# Sustainable and Efficient Water Supply in Chittagong Metropolitan City, Bangladesh: An Assessment of Quality to Improve Management Services

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**Keyword:** Water quality, environment, efficiency and co-management.

**Abstract**

This paper attempts to analyze the supply water quality in Chittagong Metropolitan City from three different perspectives: environmental, residents and management, using a set of physio-chemical and microbiological parameters. To collect data, the city area has been divided into two broad zones: Northern and Southern zones, based on the dominant sources of supply water- treated and ground. Two complementary surveys- environmental and questionnaire- were conducted as empirical exploratory devices. To conduct the environmental analysis, a total of 42 water samples on 20 parameters were taken from both the study areas. The laboratory analysis reveals that out of 13 physiochemical parameters, 8 parameters including TDS, turbidity, pH, Fe, $NO_3$, As, hardness and $Cl^-$ are found within the permissible range. However, the values of 5 parameters i.e. EC, $NO_2$, DO, BOD and free chlorine are noticed astonishingly high. Among microbiological parameters (07), total coliform and fecal coliform are present in almost all the water samples. Of the total viable count of bacteria, 19 samples are found contaminated that crossed the acceptable limit. To conduct the questionnaire survey, a total of 200 respondents (consisting of supply water users) were interviewed using stratified random sampling techniques. The survey reveals that piped water is the main source of drinking water for majority (73 percent) of the respondents. Among the various types of pollutants present in CWASA supply water, bad odour, bad colour, bacteria, insects, bleaching powder, salt, iron etc. are prominent that are widely perceived by the respondents. Some 86.5 percent of the respondents are aware of the quality of water and they follow various techniques i.e. boiling, filtering, using purifying tablet, fitcary (Potassium Alma) respectively, before uses and drinking of supply water in the city. In overall, the dwellers of CMC have been suffering from inadequate and unsafe water supply due mainly to poor management. The situation is worse in low class residential areas i.e. slums. Regular monitoring of water quality along the distribution networks, timely repair and maintenance, improving management information systems, uses of advanced technology, provisions for staff training, awareness building among users/ stakeholders, community-based co-management governing strategy have been strongly suggested.

## INTRODUCTION

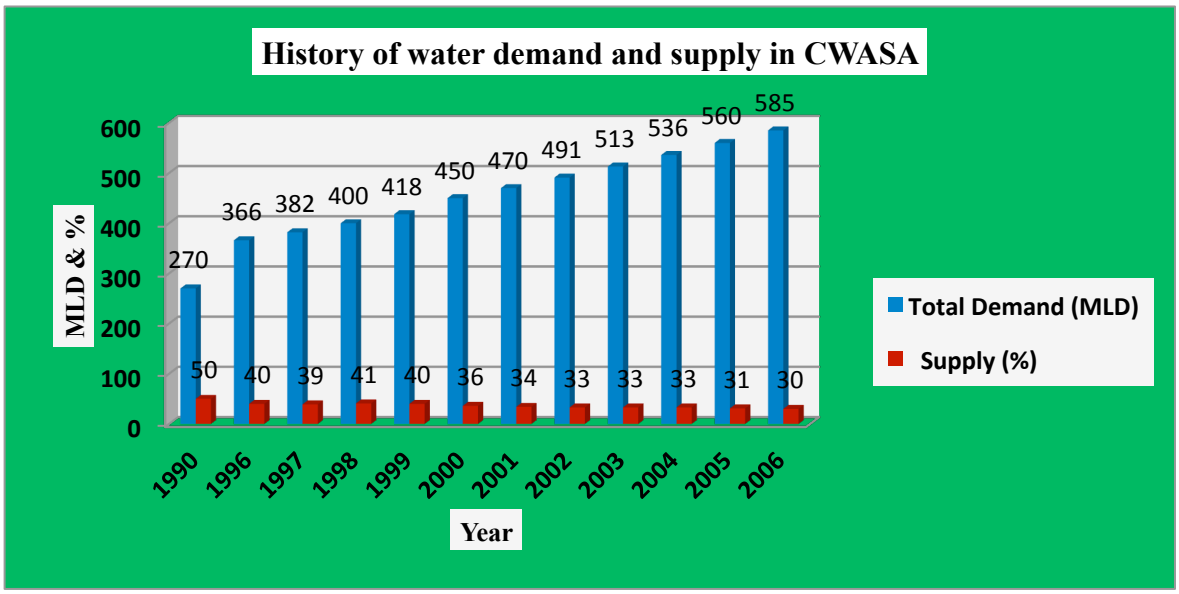
The quality of drinking water is closely associated with human health, and providing safe drinking water is one of the public health priorities. Estimated 80 percent of all diseases and one third of deaths in developing countries are caused by the consumption of contaminated water (UNCED, 1992).

Water supply has become a critical and important factor in public health and economic development in most part of the world, particularly in the developing countries such as Bangladesh, India, Pakistan and Sri Lanka etc. More than seventy percent of the urban population in the developing countries either have an inadequate water supply or are being supplied with unsafe water or both (Kamal, 2003). The extent of availability of drinking water is an indicator of the standard of quality of life in an urban area. About 25 percent population of Bangladesh live in urban areas and only 44.01 percent of the urban people are served with tap water supply (BBS, 1995 & Population census, 2001). In Dhaka and Chittagong Metropolitan areas and district Headquarters the percentage of people obtaining piped water are 65 %, 30% and 51% respectively (Fifth Five Year Plan, 1998 & CWASA, 2009). Rest of the people in those areas depend on others sources like tube-wells, ponds, shallow tube-wells, rivers and cannels to meet their water demand which are hazardous to health and sometimes insufficient and expensive. The scarcity of drinking water is a result of water bore diseases, out break of epidemics and polluted environment in the urban centers. Especially, the lower income people are the worst suffering because they cannot avail safe drinking water (Rahman & Jahan, 2003). In

Bangladesh, about 80 percent of all diseases are linked with contaminated water and 28 % of the children's death is attributed to water borne diseases caused by pathogenic microorganisms (Aziz *et al.,* 1990).
The main sources of water in Bangladesh are surface water, rain water and ground water. Piped water supply is available to about 60 percent of the Dhaka and 30 percent of the Chittagong city population respectively, but the city dwellers often find that the water is contaminated and needs boiling at home for drinking because of leaks in pipeline, imperfect water taps and misuse (Amin, 2006). More than 31 million people in Bangladesh collect drinking water from unsafe sources. In rural area 22 percent and in urban area 15 percent of the population does not have access to improve sources for drinking water (UNICEF & WHO, 2008). Water contamination in the distribution network may be attributing to leaks in the old pipes and the nature of water supply. For example, water supply in Dhaka city is intermittent in nature and absence of pressure or negative pressure (Suction) in water mains during non supply hours permit entry of contaminants in the distribution network. Suction in the distribution system is also produced by installation to unauthorized pumps in the service line to suck more water from the low pressure zones. According to study, about 25% of the water produces in Dhaka city is lost by leakage through pipes and fixtures. It also observed that if water can leak out of the pipes, contaminated water can also enter in to the system through the same route during non supply hours (Choudhury *et. al.,* 1997).

**SCENARIO OF THE PRESENT WATER SUPPLY CONDITION IN CHITTAGONG CITY**

According to the 1976 Pourashava ordinance, it is obligating for city corporations to ensure availability of safe drinking water for households (Pourashava Ordinance, Government of Bangladesh, 1976). In Chittagong, drinking water and sanitation services are provided by the CWASA. These municipal local government bodies (City Corporation & WASA) are responsible for construction and installing water supply system, operations and maintenance, connecting the households to the water supply system, licensing tube-wells and providing public taps outsides the households etc. Chittagong is inhibited by about 4.02 million people (projected from 2004 census by Amin, 2006). About 0.4 million people are served by 21,000 house connections and 0.2 million people collect water form 588 street hydrants are installed and maintained by the CWASA and the City Corporation. The capacity of all production facilities in use is 190 MLD till the end of 2007 as which are 91 MLD (surface water) of Mohora WTP and 99 MLD of ground water from deep tube well this are clear give table.



Source: CWASA, 2010

**Figure 1:** History of water demand and supply in CWASA

**OBJECTIVES**

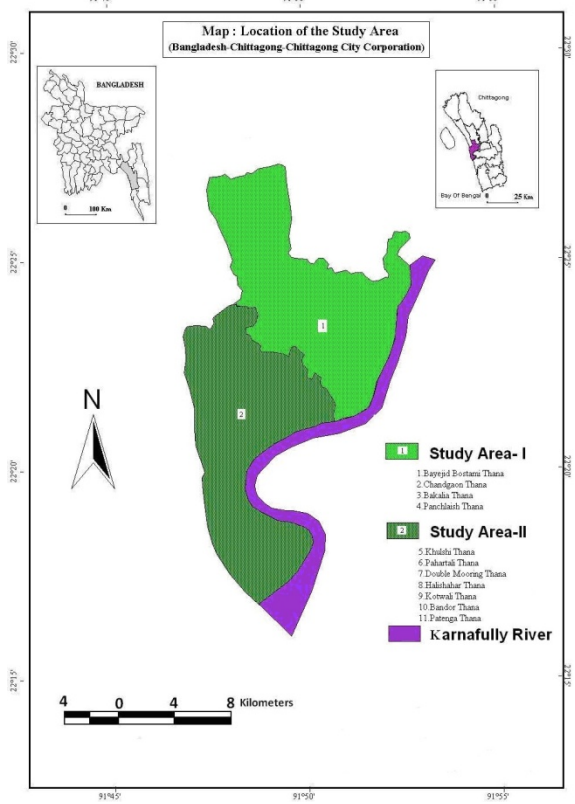
This paper attempts to analyze the supply water quality in Chittagong Metropolitan City from three different perspectives: environmental, residents and management, using a set of physio-chemical and microbiological parameters

## MATERIAL AND METHODS

### *SITE SELECTION*

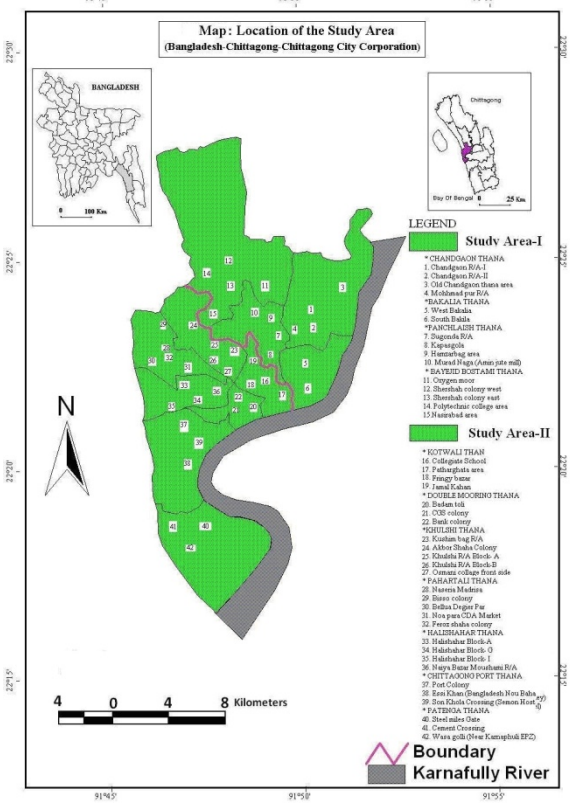
Chittagong Metropolitan city lies latitudinally between 22º14′ and 22º24′ north and longitudinally between 91º46′ and 91º53′ east (Map). It is situated on the bank of Karnaphuli River, which provides eastern boundary of Chittagong City (Amin, 2006). It is the principal city of the districts, which is now the second largest Metropolitan area of Bangladesh with an area of about 1145 square kilometers (BBS, 2007). The area of Chittagong City Corporation is 168 sq km. under 41 wards and 11 Metropolitan Thana in the area (BBS, 2008).

Map: Two Study Area (Chittagong City Corporation)




Source: Base Map Collected from CWASA, 2011.

Map: Selection of the Sampling Location




Source: Base Map Collected from CWASA, 2011

### *SAMPLING PROCEDURE*

For field study, the city area has been divided into two broad zones: Northern treated surface water and Southern ground water, based on the dominant sources of water supply. Two complementary surveys- environmental and questionnaire- were conducted as empirical exploratory devices to collect field data. To conduct the environmental and health risk analysis, a total of 42 water samples on 20 parameters were taken from both the study areas. Sample sizes were selected on the basis of residential (household) structure. For laboratory analysis total 20 water quality parameters including Physiochemical 13 and Microbiological 07 were done. Physiochemical parameters including pH, Turbidity, Total Dissolved Solid (TDS), Electric Conductivity (EC), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Hardness, Chloride, Nitrite ($NO_2^-$), Nitrate ($NO_3^-$) Iron (Fe), Arsenic (As), Chlorine ($Cl^-$). Microbiological parameters including Total Coliform, Fecal Coliform, *Salmonella* sp., *Shigella* sp., *E Coli*, Total viable count and *Vibrio Cholerae* (table 2). The standard American Public Health Association (APHA, 2003) methods were followed for collecting, preserving and analyzing of the selected samples. The collected samples were analyzed by Industrial microbiological Research Division, Bangladesh Council of scientific and industrial Research, Chittagong (BCSIR, C). Biochemical identification of isolates were used Triple sugar iron, Motility indole urase, Simmons citrate agar was used.

To investigate the provision of urban water service delivery, weaknesses in current water supply management practices, and to address the chronic lack of service provisions, a total of 200 questionnaires administered in two areas: Northern- Study Area-I, 70 Respondents and Southern- Study Area-II, 130 Respondents (table 2). For questionnaire surveying a systematic random sampling technique has been adopted. Sample size has been selected on the basis of residential structure in the household level.
Finally, to promote the management practices for urban water service delivery, weakness recovery and improve service provision, an in-depth interview was taken from CWASA authority representative in CMC. Both environmental, questionnaire and in-depth interviewing data were collected in February, 2011 to October, 2011.

**Table 1:** Location of the sampling station (questionnaire & environmental survey)

| **Study Areas (Location of the sampling station)** | | **Residential Structure*** | **Selected Sample Size** | |
|---|---|---|---|---|
| | | | **Questionnaire Survey** | **Environmental Survey** |
| Study Area-I (Northern Zone) | BAKALIA THANA | 41410 | 20 | 02 |
| | CHANDGAON THANA | 36064 | 17 | 04 |
| | PANCHLIASH THANA | 34079 | 16 | 04 |
| | BAYEJID BOSTAMI THANA | 35208 | 17 | 05 |
| **Total Residential Structure** | | **146761** | **70** | **15** |
| Study Area-II (Southern Zone) | KOTWALI THAN | 57179 | 27 | 04 |
| | DOUBLE MOORING THANA | 53849 | 26 | 03 |
| | KHULSHI THANA | 52011 | 25 | 05 |
| | PAHARTALI THANA | 25768 | 12 | 05 |
| | HALISHAHAR THANA | 24763 | 12 | 04 |
| | CHITTAGONG PORT | 41466 | 20 | 03 |
| | PATENGA | 15542 | 8 | 03 |
| **Total Residential Structure** | | 270578 | 130 | 27 |
| **MOD-I and MOD-II** | | **417339** | **200** | **42** |

**Source: Field Survey through questionnaire**, 2011. Population Census, 2001 & Master plan for water supply CWASA, 2010. *Residential structure is to be considered as population census, 2001 & Master plan for water supply CWASA, 2010.

### *DATA PROCESSING, ANALYSIS AND PRESENTATION*

The collected data were processed and analyzed by the help computer software and data interprets by the help of various statistical tools and techniques especially SPSS-version: 18 (Statistical Package for Social Science), standard deviation, mean, maximum, minimum, correlation, tables, diagrams and figures. Base maps collected from the GIS section of CDA and CWASA for showing the sampling station and division of the study area. Collected base maps were digitized and modified using Arc View 3.3 and Arc GIS 9.1 software. In addition, new map was a developed from input GPS data collected during the survey period.

## *RESULTS AND DISCUSSION*

### *ENVIRONMENTAL SURVEY*

### *ANALYSIS OF PHYSIOCHEMICAL AND MICROBIOLOGICAL PARAMETERS*

Chittagong Metropolitan City dwellers are not only suffering from inadequate water supply but also they are posed to serious threats due to the scarcity of safe water. Through the measured values of electric conductivity, total dissolve solid, turbidity, $P^H$, iron, nitrate, nitrite, dissolve oxygen, biological oxygen demand, chlorine, hardness and chloride. The measured values of water quality parameters of the selected water samples are summarized in table-2. Findings of the research have been assessed according to WHO drinking water quality guidelines and Bangladesh Standards as well.

**Table 2:** Summery of measured water quality parameters in CWASA's supply

| Parameter | Study Area-I | | | | Study Area-II | | | |
|---|---|---|---|---|---|---|---|---|
| | Max[m] | Min[m] | Mean | Std. dev[n] | Max[m] | Min[m] | Mean | Std. dev[n] |
| EC µScm$^{-1}$ | 2637.0 | 53.67 | 583.511 | 558.274 | 2637.0 | 53.67 | 733.455 | 641.11414 |
| TDS mg/l | 1450.30 | 74.44 | 394.814 | 327.569 | 1450.3 | 128.00 | 500.982 | 356.56425 |
| Turbidity (NTU) | 256.86 | 0.12 | 8.6083 | 39.3495 | 256.86 | 0.12 | 10.9307 | 49.15813 |
| P$^{H}$ | 11.80 | 5.50 | 6.8969 | 1.03752 | 8.47 | 5.50 | 6.8989 | 0.73235 |
| Arsenic (mg/l) | 0.00 | 0.00 | 0.0000 | 0.00000 | 0.00 | 0.00 | 0.0000 | 0.00000 |
| Iron (mg/l) | 1.50 | 0.00 | 0.4671 | 0.32726 | 0.80 | 0.30 | 0.4933 | 0.16352 |
| Nitrate (mg/l) | 60.00 | 0.00 | 17.8643 | 16.8045 | 60.00 | 0.00 | 25.2037 | 16.30199 |
| Nitrite (mg/l) | 14.00 | 0.00 | 1.1845 | 3.52080 | 0.60 | 0.00 | 0.0659 | 0.15633 |
| DO (ppm) | 33.50 | 6.00 | 11.5262 | 4.62169 | 33.50 | 7.20 | 11.2704 | 5.29483 |
| BOD (ppm) | 67.00 | 6.00 | 25.0845 | 16.1433 | 67.00 | 6.00 | 28.2815 | 18.87526 |
| Chlorine (mg/l) | 40.56 | 0.00 | 1.7800 | 6.16414 | 40.56 | 0.00 | 2.4393 | 7.65369 |
| Hardness (mg/l) | 430.00 | 32.00 | 140.500 | 84.9175 | 430.00 | 40.00 | 161.333 | 83.10142 |
| Chloride (mg/l) | 909.90 | 20.28 | 195.977 | 224.672 | 909.90 | 20.28 | 270.410 | 247.17871 |

Source: Field Survey through Lab. Analysais (BCSIR Laboratoires, Chittagong), 2011

***ELECTRIC CONDUCTIVITY***

Electric conductivity values of the water samples were determined by Conductivity meter, Model no.-EC214, Hanna Instruments. The acceptable limit of EC is 500µScm$^{-1}$ for drinking water, according to World Health Organization (WHO) guidelines values and Bangladesh standard. A value of electric conductivity has crossed the acceptable limit (above 500µScm$^{-1}$). The study area-II (ground water) values of electric conductivity are higher (81.5 %) or crossed acceptable level than 60.0 % in study area-I (surface water). Among the two areas the maximum (2637.00) and minimum (53.67) conductivity were same but the average value of electric conductivity was higher (733.455) in the study area-II than 583.511 study area-I.

**TOTAL DISSOLVE SOLID (TDS)**

Total dissolve solid (TDS) in water samples was determined by Portable Turbiditivity meter, Model no-Turb350IR. Total Dissolve solid values in the study area are found in acceptable limit. But the study area-II (ground water) is 37.0 % of samples total dissolve solid is above 500 mg/l. it's crossed the acceptable limit and TDS values in study area-I (surface water) are good position (6.7 %) than study area-II. The acceptable limit of TDS is 500 mg/l for drinking water (BDS, 2001). The maximum value (1450.30) was same in both areas but the minimum value was 74.44 in study area-I and 128.00 in Study Area-II. Average TDS is 500.982 in the study area-II and 394.814 in the study area-I.

**TURBIDITY**

Turbidity values of the water samples were determine by Turbidity (NTU) Portable Turbiditivity, Model no-Turb350IR. The acceptable limit of Turbidity is 5.0 NTU (max.) for drinking water (BSTI, 2001, WHO, 1993). The maximum (256.86) and minimum (0.12) turbidity were same in both study area but the average value of turbidity is higher (10.9307) in study area-II than study area-I (8.6083) as shown in Table 03. Lab analysis reveled that the turbidity in majorities (66.7%) of the samples was in acceptable limit (below 5 NTU) and 33.3 % of the samples had upper value (above 5 NTU) in study area-I. On the other hand, 92.6 % samples' turbidity was in acceptable limit (below 5 NTU) and 7.4 %

samples crossed the acceptable limit (above 5 NTU) in study area-II.

**pH**

pH values of the water samples were determined by a Digital $P^H$ meter. The permissible ranges 6.5-8.5 according to World Health Organization (WHO) guidelines values and standard values prescribed in Bangladesh Environmental Conservation Rules'1997 (BECR, 1997). Maximum $P^H$ values were 11.80 and 8.47 in study area-I and II respectably while minimum and average $P^H$ values were 5.50 and 6.8969 in both areas (Table 2). Among the both areas, A value of $P^H$ is found 21.4% samples had less than pH values (below 6.4), 33.3% were also in reasonable limit (6.4-7.4) and (48.1 %) samples crossed the standard level (above 7.4) in study area-II.

**ARSENIC**

Arsenic values in water samples were determine by Atomic Absorption Spectrometry (AAS). Lab analysis was explored that arsenic contents fully disappear in both supply system (Ground and Surface water) in Chittagong Metropolitan City.

**IRON**

Iron values in water samples were determine by Atomic Absorption Spectrometry (AAS). The acceptable limit of iron is 0.3 mg/l for drinking water, according to World Health Organization (WHO) guidelines values and standard values. The maximum concentration of iron in water was 1.50 mg/l and minimum was 0.00mg/l in study area-I while maximum and minimum concentration in the study area-II were 0.80mg/l and 0.30mg/l respectively. Average concentration (0.4671mg/l) of iron in supply water was same in both areas (Table 2). From lab investigation we came to know that 40.0% of the samples had acceptable limit (below 0.3 mg/l) of iron values while 6.7 % were also acceptable (0.3 mg/l) and 53.3% samples showed upper limit (above 0.3mg/l) in study area-I. On the other hand, 77.8% samples had acceptable iron values (below 0.3 mg/l), 22.2 % were also acceptable (0.3 mg/l) and thus no sample crossed acceptable limit in study area-II. Hence, high iron concentration in the distribution system might be due to corrosions of old pipeline (metal) and improper treatment of ground water before treatment in supply of distribution networks of CWASA.

**NITRATE ($NO_3$)**

Nitrate ($NO_3$) content of water samples were determined by titrimetric methods (APAH, 1998). The acceptable limit of nitrate is 45.0 mg/l for drinking water, according to World Health Organization (WHO) guidelines values and standard values. The two study areas had the same maximum (60.0 mg/l) and minimum (0.00 mg/l) nitrate concentration but the average concentration of nitrate was higher (25.2037 mg/l) in study area-II than study area-I (17.8643 mg/l). The acceptable limit of nitrate values in the both study area. But in the study area-II (ground water) 7.4% samples shows above 45 mg/l nitrate values which is higher than study area-I (surface water). It was remarkable that, surface water in study area-II is nitrate free.

**NITRITE ($NO_2$)**

Nitrite ($NO_2$) concentration of water samples were determined by titrimetric methods (APAH, 1998). The acceptable limit of nitrate is nil or 0.005 mg/l for drinking water, according to World Health Organization (WHO) guidelines values and standard values. Nitrite values in water was maximum 14.00mg/l and minimum 0.00mg/l in the study area-I while in the study area-II the maximum concentration was 0.60 mg/l and minimum was 0.00 mg/l. The average concentrations of nitrite in supply water were 1.1845mg/l and 0.0659 mg/l in study area-I and II respectably (Table 2). A value of nitrite is crossed the acceptable level of Chittagong Metropolitan City. In the Study area-II (ground water) value of nitrite is high (51.9% samples) or crossed acceptable limit (above 0.5 mg/l) and about 33.3% samples have crossed acceptable limit (above 0.5 mg/l) in the study area-I (surface water).
Thus, high concentration of Nitrate ($NO_3$) and Nitrite ($NO_2$) in the distribution system especially ground water dominated areas might be due to municipal waste and heavy industrial residues enter the pipeline during non-suction period through leaching point of pipeline and not properly closed unauthorized connection of CWASA pipeline network in Chittagong Metropolitan city.

**DISSOLVE OXYGEN (DO)**

Dissolve Oxygen (DO) standards of water samples were determined by Winkler titrimetric methods (Iodometric, APAH, 1998). The acceptable limit of DO is 4-6 ppm for drinking water (BSTI, 2001 and WHO, 1993). The maximum DO values (33.50 ppm) were same in the two areas and the minimum values were 6.00 ppm and 7.20 ppm in study area-I and II respectively. Again the average values were also same in these areas (Table 2). Dissolve oxygen values have all ready crossed the acceptable level in Metropolitan City. The study area-I (surface water) and study area-II (ground water) both have crossed the acceptable limit above 4-6 ppm and above 2-4 ppm respectively.

**BIOLOGICAL OXYGEN DEMAND (BOD)**

Biological Oxygen Demand (BOD) standards of water samples were determined by $BOD_5$ days Winkler titrimetric methods (APAH, 1998). The acceptable limit of BOD is 2-4 ppm for drinking water (BSTI, 2001 and WHO, 1993). The maximum (67.00) and minimum (6.00) BOD values were same in both of the study areas but the average value of BOD was higher (28.2815) in study area-II than study area-I (25.0845). All the collected water samples of both study areas of CWASA had $BOD_5$ concentration grater than the crossed of acceptable limit (above 4-6 ppm). Therefore, high DO and $BOD_5$ concentration in the distribution system might be due to cross-contamination through leaching pipes, unauthorized connection, improper and unhygienic domestic storage facilities etc.

**FREE CHLORINE**

Free Chlorine concentration of water samples were determined by Atomic Absorption Spectrometry (AAS). The acceptable limit of Chlorine is nil mg/l for drinking water, according to World Health Organization (WHO) guidelines values and standard values. Both of the areas had the same maximum (40.56) and minimum (0.00) chlorine concentration but the average value of chlorine was higher (2.4393) in study area-II than study area-I (1.7800) (Table 2). Chlorine concentration has been used to positive sense in the distribution network because it will kill all possible microorganisms present in the supply water. Although chlorine is effective in destroying pathogen and preventing the spread of communicable disease, they may be an indirect non-infections health problem caused by the chlorination process (Chhatwal, 1998). But CWASA authority already uses high quantity of chlorine in supply system and it's cross the acceptable level in some sport in Chittagong Metropolitan city. Lab investigation found that 6.7 % samples had acceptable limit (nil mg/l) of chlorine, 53.3 % had upper values (0.5 mg/l) and 40.0% samples also crossed acceptable limit (above 0.5mg/l) in study area-I. On the other hand, 7.4 % samples chlorine values had acceptable limit (nil mg/l), 51.9 % had upper values (0.5 mg/l) and majority (40.7 %) of the samples were found is in higher level (above 0.5mg/l) in study area-II.

**HARDNESS**

Hardness in water samples was determined by titrimetric methods (APAH, 1998). The acceptable limit of total hardness is 300 as $CaCO_3$ mg/l for drinking water, according to World Health Organization (WHO) guidelines values and standard values. The maximum (430.00) hardness was same in both the areas and minimum values were 32.0 and 40.0 in study area-I and –II respectively. Average value of hardness was higher (161.333) in study area-II than study area-I (140.500) (Table 3).The values of hardness of the maximum samples (86.7%) were in acceptable limit (below 300 as $CaCO_3$ mg/l), 13.4 % samples had upper values (above 300 as $CaCO_3$ mg/l) in study area-I. On the other hand, 92.6 % samples had reasonable hardness values (below 300 as $CaCO_3$ mg/l), 3.7 % samples showed higher level (above 300 as $CaCO_3$ mg/l) in study area-II.

**CHLORIDE**

Chloride concentration of water samples were determined by titrimetric methods (APAH, 1998). The acceptable limit of chloride is 250 mg/l for drinking water, according to World Health Organization (WHO) guidelines values and standard values. The maximum (909.90) and minimum (20.28) hardness was same in study area-I and -II. Average value of hardness was higher (270.410) in study area-II than study area-I (195.977) (Table 2). A chloride content of supply water is 93.3% of the samples showed acceptable limit (below 250 mg/l) of chloride and 6.7 % had higher values (above 250 mg/l) in study area-I. On the other hand, 55.6 % samples had reasonable limit of chloride (below

250 mg/l), 44.4 % were also in acceptable level (above 250 mg/l) in study area-II. High chloride concentrated values may be due to saline water intrusion problem during non-suction period, corrosion of distribution network and illegal linkage in CWASA pipe line of Chittagong Metropolitan city.

### *ANALYSIS OF MICROBIOLOGICAL PARAMETERS*

Among the 42 samples in study area-I and II, 24 are detected presence of Total Coliform and Fecal Coliform of supply water in Chittagong Metropolitan City and majority contain in study area-II than study area-I. Nearly all of the samples are contents of Total Coliform and Fecal Coliform in supply water of Chittagong Metropolitan City. Test results of the presence of selected samples in the samples of supply water are given in the following table (Table 3).

**Table 3:** Results of Microbiological Parameter of Supply Water in Chittagong Metropolitan City

| **Total Coliform (/100ml)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***S.L** | **01** | **07** | **08** | **09** | **10** | **16** | **17** | **18** | **19** | **20** | **21** | **22** |
| Values | 210 | $1100^{+}$ | 93 | 120 | $1100^{+}$ | $1100^{+}$ | 23 | 9 | 240 | $1100^{+}$ | $1100^{+}$ | $1100^{+}$ |
| **S.L** | **23** | **25** | **28** | **30** | **32** | **34** | **35** | **38** | **39** | **40** | **41** | **42** |
| Values | 15 | 23 | 43 | 9 | $1100^{+}$ | 23 | 64 | $1100^{+}$ | $1100^{+}$ | 9 | 240 | 42 |
| **Fecal Coliform (/100ml)** | | | | | | | | | | | | |
| **S.L** | **01** | **07** | **08** | **09** | **10** | **16** | **17** | **18** | **19** | **20** | **21** | **22** |
| Values | 150 | $1100^{+}$ | 43 | 9 | $1100^{+}$ | $1100^{+}$ | ….. | 9 | 210 | $1100^{+}$ | $1100^{+}$ | 210 |
| **S.L** | **23** | **25** | **28** | **30** | **32** | **34** | **35** | **38** | **39** | **40** | **41** | **42** |
| Values | 23 | 9 | 23 | ….. | $1100^{+}$ | ….. | 39 | $1100^{+}$ | 240 | 4 | 150 | …… |

Source: Field Survey through Lab. Analysais (BCSIR Laboratoires, Chittagong), 2011.
*S.L- Sample location.

### *TOTAL COLIFORM*

Values of Total Coliform of water samples were determined by Most Probable Count Methods (MNP). The acceptable limit of Total Coliform is 0/100 ml for drinking water, according to World Health Organization (WHO) guidelines values and standard values. Total Coliform was count in (57.14 %) was existed in the supply water of Chittagong Metropolitan City while 70.37 % of the samples in study area-II and 33.33% samples in study area-I.

### *FECAL COLIFORM*

Values of Fecal Coliform of water samples were determined by Most Probable Count Methods (MNP). The acceptable limit of Fecal Coliform is 0/100 ml for drinking water, according to World Health Organization (WHO) guidelines values and standard values. Fecal Coliform was existed in the supply water of Chittagong Metropolitan City. It was remarkable portion of the water is 55.55% samples in study area-II and the 33.33 % samples in study area-I.

### *TOTAL VIABLE COUNT*

Total Viable Count was determined by Nutrient agar, Plate Count. The acceptable limit of Total Viable Count is $10^4$/ml for drinking water, according to World Health Organization (WHO) guidelines values and Bangladesh standard values. Lab analysis revealed that, Total Viable Count of bacteria was critical position in 19 samples are directly crossed the acceptable limit and rest of samples the values of total viable count is near unacceptable limit in Chittagong Metropolitan City. While 73.33 % samples crossed the acceptable limit (above 10X $10^4$) in the study area-I and 59.25 % samples crossed the acceptable limit in the study area-II.

### *PATHOGENIC ORGANISM ANALYSIS*

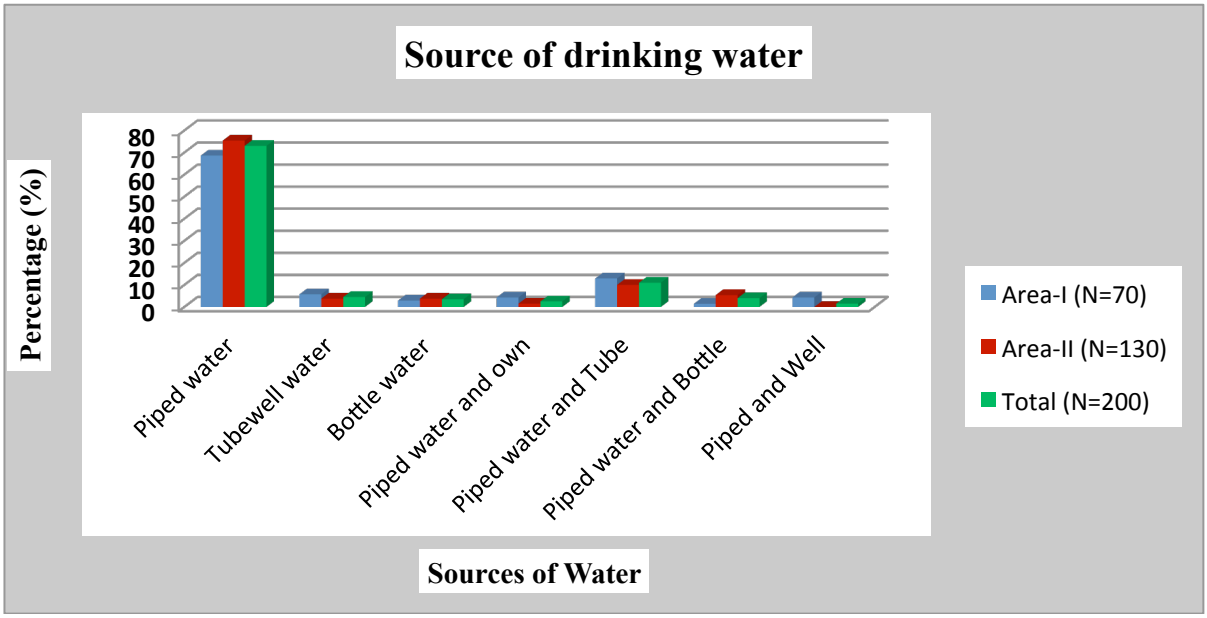
The pathogenic organism such as *Salmonella* spp., *Shigella* spp., *Escherichia coli* and *Vibrio cholerae* were present in both study areas. *Salmonella* spp., was detected samples 02 and 34. Sample 02 contain in Chandgaon residential area (block-b) of chandgaon thana and sample 34 contain in steel miles of potenga thana. *Shigella* spp., were detected samples 07 in baparipara kulgaon, Bayzid bostami thana. *Escherichia coli* were detected in samples 15 and 21. Sample 15 contain sharshah

colony in Bayzid bostami thana and 21 sample contain Agarabad Badamtoli in Double Mooring thana. *Vibrio Cholerae* is detected in different places in the study area-II such as, 16, 28, 29, 38 and 41. 16 sample is contain East nalapara Collegiate School in Kotwali thana, 28 is Akbor shah in pahartali thana, 29 is Block-A in Khulshi R/A, 38 is port colony in Bandor thana and 41 is contain I Block in Halishahar respectively.

***QUESTIONNAIRE SURVEY***

***SOURCE OF DRINKING WATER***

Water supply is very important for human beings. Its demand increases along with population growth as well as the development of every sector in the country to improve the quality of life. The supply of water depends on the availability of its sources, availability of electricity, production rate, and rate of purification from treatment plant. The dwellers of Chittagong Metropolitan area never get their demanding water due to the shortage network and irregular supply of supplied water as result dwellers face unsafe and scarcity of drinking water. The main source of drinking water (figure 2) in Chittagong Metropolitan city is piped water, tube-well water, well water, bottle water and so on. It was observed that piped water is the major (73.0 %) source of drinking water in Chittagong area and other source of water is tubewell, bottle, own pump, and well.

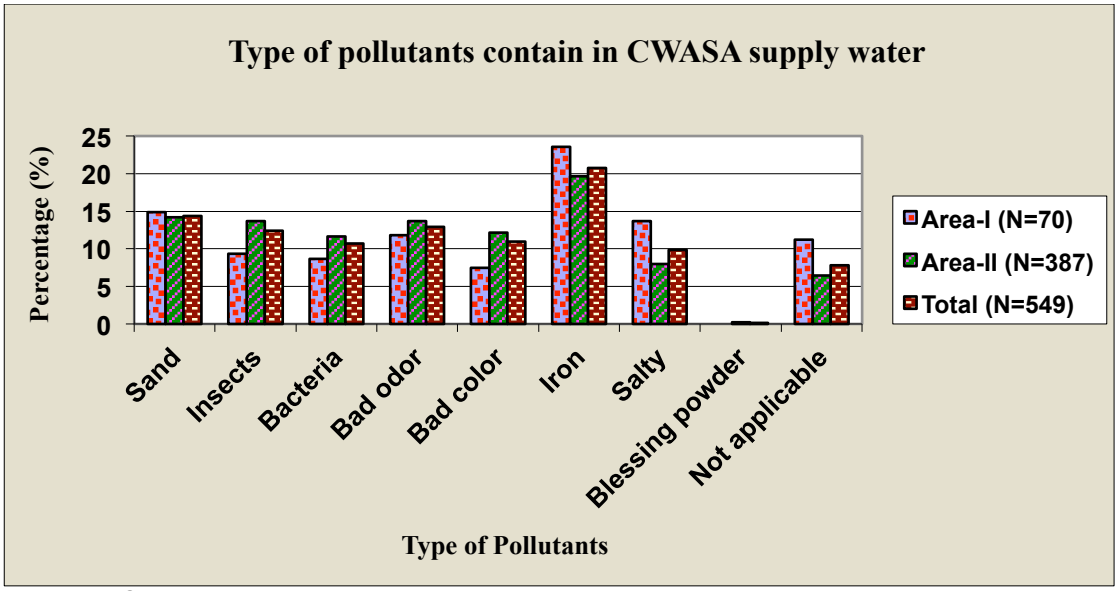



Source: Field Survey through questionnaire, 2011

**Figure 2:** Source of drinking water (percentage of the sample)

***TYPES OF POLLUTANTS CONTAIN IN CWASA SUPPLY WATER***

Supply water for drinking, cooking and households purposes is bad and very bad because presence of various unexpected elements like salt, iron, sand, bad odor and color and insects. Survey revealed that various types of pollutants (figure 3) like iron, sand, insects, bad odor, bacteria, bad color, salt and blessing powder etc. present in CWASA supplying water in Chittagong metropolitan city. Pollutant types are heterogeneous especially iron, sand, bad odor and color and insect present in both area of Chittagong Metropolitan city.



Source: Field Survey through questionnaire, 2011

**Figure 3:** Types of pollutant contain in CWASA water

***USE OF PURIFICATION TECHNIQUES TO REMOVE UNEXPECTED MATERIALS FROM CWASA WATER***

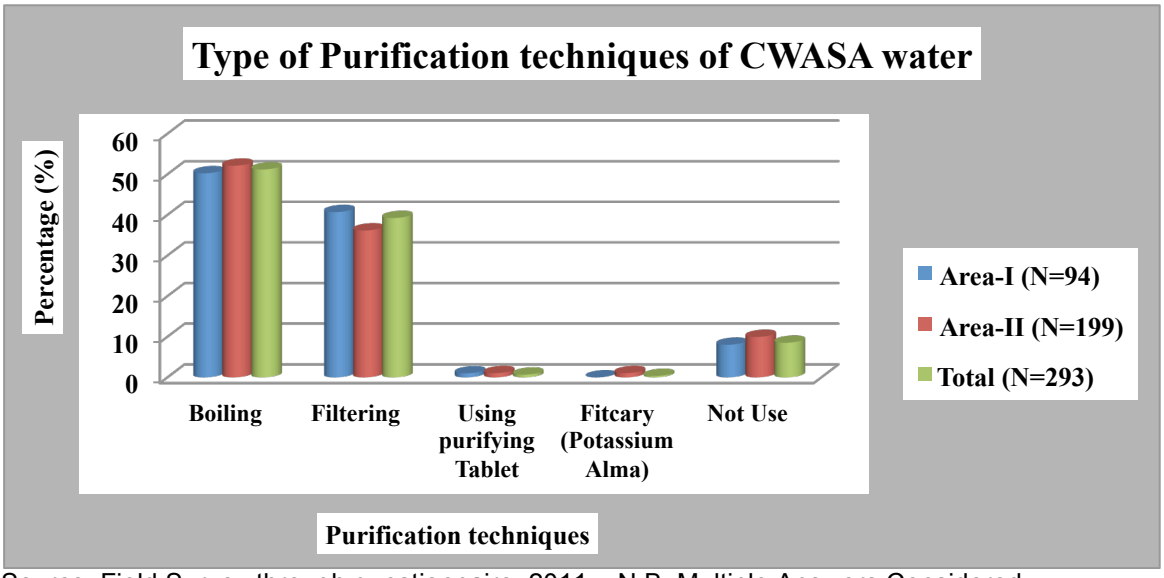
Water using practices (drinking, cooking, bathing and washing etc.) depend on the acceptances of purity level of supply water. Different types of unexpected materials have been present during consuming purposes in Chittagong Metropolitan city dwellers. Citizens are very much conscious to purify their using water during different using purposes. But small portion are unconscious about water purity level in the study area.

**Table 3:** Use of purification techniques of CWASA water (percentage of the sample)

| Water purity | Area-I (N=70) | Area-II (N=130) | Total (N=200) |
|---|---|---|---|
| **Yes** | **87.1** | **86.2** | **86.5** |
| **No** | **12.9** | **13.8** | **13.5** |
| **Total** | **100.0** | **100.0** | **100.0** |

Source: Field Survey through questionnaire, 2011

Type of practices (figure 4) like boiling, filtering, using purifying tablet and fitcary (Potassium Alma) are used for purification of water before used of household's purposes in Chittagong Metropolitan city. A majority of the dwellers has been followed boiling and filtering techniques for purification of supply water before household's uses in the both study area. Little parentages of city dwellers has been used using purifying tablet and fitcary (Potassium Alma) for purification of supply water before household's uses in the both study area.




Source: Field Survey through questionnaire, 2011 N.B. Multiple Answers Considered

**Figure 4:** Purification techniques of CWASA water (percentage of the sample)

***IN-DEPTH INTERVIEW HAS BEEN CONDUCT FROM CWASA AUTHORITY (CHIEF ENGINEER)***

The water supply in Chittagong began in 1916 when individual water supply facilities were installed in urban areas. In the install age the water source was ground water. As the area of the city has been expanded, the scope of those facilities also was increased in 1963, CWASA was established in Chittagong. At that time, the total water supply was 20500 $m^3$ /day. The service ratio of water supply was 68 %. Subsequently, increasing demand was addressed by conducting the Kalurghat IRP project Phase-I (1977) and Phase-II (1987) and constructing the Mohara WTP (1990). As of 2007 the Phase-III interim expansion project (ground water development 90,000 $m^3$ /day) has been completed.

***WATER PURIFICATION PROCESS***

Surface or River water supplying in Chittagong Metropolitan city after proper treatment of Mohara water treatment plant and Ground water collection by the submerge tubewell in different location of city after proper treatment of Kalughat Iron Removal Plant. Quality controlled by authority of Mohara water treatment plant, Kalughat Iron Removal Plant, use of scientific method (on line water quality assessment) before distribute of water in the pipe line and some time the water quality test by Bangladesh University of Engineering and Technology, Dhaka, Bangladesh of both types of water in CWASA.

***DETERIORATION OF SUPPLY WATER***

We are ensured quality of water before supply by the online quality assessment in Mohara water treatment plant and Kalughat Iron Removal Plant center. Consideration of public health we are conduct weekly and monthly sampling in randomly but some time daily sampling occurred in different place of CMC. But Water contamination in the distribution may be attributing to leaks in the old pipes and the nature of water supply and water supply in Chittagong city is intermittent in nature and absence of pressure or negative pressure (Suction) in water mains during non supply hours permit entry of contaminants in the distribution network. Suction in the distribution system is also produce by installation to unauthorized pumps in the service line to suck more water from the low pressure zones.

***LINKAGE OF SUPPLY WATER***

Construction of water supply and distribution piped are 100mm,150mm,200mm,300mm,450mm,600mm,750mm,900mm and 1200mm and four types of piped material and pipe line span i. Cast iron pipe (DI) ii. Asbestos pipe (AC) iii. PVC iv. Others (MS pipe). The current linkage is coverage about 600km around the city.

***FUTURE INITIATIVE***

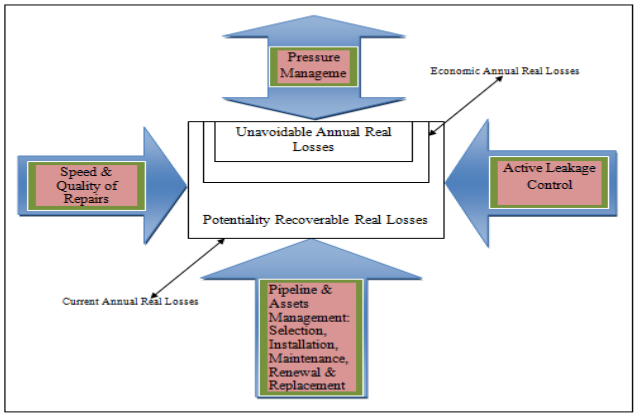
Recently CWASA and JICA (Japan International corporation agency) Collaboration prepared a "Preparation of Master Plan for Water Supply and Wastewater Management of the Detailed Planned Area of Chittagong, Bangladesh". This plan more emphasis on following initiatives such as projected of total population, supply demand & rate, CMC will be divided in 11 service block, increase per capita water (currently 200 l/d it will be increase 300 l/d until in 2031), rehabilitees & improving supply network, expansion of Mohora & Kalurghat IRP ongoing Madunaghat (1st & 2nd phase), Karnaphuli (1st, 2nd, 3rd & 4th phase), Patehabad and Bandar Jhuri (1st & 2nd) WTP. The ongoing project not only fulfills the demand of supply water but also reduce the withdrawal ground water in CMC area.

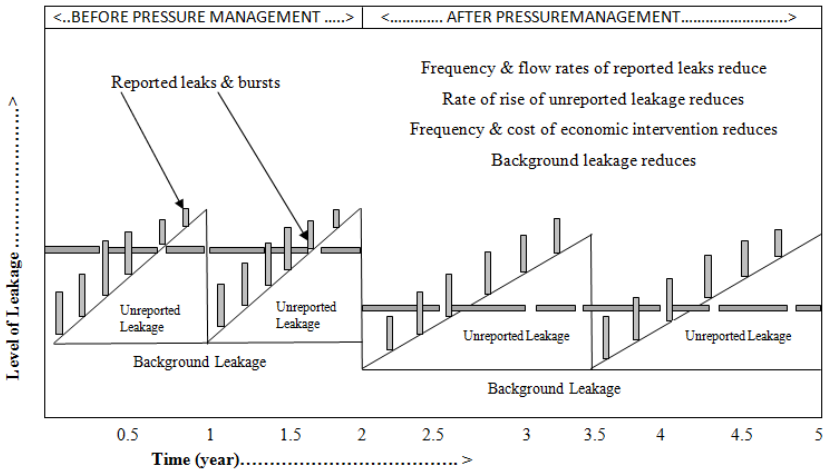
**RECOMMENDATIONS AND CONCLUSION**

The present study delineates that water is unsuitable for drinking and cooking purpose water in terms of physio-chemically and biologically as a results dwellers are affected various types of water borne diseases. To make the available potable water for household consumption purpose the following consideration can be recommended.

- ***REGULAR MONITORING OF WATER QUALITY ALONG THE DISTRIBUTION NETWORKS***: Uses of disinfectant residuals control the growth of microorganisms in distribution systems and to act as a final barrier, to help maintain the microbial safety of supply water. Realistic residual concentration at least inactivate the least resistance microorganisms such as E.Coli and thermo tolerant Coli forms that are used as the main indicators of water safety (Payment,1999). One way to monitor effectively is to perform both routine sampling for Physio-chemical and microbial quality and real time (possibly online) monitoring of parameters linked to physio-chemical and microbial quality of at selected locations throughout the storage and distribution system.

- ***TIMELY REPAIR AND MAINTENANCE***: Contamination via cross-connection, disclose pipe joints or pipe breaks may influence water quality. Pathogens may enter the system through contaminated supply water, in line reservoir etc. System personnel need immediately repairs the faults point of supply and water holding system. Following two examples is help to leakage control in CWASA pipeline. Example ***One***; following diagram, (IWM, 2011) (Fig: Leakage control activity) the leakage is divided in to 2 parts unavoidable real losses and potentially recoverable real losses. The leakage can be reduced by leakage control activity, which area speedy and quality repair, pressure management for preventing pipe bursting, active leakage control and management of pipeline and assets. More speedy and quality repairing of found leakage is required, however repairing of found leakage is being implemented by authority. The next step to control leakage should be



replacement of deteriorated pipelines and assets as planned by CWASA, which will reduce the bursting of pipes so that optimum repairing work is possible under the same pressure condition.

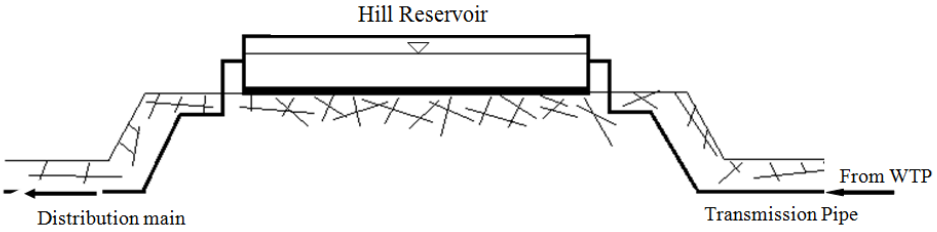
***Two;*** The next steps are active leakage control be leakage detection and pressure management. The pressure management is required for reduction of pipe bursting and leak flow in the busted condition. The above figure shows the influence of pressure management.

- **IMPROVING INFORMATION SYSTEMS**: CWASA immediately take attempts to create data based management practices such as, ***Demand Assessment;*** The demand assessment for the present and future years with respect to water supply would be based on present and future population of the project area i.e. equation, **Q*f* = P*f* ×q** Where, Q*f,* is the quantity of water requirement per day; P*f,* is the projected population estimated; at the end of the design period; q, is the rate of consumption per capita per day. ***Population Assessment;*** The most widely used method is geometric progressive method. This is also known as empirical method suggested by Hardenberg. The future population can be estimated by this method using the following equation

  **P*f* = P*p* (1+r),** where, P*f,* is the estimated on Future population; P*p,* is the estimated on present population; r, Rate of early growth; n, Number of year to be considered.

- **USES OF ADVANCED TECHNOLOGY:** ***LINKAGE:*** CWASA should be use thick PVC pipeline. This pipeline is not corrosive and not easy to leakage. **Online *quality control assessment;*** CWASA should be promoting online quality control assessment from treatment plant to consumer (households) and it will be operate minimum two times in a day.

- ***SETUP OVERHEAD AND RESERVOIR:*** However, Chittagong city is situated on the undulating area as a result supplied water not move optimally. Authors strongly recommended in future setup all types of overhead and reservoir on the hill tops (above figure). Its helps to distribution of gravity flow, no need lift pump only need small boost pump, easy operation and strong to electrical shortage etc.




- **PROVISIONS FOR STAFF TRAINING:** CWASA should be arrange training camp and workshop for laboratory (scientific officer) level to ensure acceptable water quality, mechanical level (engineering) to ensure site selection, selection of pipe (metal or plastic) & GIS map division, field personnel to ensure proper service connection, rehabilitated old pipe and setup new pipe, sluice valves and chamber repair, leakage or fault line identified and repaired this immediately.

- **AWARENESS BUILDING AMONG USERS/ STAKEHOLDER:** ***Users;*** every morning before using the water for drinking of cooking purpose the water from the taps should run for several minutes. Consumer should also very careful in storing water. Storing pot should be washed in a regular basis by bleaching powder to store water safe and hygienically**.** ***Stakeholder;*** CWASA should be organized in different types of initiatives like seminar, symposium, advertisement and campaign etc. & to ensure the participation all class income groups (elite to poor) for awareness build to proper uses of getting water, discourages of unauthorized connections and water pricing in city area.

- **COMMUNITY- BASED CO-MANAGEMENT GOVERNING SYSTEM:** CWASA administrative body will be ensured that collaborative concentration of citizens, specialist class (i.e. urban geographer, urban planner and urban environmentalist), CWASA personnel (in every phases such as production center, distributor, line installation & line repair, mechanical and GIS section etc.) and other related autonomous body like Chittagong Development Authority (CDA), Chittagong City Corporation (CCC), Department of Environment (DoE), Power Development Board (PDB) and Local Government Engineering Department (LGED) during

supply water related planning design and implementing planning.

## CONCLUSION

Chittagong city dwellers are not only facing the problem of inadequate water supply but also serious threat due to the scarcity of safe water. The test result of water samples selected by stratified random sampling indicated the water quality of two study areas of CWASA's distribution system which revealed that the physio-chemical and microbial water quality deteriorated during water's flow from treatment plant through the distribution system. City dwellers get water for daily uses for different sources such as indoor tap water, shared tap, and tubewell connection with CWASA line and tubewell. Major people use indoor tap water for household purpose in Chittagong Metropolitan city and rest of the residents get water from shared tap (generally in lower class residential areas), tubewell connection with CWASA line (generally in middle and higher class residential areas). Most of the respondents are affected by diarrhoea, dysentery and skin disease while minorities are affected by typhoid, cholera and fever in Chittagong Metropolitan City. Ensuring the quality is the prime suggestion through sampling of supply water, cleaning the pipe line, supplying safe water, using proper chemical, making supply water available and set up separate line for drinking water to ensure supply water quality in Chittagong Metropolitan city. Maximum utilization of water should be ensured protecting the waste of water, building awareness among the people and using water for vital causes. Public suggested that CWASA should supply safe water and people should use safe water by boiling and filtering the supply water before drinking, using proper chemical to protect water borne disease. Development of reservoirs system and water saving appliance in their house like, underground reserve tank, drum inside the house, well and pond help the city dwellers in crisis time.

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