EFFICACY ANALYSIS OF WATER DISTRIBUTION NETWORK AT A UNIVERSITY CAMPUS IN BANGLADESH

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ABSTRACT

Water quality is a vital concern for mankind as it is directly linked with human welfare. Since 2001, a water treatment plant (WTP) has been established at KUET campus with a view to supplying potable water to its residents through its Water Distribution Network (WDN). However, water quality should meet the requirements at the consumers' tap. The main goal of this study is to investigate the physico-chemical and bacteriological changes of treated water quality in the distribution network and to evaluate the efficacy of distribution network based on water quality index (WQI) with ArcGIS representation of supplied water quality across the WDN. This study shows that the analyzed physico-chemical parameters in the treated water range in various batches of WTP operations as: pH (7.16-7.41), turbidity (0.5-2 NTU), color (0 Pt.Co), iron (0.1-0.5), manganese (0 mg/L) chloride (510-630), and TDS (800-1100 mg/L). However, the quality of water at the consumer's tap was not satisfactory. The water in the consumption point was classified as 'Poor' for WQI value of 32.02 having an explanation of the distribution network is that 'the Conditions usually depart from natural or desirable levels'. Furthermore, the supplied water through the WDN was categorized as 'polluted' based on water pollution index (WPI) value of 3.84 and 'highly contaminated' based on water contamination index (WCI) value of 25.52. According to our observation, two pick hours i.e. during morning (from 8 AM to 9 AM) and during evening (from 6.30 PM to 7.30 PM) have been found in 24 hours of operation period.

Keywords:*ArcGIS, bacterial contamination, consumption pattern, distribution network, water quality index*

1. INTRODUCTION

One of the things which make the Earth a unique planet in this universe is continuous availability of water, second essential factor for the existence of life after oxygen. Thus, life on earth is entirely and exclusively dependent on water. Though, water covers more than 70% of the earth; only 1% of the earth's water is available as a source of drinking. Yet, our society continues to pollute it (Sadhale, 2006). The majorities of the populations in developing countries are inadequately supplied with potable water and are thus bound to use water from doubtful sources that have high potential of contamination (WHO, 2011). Generally, water-related diseases continue as a major health problem globally since time immemorial.The World Health Organization (WHO) reported that every year more than 3.4 million people die as a result of water related diseases, making it the leading cause of disease and death around the world (Ibrahim*et al.*, 2014). The WHOalso included that four out of every 10 people in the world, particularly those in Africa and Asia, do not have clean water to drink. For instance, in West Bengal (India) as well as in Bangladesh, water sources are contaminated with pathogenic bacteria (UNEP, 1999).In 1996, WHO recommended for regular testing and monitoring of microbial parameters of drinking water.In ensuring the supply of safe drinking water, the distribution system is as important as the water resources and treatment facilities. The water quality changes between the time drinking water leaves the treatment plant and the time it arrives at the consumers tap. The change of water quality is also dependent upon the type of network the material used and the hydraulic regimes (Vreeburg, 2007). Khulna University of Engineering & Technology (KUET),situated at the southwest coastal belt of Bangladesh is facing enormous challenges in meeting the rising fresh water demand due to limited water supply from the available groundwater and surface water sources as they are affected by the salinity and other water quality problems.It was a challenging task for the university authority to eliminate the crisis of potable water as well as to ensure the quality of living in the entre university area. Consequently, a water treatment plant (WTP) has been established in 2001 at KUET campus with a view to supplying potable water to its residents through its water distribution network (WDN). Usually, the quality of drinking water changes due to the transportation through the WDN and the time spent in the reservoirs until the last point of consumption. The present study was aimed to investigate the physico-chemical and bacteriological changes of treated water quality in the distribution network and to evaluate the efficacy of WDN based on water quality index (WQI) with ArcGIS representation of supplied water quality across the WDN.

2. METHODOLOGY

2.1 Study Area

Khulna University of Engineering & Technology (KUET), the present study area, is one of the leading public engineering universities in Bangladesh. It was founded in 1967 as Khulna Engineering College and converted to Bangladesh Institute of Technology (BIT), Khulna on 1986. Finally, this institute was upgraded as Khulna University of Engineering & Technology (KUET) in 2003. Presently, it comprises 16 Departments including major branches of Engineering and sciences offering both the undergraduate and postgraduate degrees, with 875 fresh UG and about 100 PG students in each year. It is situated at Fulbarigate covering a land area of 101 acres, about 13km north from Khulna City, a metropolitan City in Bangladesh. It is located at 22.8997°N and 89.5026°E on the bank of the Bhairab River with an annual average rainfall is 1809.4mm.

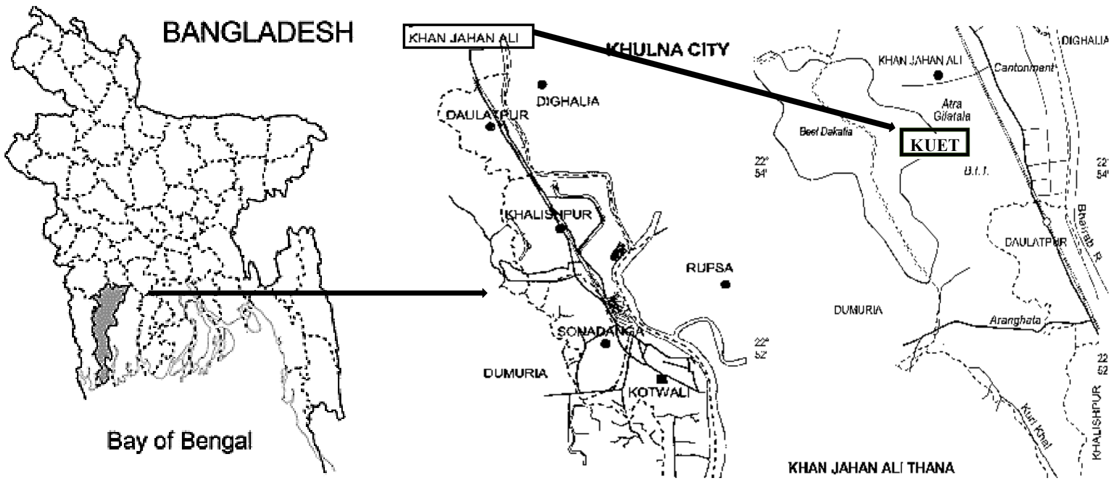

Figure 1: Study area boundary

2.2 Study Outline

This study had been proposed to field observation, sample collection, water quality analysis, determination of water consumption pattern, efficiency assessment and finally proposals for sustainable development Field investigation of the study includes collection of basic data and map of WDN as well as observation of consumers tap. Finally interviewing consumers and worker were performed for necessary statement. The details framework for the efficacy analysis of distribution network is shown in figure 2.

2.3 KUET Water Distribution Network (KWDN) with Sampling Location

The KUET water distribution network was installed initially with the establishment of water treatment plant of KUET campus in 2001. The existing water distribution network is being used to supply treated water to the teacher's residential area and academic buildings but the supplied water is not being used for drinking purpose rather than the domestic purpose due to high chloride and TDS content. Though, the distribution network had been installed throughout the whole campus area, treated water is being supplied to teacher's and staff's residential areas and office buildings only due to insufficient treatment capacity of WTP and therefore, all the students residential hall of this campus contains their own on-site water supply system. Sampling of water from various consumption points was implemented in order to evaluating the qualitative performance of existing WDN of KUET campus. Samples were collected in such a manner so that most of the distribution areas were enclosed and consequently, minimum one sampling location was selected in each route of flow. Also, random sampling was performed for old distribution network and finally, a total number of 16 sampling point were considered for sampling.

2.4 Laboratory testing and analysis

In order to identifying various water contamination problems, water samples were collected from 16 selected points of the WDN. All the sampling and tasting were implemented according to the Standard methods and procedures.

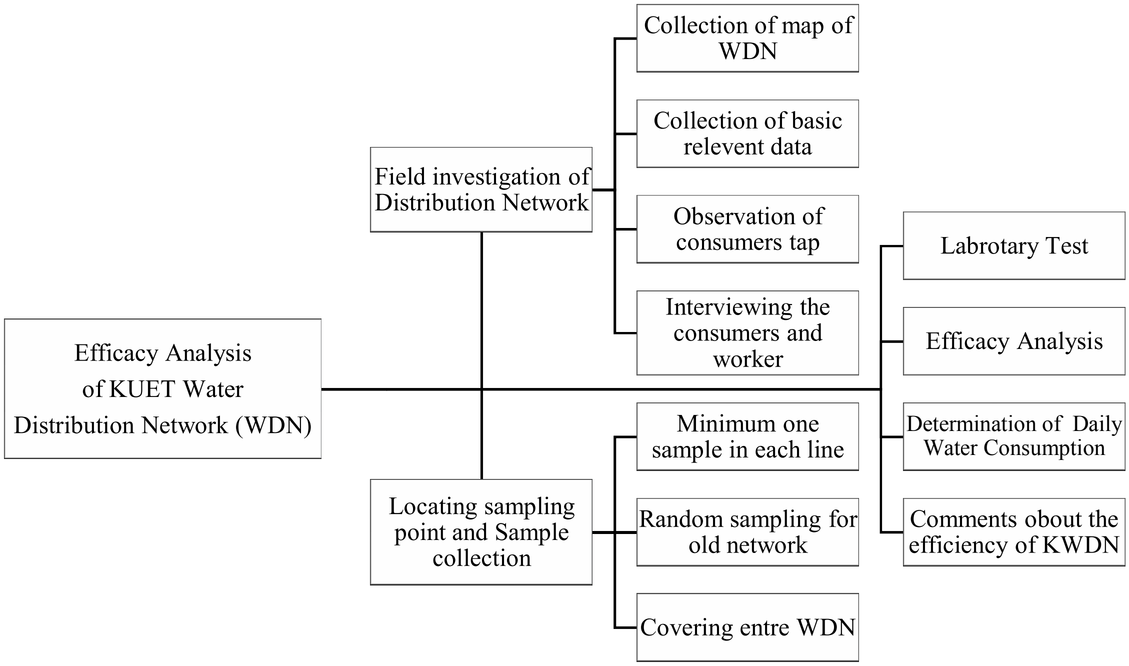

Figure2: Study framework on evaluation of water distribution network (WDN)

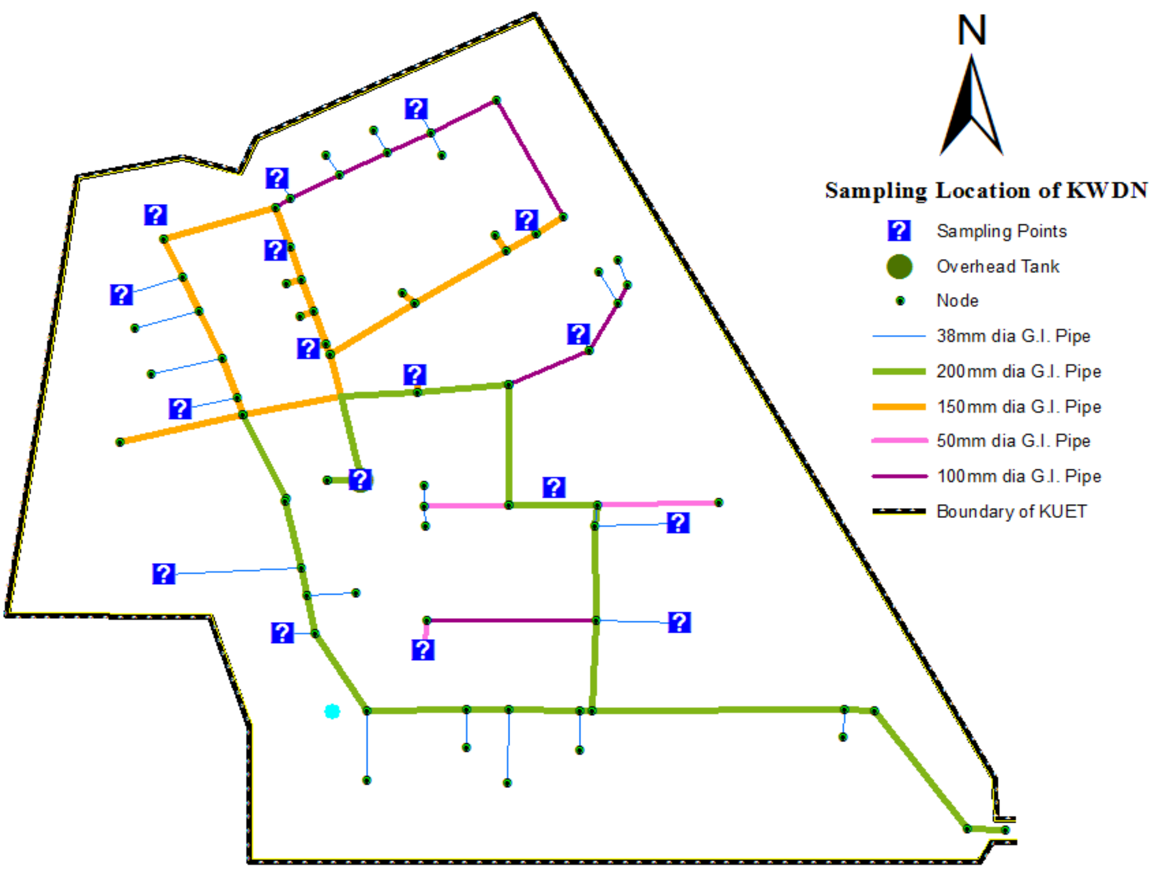

Figure 3:KUET Water distribution network and Sampling location

2.5 Determination of hourly water consumption pattern

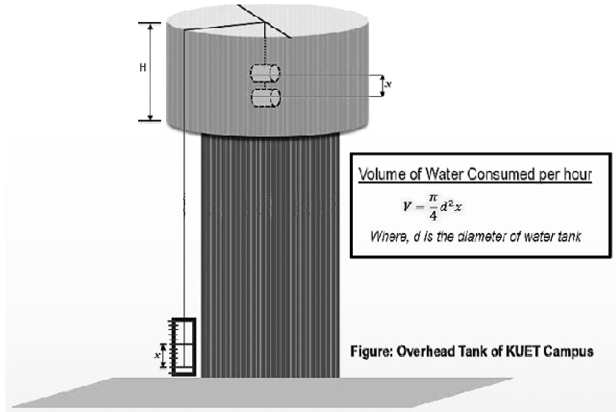

Figure 4:Instrumental setup for the determination of consumption rate

The hourly water consumption in this area was calculated by using a simplest technique. Consider, an unsinkable box is connected with a frictionless rope hanging into the overhead tank at one end of the rope and other end of the rope is installed with a scale at the earth surface. Due to consumption of water, the water level of overhead tank will be decreased and therefore, the box will be lowered down. Also, the point of rope at scale will be moved upward and using the hourly variation, the volume of hourly water consumption can be calculated easily. Another consideration is that, the capacity of hourly pumping should be subtracted if the pumping operation is found to be performed for re-loading the overhead tank by the authority during the study period. The study was performed for 24 hours in a day. The details instrumental setup is shown in the figure 4.

2.6 Key Terms for Efficiency Assessment

2.6.1 Water Quality Index (WQI)

This index allows measurements of the frequency and extent to which parameters exceed their respective guidelines at each monitoring station. Therefore, the index reflects the quality of water for both health and acceptability, as set by the World Health Organization as well as any other standard. The CWQI equation is calculated using three factors as follows:(UNEP, 2007)

$$WQI = 100 - \left[\frac{\sqrt{F_1^2+F_2^2+F_3^2}}{1.732}\right] \quad (1)$$

F1 represents Scope: The percentage of parameters that exceed the guideline

$$F1 = \left[\frac{\text{No of failed parameters}}{\text{Total Number of parameters}}\right] \times 100 \quad (2)$$

F2 represents Frequency: The percentage of individual tests within each parameter that exceeded the guideline

$$F_2 = \left[\frac{\text{No of failed test}}{\text{Total Number of test}}\right] \times 100 \quad (3)$$

F3 represents Amplitude: The extent (excursion) to which the failed test exceeds the guideline

$$Excursion = \left[\frac{\text{Failed Test value}}{\text{Guideline Value}}\right] - 1 \quad (4)$$

Normalized Sum of Excursion, $NSE = \left[\frac{\sum Excursion}{\text{Total no of test}}\right]$ (5)

$$F_3 = \left[\frac{NSE}{0.01NSE+0.01}\right] \quad (6)$$

Table 1: Water quality classification according to WQI (UNEP, 2007)

Designation	WQI	Description
Excellent	95-100	All measurements are within objectives virtually all of the time
Good	80-94	Conditions rarely depart from natural or desirable levels
Fair	65-79	Conditions sometimes depart from natural or desirable levels
Marginal	45-64	Conditions often depart from natural or desirable levels
Poor	0-44	Conditions usually depart from natural or desirable levels

2.6.2 Water Pollution Index (WPI)

This is a combined physical-chemical index which makes it possible to compare the water quality of various water bodies (Filatov*et al*., 2005). Therefore, it has wide application and it is used as the indicator of the quality of sea (Filatov*et al*., 2005) and river (Lylko*et al*., 2001) water, as well as of drinking water (Nikoladis*et al*., 2008). The WPI represents the sum of the ratio between the observed parameters and regulated standard values:

$$WPI=\sum_{i=1}^{n}\frac{Ci}{SFQS}\times\frac{1}{n} \quad (7)$$

Where, $Ci$is the average annual concentration of the analyzed parameters, which are sampled approximately once a month. The following parameters are taken into consideration: pH, color, turbidity, iron, manganese, chloride, TDS, EC, and TC. SFQS represents the standard values for the i^{th} water quality, while n indicates the number of analyzed parameters. The water quality classification according to WPI is listed in table 2.

Table 2: Water quality classification according to WPI (Lyulko*et al.*, 2001)

Class	Characteristics	WPI
I	Very pure	≤ 0.3
II	Pure	0.3-1.0
III	Moderated polluted	1.0-2.0
IV	Polluted	2.0-4.0
V	Impure	4.0-6.0
VI	Heavily Impure	> 6

2.6.3 Water Contamination Index (C_d)

The contamination index (C_d) summaries the combined effects of several quality parameters considered harmful to health (Backman*et al.*, 1997) and the contamination index is calculated from equation below:

$$C_d=\sum_{1}^{n} C_{fi} \quad (8)$$

Where, $C_{fi}=\frac{C_{Ai}}{C_{Ni}}-1 \quad (9)$

Where C_{fi}, C_{Ai}andC_{Ni} represent contamination factor, analytical value and upper permissible concentration of the i^{th} component, respectively. Here, N denotes the 'normative value'. The water quality classification according to WCI is shown in table 3.

Table 3: Water quality classification according to C_d (Backman*et al*., 1997)

Class	Characteristics	WPI
I	Low	< 1
II	Medium	1.0-3.0
III	High	> 3

3. RESULTS AND DISCUSSION

3.1 Water Consumption and Leakage Possibilities

3.1.1 Hourly Water Consumption Pattern

The maximum and minimum water consumption was found around 7189 gallon/hour and 631 gallon/hour during the morning period from 8 AM to 9 AM and at 3.00 AM respectively. An increasing trend was noticed from 3.00 AM to 9.00 AM and then the consumption pattern shows a decreasing trend to 11.00 AM. Further increasing was found up to 2 PM and water consumption swiftly lowered down at 4.00 PM. Further increasing in consumption was found up to 7 PM to a value of 6266 gallon. At last, a gradual decrease in consumption was displayed up to 3 AM According to our observation, two pick hour i.e. during morning (from 8 AM to 9 AM) and during evening (from 6.30 PM to 7.30 PM) has been found in 24 hours of operation period.

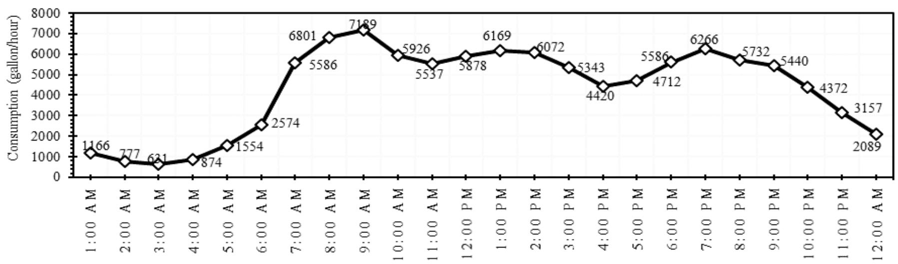

Figure 5:Hourly water consumption pattern in terms of Gallon /hour

3.1.2 Leakage possibilities

The exact water demand in the present service area of KUET is around 2,18,000 Liter/day whereas the plant operation is to be performed for 18 hours per day and the duration of operation was found to be increased to 20 hours for increasing water demand at dry season. Again, the treatment capacity of WTP is approximately 393600 Liter/day and 437000 Liter/day for 18 hours and 20 hours operation respectively. Thus, the wastage of treated water was found to be around 175600 Liter/day that is about 44.61% of total treated water (Hossain and Hassan, 2015). Again, the water consumption in off-pick period was found to be 631 gallon/hour at 3AM. Hence, there was a great possibility of system leakage in the distribution network.

3.2 Comparison Between Treated and Supplied Water Quality

3.2.1 Color and Turbidity

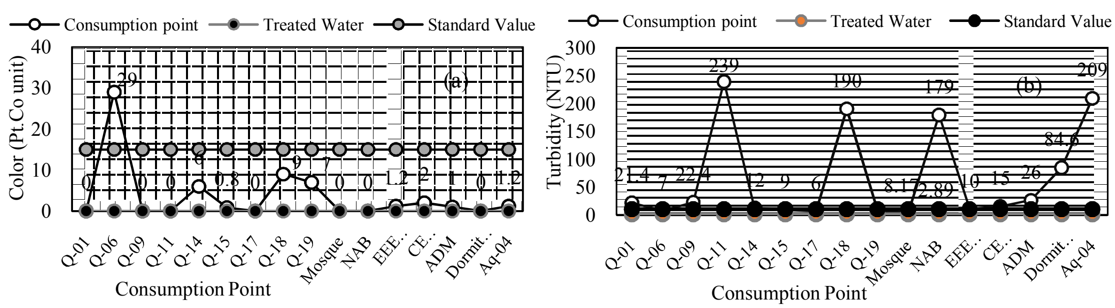

Figure 6:Comparison of(a) Color (b) Turbidityamong treated water, consumption points and BDS value

This study depicters that the average value of color for most of the consumption points was within acceptable limit of BDS value (15 Pt.Co) during the studyperiod except only quarter Q-06. The values of color were found to be in range of 0 to 29 Pt.Co as shown in figure 6(a).Furthermore, the average value of turbidity was exceeded the acceptable limit of BDS value (10 NTU). The maximum and minimum value of turbidity were found to be 239 NTUfor the quarter Q11 and 6 NTU for quarter Q-17, respectively as shown in figure 6(b).

3.2.2 Total Dissolved Solids and Chloride Content

The average values of TDS for most of the consumption points were found to be exceeded acceptable limit of BDS value (1000mg/L) during the period of the study.The maximum and minimum value of TDS were found to be 1330 and 1120 mg/L for the quarter Q-17 and Q-01 respectively as shown in figure 7(a) below. Moreover, the TDS value of treated water was not within the acceptable limit of BDS value.The average value of chloride was found to be exceeded the acceptable limit of BDS value (600 mg/L). The maximum and minimum value of chloride content were found to be 640 for the quarter Aq-04 and 570 mg/L for quarter Q-06, respectively as shown in figure 7(b).

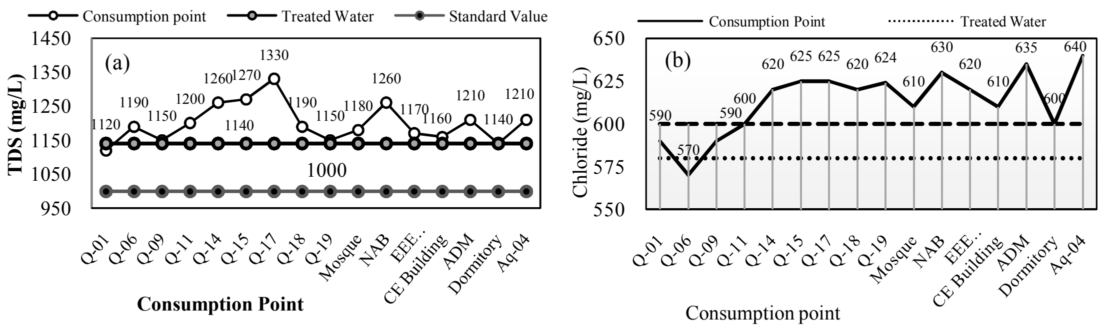

Figure 7:Comparison of(a) TDS (b) Chlorideamong treated water, consumption points and BDS value

3.2.3 Iron and Manganese

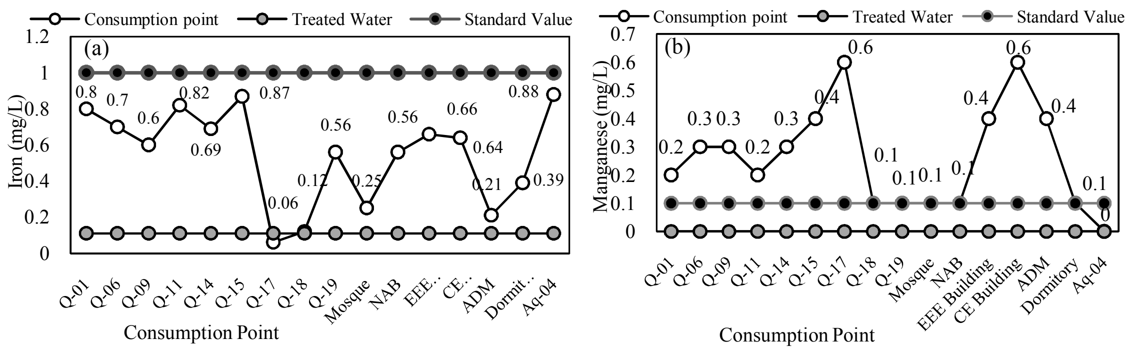

Figure 8:Comparison of (a) Iron (b) Manganese among treated water, consumption points and BDS value

Ironwas found within the acceptable limit of BDS value (1mg/L) for most of the tested sample during the study period as shown in figure 8(a). The maximum and minimum value of Iron content were found to be 0.88 for the quarter Aq-04 and 0.06 mg/L for quarter Q-17, respectively.The maximum and minimum values of manganese were found to be 0.6 and 0 mg/L for the quarter Q-17 and Aq-04, respectively. Theaverage value of manganesewere exceeded the acceptable limit BDS value (0.1 mg/L) for most of the sample as shown in figure 8(b).

3.2.4 Total Coliform and E. Coli

Our observation shows that the entire water sample collected from various consumption points were highly contaminated with total coliform (TC). The maximum and minimum values of TC content were 46 N/100mL and 5N/100mL at Q-19 and Q-15 respectively. All the samples were exceeded the BDS recommended value (0 N/100mL) for total coliform. The variation of TC in various consumption points is shown in figure 9 (a).

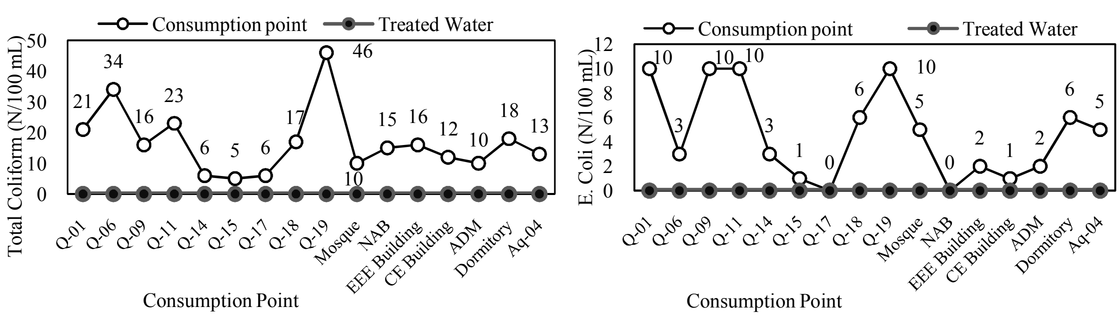

Figure 9:Comparison of (a) TC (b) EC among treated water, consumption points and BDS value

Faecal pollution of water may introduce a variety of intestinal pathogens as bacterial, viral or parasitic.Faecalcoliform bacteria are not pathogenic but they can be used as an indicator of recentfaecal contamination from either animal or human origin (Muller, 1977). In our observation, all of the water samples were highly contaminated with E. coli bacteria, also. The maximum value of EC content were 10 N/100mLat Q-

1, Q-09, Q-11, Q-19 and the minimum value of EC content were 0 N/100mL for quarter 17 and new academic building. Most of the samples were exceeded the BDS recommended value (0 N/100mL) for drinking water.

3.3 WASA pipeline and Supplied Water Quality

Khulna Water Supply and Sewerage Authority (KWASA) is supplying water to the Khulna city dwellers since March, 2008, through its distribution network from the groundwater source. Recently a new pipeline of 150mm diameter has been connectedwith the existing KWDN by a 100mm diameter pipeline (figure-10) to fulfill the rising water demand in KUET campus area.Thus, quality control of supplied water by WASA should be a great concern in the development of water supply system in this campus. Our query is to find out the suitability of supplied water of KWASA for the water distribution in KUET campus.

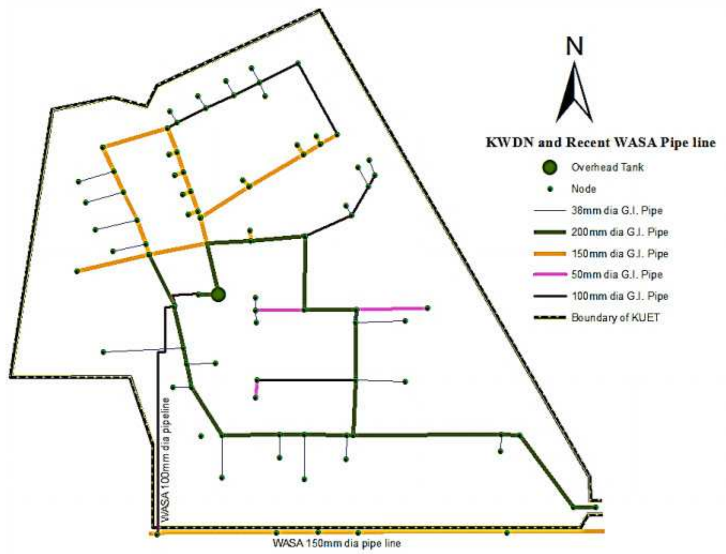

Figure 10: WASA pipeline alignment with existing WDN

A recent study on KWASA by Fahmida*et al.*, (2013), concluded that the quality of supplied water was not satisfactory. In case of microbial water quality parametersi.e. TC and EC, about 66.67% and 100% of total sample were found to be exceeded the permissible BDS of drinking water, respectively.Furthermore, most of sample exceeded the BDS recommended value for color content. Except very few cases, other water quality parameters of almost all samples satisfy the allowable limits recommended by WHO and BDS guidelines. Therefore, a pre-treatment is needed for the removal of color and bacterial contamination before the distribution of supplied water by KWASA to the residents of KUET campus. The summary of supplied water quality is listed in the table 4.

Table 4: Comparison of water quality with its standard values (Fahmida*et al.,* 2013)

Parameters	Units	Max	Min	Water Quality Standard		% of samples exceeding water quality	
				BDS(1997)	WHO(2006)	BDS(1997)	WHO(2006)
pH	-	7.78	6.76	6.5-8.5	6.5-8.5	0	0
Color	Pt.Co	166	25	15	15	100	100
Turbidity	NTU	9.09	0.46	10	5	0	13.33
Chloride	mg/L	550	72	150-600	250	0	13.33
Iron	mg/L	0.31	0.01	0.3-1	0.3	0	6.57
TDS	mg/L	1870	220	1000	1000	6.67	6.67
TC	N/100mL	335	10	0	0	100	100
EC	N/100mL	120	0	0	0	66.67	66.67

3.4 Categorization of Distribution Network

3.4.1 Analysis based on Water Quality Index (WQI)

Based on the tested water quality, the Canadian Water Quality Index (CWQI) has been computed for each sample as describe in section 2.6.1. The supplied water quality to mosque and quarter Q-15 were categorized as marginal and that at other consumption points were found to be polluted as described in table 5.The Average

WQI value was computed as 32.02. The value ranges at 0-44 and so, the water quality can be classified as 'Poor' having an explanation of the distribution network is that 'the Conditions usually depart from natural or desirable levels'.

Table 5: Determination of Water Quality Index (WQI)

Consumption Point	TP*	FP*	F_1	TT*	FT*	F_2	NSE	F_3	WQI	Designation
Q-01	9	4	44.44	4	2	50	7.82	88.66	35.88	Poor
Q-06	9	4	44.44	4	4	100	9.53	90.50	18.01	Poor
Q-09	9	4	44.44	4	2	50	6.85	87.26	36.52	Poor
Q-11	9	4	44.44	4	4	100	13.78	93.23	17.00	Poor
Q-14	9	5	55.56	4	3	75	1.90	65.50	34.17	Poor
Q-15	9	4	44.44	4	2	50	1.83	64.64	46.29	Marginal
Q-17	9	3	33.33	4	4	100	1.79	64.16	28.75	Poor
Q-18	9	4	44.44	4	3	75	9.81	90.75	27.35	Poor
Q-19	9	3	33.33	4	3	75	18.06	94.75	27.62	Poor
Mosque	9	3	33.33	4	1	25	1.40	58.31	58.62	Marginal
NAB	9	3	33.33	4	4	100	10.40	91.23	19.51	Poor
EEE Building	9	4	44.44	4	4	100	4.80	82.76	20.78	Poor
CE Building	9	5	55.56	4	2	50	3.34	76.93	38.07	Poor
ADM	9	5	55.56	4	2	50	2.97	74.83	38.93	Poor
Dormitory	9	3	33.33	4	2	50	9.87	90.80	37.14	Poor
Aq-04	9	4	44.44	4	3	75	9.04	90.04	27.64	Poor

**FP= No of Failed Parameters, TP= No of Total Parameters, FT= No of Failed Test, TT= No of Total test.*

3.4.2 Analysis based on Water Pollution Index (WPI)

The analysis based on Water Pollution Index (WPI) has been performed for each sample according to the analysis described in section 2.6.2.The overall scenario of supplied water was not satisfactory. The quality of water at quarter Q-01, Q-06, Q-18, Aq-04, New Academic Building (NAB) and Dormitory were found to be impure and that for quarter Q-19 and Q-11 were found as heavily impure. Also the quality of water for quarter Q-09, Mosque, EEE building, CE building and Administrative building were found to be polluted and that for quarter Q-14, Q-15, Q-17 were found as moderately polluted. The maximum and minimum values of WPI were found to be 6.99 and 1.78 in quarter Q-11 and Q-17, respectively. The average value of water pollution Index (WPI)was 3.84 that is within the range of 2.0-4.0. Therefore, the water quality has been classified in 'Class IV' according to table 2 with a designation of polluted category water is. The water quality at various pointacross the water distribution network is listed in the table below.

Table 6: Determination of Water Pollution Index (WPI)

Consumption Point	n	$\sum_{i=1}^{n} \frac{Ci}{SFQS}$	WPI	Designation	Average WPI
Q-01		39.04	4.34	Impure	
Q-06		46.47	5.16	Impure	
Q-09		34.97	3.89	Polluted	
Q-11		62.92	6.99	Heavily Impure	
Q-14		17.58	1.95	Moderately Polluted	
Q-15		15.14	1.68	Moderately Polluted	
Q-17		16.03	1.78	Moderately Polluted	
Q-18	9	46.94	5.22	Impure	3.84
Q-19		62.03	6.89	Heavily Impure	
Mosque		19.74	2.19	Polluted	
NAB		37.77	4.20	Impure	
EEE Building		26.94	2.99	Polluted	
CE Building		24.45	2.72	Polluted	
ADM		22.15	2.46	Polluted	
Dormitory		36.99	4.11	Impure	
Aq-04		43.14	4.79	Impure	

The water distribution network has been divided into14 different routes based on the sampling location. The pollution level in different routes is illustrated with ArcGIS in the figure 10. The figure shows that the quality of water in route-8 and route-10 was found to be as heavily impure. Whereas, that in route-1 and route-11 were found to be as moderately polluted. Furthermore, route-02, route-06, route-07, route-09, route-12 and route-14 were designated as impure category. Also, route-03, route-04, route-05 and route-13 were marked as polluted.

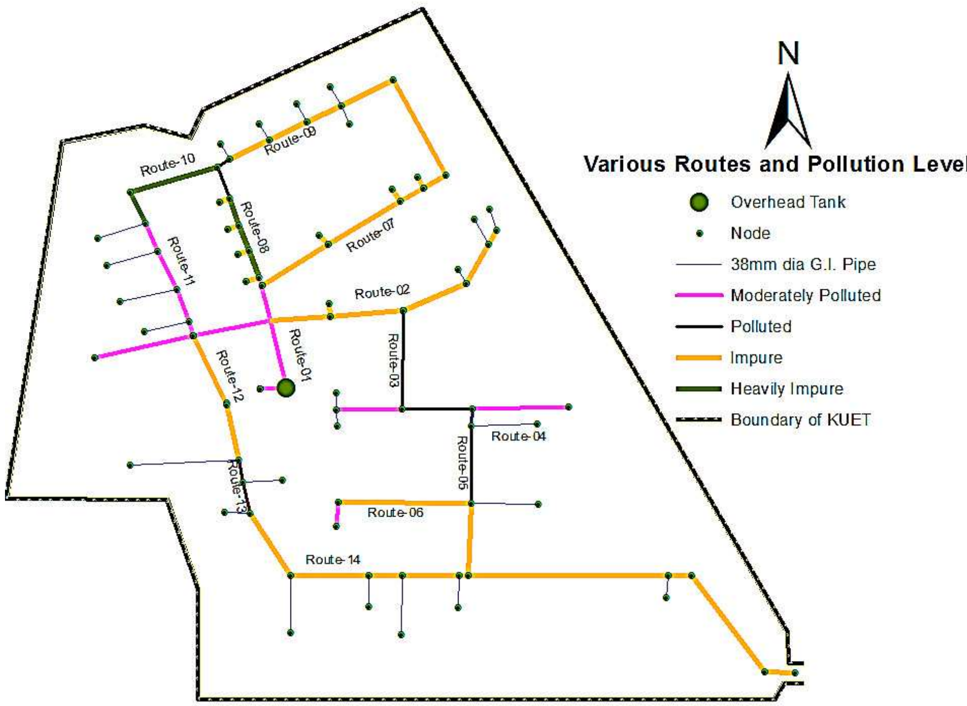

Figure 11:Various route with pollution level based on WPI

3.4.3 Analysis based on Water Contamination Index (WCI)

The analysis based on Water Contamination Index (WCI) has been performed for each sample according to the analysis described in section 2.6.3. The average value of Water Contamination Index (WPI)was found to be 25.52.As the average value is greater than 3, the water quality is classified as 'Class III' and it interprets that the water is highly contaminated according to table 3. The details computation is listed in table 7.

Table 7: Determination of Water Contamination Index (WCI)

Consumption Point	C_{f1}	C_{f2}	C_{f3}	C_{f4}	C_{f5}	C_{f6}	C_{f7}	C_{f8}	$\sum_1^n C_{fi}$	Average WCI
Q-01	-1.00	1.14	-0.20	1.00	-0.02	0.12	20.00	9.00	30.04	25.52
Q-06	0.93	-0.30	-0.30	2.00	-0.05	0.19	33.00	2.00	37.47	
Q-09	-1.00	1.24	-0.40	2.00	-0.02	0.15	15.00	9.00	25.97	
Q-11	-1.00	22.90	-0.18	1.00	0.00	0.20	22.00	9.00	53.92	
Q-14	-0.60	0.20	-0.31	2.00	0.03	0.26	5.00	2.00	8.58	
Q-15	-0.95	-0.10	-0.13	3.00	0.04	0.27	4.00	0.00	6.14	
Q-17	-1.00	-0.40	-0.94	5.00	0.04	0.33	5.00	-1.00	7.03	
Q-18	-0.40	18.00	-0.88	0.00	0.03	0.19	16.00	5.00	37.94	
Q-19	-0.53	-0.18	-0.44	0.00	0.04	0.15	45.00	9.00	53.03	
Mosque	-1.00	-0.71	-0.75	0.00	0.02	0.18	9.00	4.00	10.74	
NAB	-1.00	16.90	-0.44	0.00	0.05	0.26	14.00	-1.00	28.77	
EEE Building	-0.92	0.00	-0.34	3.00	0.03	0.17	15.00	1.00	17.94	
CE Building	-0.87	0.50	-0.36	5.00	0.02	0.16	11.00	0.00	15.45	
ADM	-0.93	1.60	-0.79	3.00	0.06	0.21	9.00	1.00	13.15	
Dormitory	-1.00	7.46	-0.61	0.00	0.00	0.14	17.00	5.00	27.99	
Aq-04	-0.92	19.90	-0.12	-1.00	0.07	0.21	12.00	4.00	34.14	

4. CONCLUSIONS

This study clarified thatthe distribution network efficiency was not up to the mark. The analyzedphysio-chemical parameters in the treated water range in various batches of treatment plant operations as: pH (7.16-7.41), turbidity (0.5-2 NTU), color (0 Pt.Co), iron (0.1-0.5), manganese (0 mg/L) chloride (510-630), and TDS (800-1100 mg/L). But the quality of water at the consumer's tap was not satisfactory. Therefore, the water in the consumption point was classified as 'Poor' for WQI value of 32.02 having an explanation of the distribution network is that 'the Conditions usually depart from natural or desirable levels'. Again the supplied water through the WDN was categorized as 'polluted' based on water pollution index (WPI) value of 3.84 and 'highly contaminated' based on water contamination index (WCI) value of 25.52. According to our observation, two pick hours i.e. during morning (from 8 AM to 9 AM) and during evening (from 6.30 PM to 7.30 PM) have been found in 24 hours of operation period. Based on the study following recommendation have been drawn:

a) Water-meters could be installed with a view to minimize the misuse or wastage of water by the beneficiaries.
b) Leakage detection, rehabilitation or renewals of the pipeline in special cases are suggested.
c) Regular washing of pipeline as well as proper monitoring is required for the development of present status of the water distribution system.
d) Regular water quality monitoring is also suggested for the distribution network.
e) Therefore, a pre-treatment is needed for the removal of color and bacterial contamination before the distribution of supplied water by KWASA to the residents of KUET campus.

REFERENCES

Backman, B., Bodis, D., Lahermo, P., Rapant, S. Tarvainen (1997). Application of a groundwater contamination index in Finland and Slovakia. Environmental Geology, 36: 55-64.

Fahmida,K.,Lemon,M.H.R.,Islam,M.S., Kader,M.A. (2013).Assessment of Supplied Water Quality of Khulna WASA of Bangladesh, International Conference on Mechanical, Industrial and Materials Engineering 2013 (ICMIME2013), RUET, Rajshahi, Bangladesh.Paper ID: RT-17 Page-852

Hossain, M. S. and Hassan, K. M. (2015), Present Status and Imminent Scheme for Water Treatment Plant at KUET campus in Bangladesh, International Conference on Recent Innovation in Civil Engineering for Sustainable development, IICSD 2015, DUET, Dhaka, ID-EE 032.

Ibrahim, A.Q.,Onyenekwe, P.C,Nwaedozie, I.M, (2014).An Efficiency Assessment of Lower Usuma Water Treatment Plant in Abuja Metropolis, Nigeria. IOSR-JESTFT, e-ISSN: 2319-2402, p- ISSN: 2319-2399.Volume 8, Issue 12 Ver. II, PP 46-53

Lyulko, I., Ambalova, T. and T. Vasiljeva(2001).To Integrated Water Quality Assessment in Latvia.MTM (MonitoringTailor-Made) III, Proceedings of International Workshop onInformation for Sustainable Water Management.Netherlands, 449-452.

Muller G. (1977). Bacterial indicators and standards for water quality in the Federal Republic of Germany. Bacterial indicators/hazards associated with water Philadelphia: ASTM, 159-167.

Nikolaidis, C., Mandalos P. and VantarakisA.(2008).Impact of intensive agricultural practices on drinking water quality in the EVROS Region (NE GREECE) by GIS analysis.Environmental Monitoring and Assessment.143, 1-3, 43-50.

Sadhale, N. (2006): "Water harvesting and conservation in ancient agricultural texts". Asian Agricultural History, vol. 10, pp. 105-120.

UNEP (United Nations Environment Program) (1999). Vital Water Graphics, An Overview of the State of the World's Fresh and Marine Waters, United Nations Environment Program.

Vreeburg, J. (2007).Discoloration in Drinking Water Systems: A Particular Approach, PhD thesis, Technical

World Health Organization (WHO) (1996). "Guidelines for Drinking Water Quality", 2nd Edition.Vol.2- Health Criteria and Other Supporting Information. Geneva, Switzerland.

World Health Organization (WHO) (2011)."Guidelines for Drinking Water Quality", World Health Organization, Geneva, Switzerland.