	3.08	2.98	1.39
30	9.15	9.89	8.82
31	3.73	4.13	2.97

Appendix - M

pH of water samples in JP:

Sample No.	value 1	value 2	value 3
1	7.75	7.87	7.78
2	7.26	7.29	7.39
3	7.79	7.78	6.86
4	7.33	7.19	7.51
5	7.3	7.39	7.41
6	7.52	7.18	7.17
7	8.19	8.34	7.89
8	7.61	7.43	7.35
9	7.29	7.37	7.41
10	7.11	7.57	7.24
11	7.44	7.98	7.21
12	7.26	7.09	7.35
13	7.17	7.08	7.26
14	7.11	7.37	7.17
15	7.12	7.15	6.84
16	7.15	7.13	6.81
17	7.18	7.2	6.79
18	8.15	8.45	8.42
19	8.1	8.11	8.19
20	7.07	6.97	6.79
21	7.11	6.98	6.85
22	7.34	7.1	6.82
23	6.7	6.56	6.8
24	7.17	7.34	6.85
25	6.67	6.76	6.84
26	7.23	7.26	6.9
27	7.33	7.15	6.95
28	7.22	7.29	7.33
29	7.45	7.59	7.02
30	7.28	7.01	7.58
31	7.32	7.3	7.25

Appendix – N

Conductivity (µS/cm) of water samples for KCC:

Sample No.	Value 1	Value 2	Value 3
1	406	452	425
2	548	572	532
3	611	606	694
4	350	365	348
5	702	669	639
6	471	487	497
7	593	581	557
8	595	598	624
9	420	423	445
10	641	623	649
11	475	412	515
12	230	245	256
13	647	599	542
14	547	537	497
15	635	661	616
16	526	519	544
17	604	634	629
18	402	408	389
19	404	409	413
20	518	569	557
21	509	537	562
22	598	607	661
23	721	778	809
24	578	596	617
25	787	726	746
26	699	733	768
27	741	734	773
28	350	321	431
29	497	503	558
30	340	345	355
31	245	276	222

Appendix –O

Chloride Concentration (mg/L) in water for JP:

Sample No.	valuel 1	value 2	value 3
1	16.25	22.5	32.5
2	57.5	62.5	52.5
3	262.5	252.5	250
4	295	320	230
5	495	420	385
6	20	22.5	35
7	320	325	332.5
8	375	370	345
9	57.5	75	82.5
10	70	42.5	52.5
11	22.5	17.5	20
12	120	115	137.5
13	22.5	20	32.5
14	22.5	37.5	27.5
15	110	137.5	150
16	150	125	180
17	145	122.5	140
18	230	295	275
19	242.5	320	355
20	132.5	157.5	120
21	395	370	110
22	420	400	360
23	295	287.5	320
24	185	225	240
25	317.5	345	370
26	322.5	327.5	380
27	62.5	72.5	80
28	22.5	17.5	27.5
29	120	175	140
30	22.5	20	37.5
31	45	57.5	62.5

Appendix – P

Hardness of Water as $CaCO_3$(mg/L) in JP:

Sample No.	Value 1 (mg/L)	Value 2 (mg/L)	Value 3 (mg/L)
1	287.06	236.13	254.65
2	476.89	467.63	449.11
3	537.08	588.01	444.48
4	175.94	152.79	189.83
5	157.42	162.05	166.68
6	138.9	120.38	157.42
7	138.9	194.46	180.57
8	189.83	106.49	120.38
9	125.01	189.83	175.94
10	162.05	180.57	166.68
11	166.68	157.42	157.42
12	439.85	421.33	412.07
13	111.12	106.49	134.27
14	152.79	166.68	129.64
15	347.25	310.21	370.4
16	365.77	356.51	388.92
17	402.81	407.44	444.48
18	231.5	240.76	185.2
19	208.35	212.98	192.145
20	541.71	550.97	463
21	421.33	439.85	425.96
22	402.81	416.7	481.52
23	398.18	393.55	425.96
24	430.59	430.59	444.48
25	407.44	412.07	388.92
26	500.04	402.81	407.44
27	481.52	495.41	416.7
28	106.49	129.64	171.31
29	472.26	486.15	425.96
30	300.95	310.21	324.1
31	222.24	208.35	263.91

Appendix – Q

Alkalinity as $CaCO_3$ (mg/L) in water for JP:

Sample No.	Value 1	Value 2	Value 3
1	675	645	610
2	755	730	705
3	405	475	310
4	235	215	250
5	365	315	365
6	320	310	320
7	895	925	900
8	130	120	145
9	105	110	120
10	140	115	130
11	790	735	760
12	245	255	285
13	555	530	545
14	410	335	395
15	385	380	320
16	365	380	375
17	310	370	325
18	445	455	435
19	125	135	140
20	320	310	370
21	385	310	305
22	405	355	340
23	345	310	305
24	410	435	345
25	300	345	325
26	425	390	310
27	380	320	375
28	355	330	335
29	375	355	335
30	435	415	465
31	395	385	390

Appendix – R

Concentration of TDS (mg/L) in water for JP:

Sample No.	value 1	value 2	value 3
1	217	210	231.2
2	280	267	245
3	397	378	345
4	182.3	178.2	150.4
5	166	159.8	130.3
6	155.9	220	176.9
7	187	145.5	129.2
8	137	148	155.7
9	299	269	169.8
10	242	220	140.9
11	187	198	176.5
12	127.9	121	136.6
13	145.5	140	198.8
14	263	259	203
15	236	233	321
16	146	143	180
17	314.5	298.2	367
18	127	157	222
19	135.5	139	184.3
20	237.9	231	278
21	251	243	282
22	361.2	286.3	332
23	424.8	430.1	403
24	342.3	298.9	309
25	358.7	330	371
26	398.3	350.4	380
27	386.6	320	386
28	148	139	144.1
29	142.8	229.9	278
30	163.3	159	165
31	136.8	129	147.7

Appendix – S

Concentration of Total Coliform (No./100 ml) in water for JP:

Sample No.	value 1	value 2	value 3
1	0	1	12
2	0	0	5
3	14	17	17
4	0	2	74
5	16	10	44
6	0	2	52
7	1	0	41
8	0	8	14
9	2	10	4
10	32	45	26
11	0	8	42
12	0	1	41
13	10	13	86
14	1	0	22
15	0	2	2
16	2	7	16
17	44	59	76
18	36	39	58
19	42	51	32
20	54	50	5
21	4	2	84
22	1	0	47
23	0	0	24
24	0	1	27
25	7	10	42
26	2	0	57
27	23	34	70
28	11	23	60
29	21	28	29
30	25	24	12
31	15	19	6
32	4	4	
33	6	9	
34	7	5	

Appendix – T

Concentration of E.Coli (No./100 ml) in water for JP:

Sample No.	value 1	value 2	Value 3
1	0	0	2
2	0	0	3
3	1	4	1
4	0	1	34
5	1	3	12
6	0	0	10
7	1	1	17
8	0	1	8
9	0	2	2
10	7	8	10
11	0	1	21
12	1	1	7
13	3	7	44
14	0	0	7
15	0	0	1
16	4	7	3
17	5	12	25
18	1	6	48
19	6	9	15
20	2	4	1
21	3	2	7
22	0	0	3
23	0	0	3
24	0	0	13
25	7	9	2
26	3	1	10
27	8	19	10
28	8	14	4
29	5	7	8
30	4	9	1
31	4	9	2
32	3	4	
33	3	5	
34	3	4	