VOL. 4, NO. 3, MAY 2009 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ASSESSMENT OF SUPPLY WATER QUALITY IN THE CHITTAGONG CITY OF BANGLADESH

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ABSTRACT

Chittagong Water Supply and Sewerage Authority (CWASA) of Bangladesh is supplying water to the Chittagong city dwellers through its distribution network after proper treatment of water drawn from the Halda River and groundwater source. But the quality of water is at risk to deteriorate during its flow through the distribution system as regular monitoring of the distribution network is not usually done. In order to identify such water contamination problems, water samples from different locations of the four routes of the distribution network of CWASA were analyzed in this study. The study revealed that most of the important water quality parameters except BOD_5 were in the permissible limit. More than 95% of the collected water samples had BOD_5 greater than 0.20ppm with maximum of those found 5.2ppm at a house connection near Polytechnic College. Microbial water quality parameters examined at some selected locations showed the presence of pathogenic organisms in water exceeding the permissible limit. Few sources of contamination along the CWASA's distribution network have been identified. In order to avoid water contamination problems, awareness raising and regular monitoring of water distribution network have been suggested in this study.

Keywords: water quality, distribution system, assessment, Chittagong.

INTRODUCTION

Water is one of the vital components of the physical environment. The quality of drinking water is closely associated with human health, and providing safe drinking water is one of important public health priorities. Estimated 80 per cent 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). The quality of drinking water in Bangladesh is also at high risk. Problems are acute, especially in the urban areas due to increased migration of rural people and increased economic growth as well. Chittagong, the commercial capital of Bangladesh, is one of the densely populated urban areas which has been suffering from inadequate supply of drinking water often associated with water quality problems too.

A drinking water system's water quality may be acceptable when the water just leaves a treatment plant. However, a variety of physical, chemical and biological transformations can happen once the water travels through a distribution system (Lahlou, 2002). Deteriorating water treatment facilities and distribution systems can pose a significant public health threat, as illustrated by a study in Uzbekistan (Semenza *et. al.*, 1998). The authors concluded with the epidemiological data that diarrhoeal diseases could be attributed to cross-connection between the municipal water supply and sewer due to leaky joints. In the United States of America, 11-18% (1920-1990) and 22% (1991-1996) of reported outbreaks of waterborne disease were attributable to contamination of the distribution system and storage facilities respectively (Craun and Calderon, 1999; Craun, 1986) whereas in the United Kingdom 36% (1911-1995) reported waterborne disease outbreaks in public water supplies were related to the distribution system (Hunter, 1997).

Observed the significance of monitoring supply water quality, a similar study on drinking water quality in the distribution network was done in Khulna city corporation area of Bangladesh. In the Khulna study, the authors revealed that the supply water at some locations did not meet the potable water quality standard (Nasrin *et. al*, 2005). No further study was conducted in other urban areas of Bangladesh. Since contaminated water can pose a potential source of health risk to Chittagong city dwellers, the present investigation was undertaken with an objective to assess important water quality parameters of the CWASA's supply water. The study was undertaken as part of the under-graduate program of the Department of Civil Engineering of Chittagong University of Engineering and Technology (CUET).

DRINKING WATER SUPPLY FOR CHITTAGONG CITY DWELLERS

Chittagong is inhibited by about 4.02 million people (projected from 2004 census by Amin, 2006). The city attracts many tourists and business entrepreneurs because of its spectacular natural beauty and resources. Thus it is imperative that the city should maintain healthy and friendly environment. But the scarcity of adequate and safe drinking water has posed a serious threat to city dwellers in recent days. CWASA is supplying water to the city dwellers by its limited distribution network system and is able to meet only one-fourth of the total demand for water of the port city (Amin, 2006). The water supply is not also regular but intermittent. Although some private and community tube wells are found in the city, a large fraction of the people directly depend on CWASA's supply water. The main sources of CWASA's supply water are surface water from Halda River and ground water from deep tube wells at different locations of the city. Surface water extracted from the above source is being supplied to the distribution network after treatment at Mohra Treatment Plant whereas groundwater is being treated at Kalurghat Treatment Plant.

SAMPLING LOCATION AND SAMPLE COLLECTION

Meaningful and reliable sampling assures the validity of analytical findings. Therefore, utmost care was exercised to ensure that the analyses were representative of the actual composition of the water samples. The samples from different locations were collected in sterilized bottles and prior to filling the sample bottles were rinsed two to three times with the water to be collected. Collected samples were promptly carried to the Environmental Engineering laboratory of the Department of Civil Engineering of CUET and almost all the important water quality parameters were measured within four hours of collection. Chittagong Water Supply and Sewerage Authority (CWASA) have divided its water supply network into four routes. An assessment of the water quality in all the four routes has been made in this study. Sampling points with number of collected samples is summarized in Table-1. Water samples collected from Chittagong city were tested for physical, chemical and bacteriological parameters in order to determine the water quality and the degree of contamination.

Table-1. Sample collection from different routes of CWASA in Chittagong city

Water supply and distribution route	Number of samples taken for tests
Route 1 Mohra- Batali Hill	30 samples
Route 2 Hathazari road	4 samples
Route 3 Nasirabad road	4 samples
Route 4 WASA-Patenga	14 samples

Sample numbers and sampling locations were selected based on the density of population, the frequency of water supply in an area etc. During the year 2006-2007, a total of 56 samples were collected from different locations of each route as shown in Figure-1. Maximum water samples were collected from different points along the Route 1 (Mohra-Batali Hill) as it is the largest route and most densely populated among the 4 distribution zones. Some water samples were also collected from Halda river intake point, at the outlet of Mohra treatment plant and Kalurghat iron removal plant in order to assess the efficiency of those treatment plants and to measure water quality just before entering to the transmission line.

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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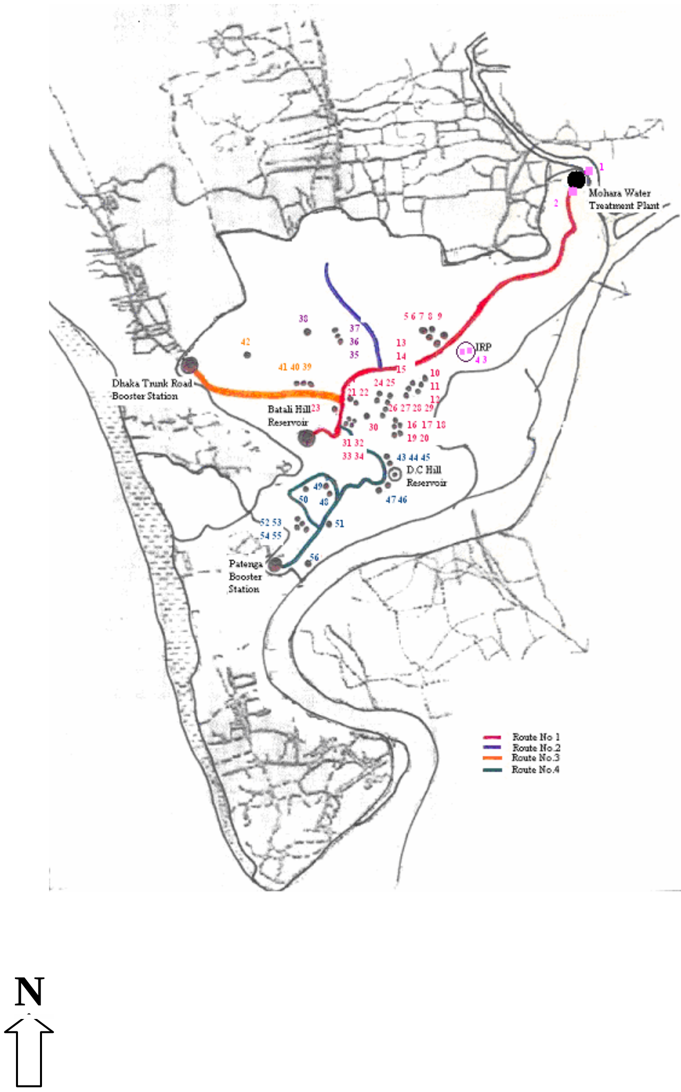

1.Intake of MSWTP
2. Outlet of MSWTP
3. Intake of KIRP
4. Outlet of KIRP
5. Wapda Pump Station
6. Wapda Colony House-1
7. Wapda colony House-2
8. Wapda Colony-Tap 1
9. Wapda Colony-Tap 2
10. Kapasgola-Tap
11. Kapasgola-House 1
12. Kapasgola-House 2
13. Munsipukur Par-Tap
14. Munsipukur Par-House 1
15. Munsipukur Par-House 2
16. Medical Staff Quarter-Reservoir
17. Medical Staff Quarter-House 1
18. Medical Staff Quarter-House 2
19. Medical Staff Quarter-House 3
20. Chittagong Medical
21. G.E.C (Hotel)
22. Central Plaza
23. Garibullah Shah Majar Road
24. Mehedibag-Tap
25. Mehedibag-House
26. Panaroma Hospital
27. Divisional Comissioner Office
28. Chattassari Road-House 1
29. Chattassari Road-House 2
30. Paltan Road
31. Dampara-Pump House
32. Dampara-Tap
33. Dampara-House 1
34. Dampara-House 2
35. Polytechnic college reservoir
36. Polytechnic college (H-1)
37. Polytechnic college(H-2)
38. Shershah colony
39. Nasirabad (H-1)
40. Nasirabad (H-2)
41. Nasirabad (H-3)
42. Jalalabad
43. Love lane house
44. Love lane Mosque
45. D.C. Hill
46. Rifles Club
47. Aparnacharan School
48. PTI School
49. Collegiate School
50. Madarbari
51. Pathantuli
52. Bank colony (R-1)
53. Bank colony (H-1)
54. Bank colony (R-2)
55. Bank colony (H-2)
56. Agrabad

Figure-1. Sampling locations in CWASA base map of water distribution network (Map source: CWASA base map for water supply after Karim, 2006).

RESULTS AND DISCUSSIONS

The measured value of different physical and chemical water quality parameters of the collected water samples is summarized in Table-2. Findings of the study have been assessed according to WHO drinking water quality guidelines and Bangladesh standards as well.

Water quality parameters of CWASA supplied water

pH

pH values of the water samples were determined by a digital pH meter. pH values of all the water samples of different routes of CWASA were in the permissible range of 6.5-8.5 according to World Health Organization (WHO) guideline values and standard values prescribed in Bangladesh Environment Conservation Rules' 1997 (BECR'97). Among the four routes, the maximum pH value 8.2 was found in a water sample collected from a house connection at Munshipukur Par in Route-1 whereas the minimum pH, 6.6 was measured in water samples collected from Wapda Pump Station in Route-1.

Table-2. Summary of measured water quality parameters in CWASA's supply.

Parameter		pH	Turbidity	TDS	TSS	Hardness	Alkalinity	Chloride	BOD_5
Route-1	Max^m	8.2	28.2	1255	4.6	384	239	1300	3.6
	Min^m	6.6	0.09	126	0.2	20	70	43	0.2
	Mean	7.24	11.40	710.87	2.15	114.30	121.93	364.77	1.81
	Std. dev^n	0.60	15.88	377.24	1.91	95.16	36.31	320.35	1.04
Route-2	Max^m	7.47	6.61	237	3	316	116	82	5.2
	Min^m	7.35	0.97	89	0.3	58	49	10	1.4
	Mean	7.43	3.68	189.75	1.58	177.50	65.75	59.75	3.40
	Std. dev^n	0.05	2.39	68.13	1.18	112.36	33.51	33.53	1.57
Route-3	Max^m	7.1	15.08	1223	4.1	340	159	1050	2.2
	Min^m	7	0.6	547	1.7	191	58	17	0.2
	Mean	7.08	8.64	958.15	2.80	226.75	85.25	729.25	1.05
	Std. dev^n	0.05	6.65	289.16	1.02	75.58	49.26	478.91	0.87
Route-4	Max^m	7.35	56.2	403	6	248	234	145	2.2
	Min^m	6.87	0.04	30	0.1	34	51	8	0.1
	Mean	7.10	6.50	240.29	1.30	104.00	123.79	51.64	0.76
	Std. dev^n	0.18	14.52	111.62	1.44	48.48	65.73	46.22	0.48

Turbidity

The maximum turbidity was found in a water sample collected from Route-4 and the value was 56 NTU. The minimum turbidity, 0.04NTU was also found in a water sample collected from Route-4. Maximum and minimum turbidity values were 28.2 NTU and 0.09 NTU respectively in Route-1, 6.61 NTU and 0.97 NTU in Route-2, 15.08 NTU and 0.6 NTU in Route-3 and 56.2 NTU and 0.04 NTU in Route-3.

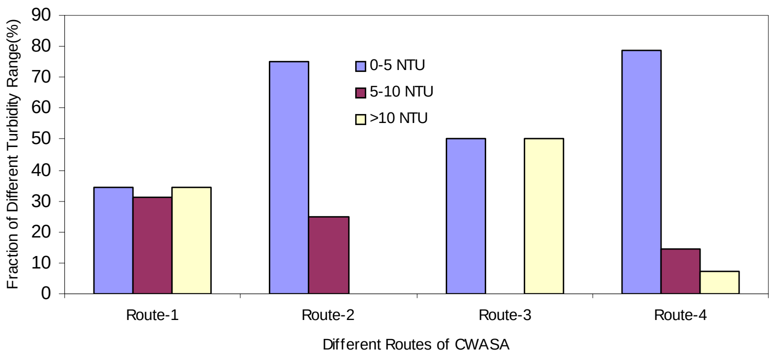

Figure-2. Turbidity in water samples in different CWASA water distribution routes.

Turbidity test results of most water samples were within the permissible value of 10 NTU according to BECR'97 but many exceeded the permissible value of 5 NTU according to WHO Guideline value. Among the samples of Route-1, 34% samples did not exceed the permissible value of 5 NTU and 31% samples were in the range of 5-10NTU where as 34% samples exceeded the permissible value of 10NTU. In case of Route-2, 75% samples were below 5 NTU and the remaining 25% exceeded 5 NTU but remained within the range of 10NTU. In case of Route-3, 50% samples had turbidity less than 5 NTU and the remaining 50% exceeded the value 10 NTU. In case of Route-4, around 79% samples had the turbidity value of less than or equal to 5 NTU and only 7% samples exceeded the BECR'97 permissible value, 10 NTU. However, relative higher standard deviation of turbidity values in all the four routes indicates high degree of scatter about the mean value which is perhaps indicating the random events of increasing turbidity problems from other sources.

Total dissolved solids

Total dissolved solid (TDS) in water samples was determined by test procedures described in Standard Methods (APHA 1998). The maximum concentrations of TDS were 1255ppm, 237ppm, 1223ppm and 403ppm in Route-1, Route-2, Route-3 and Route-4 respectively. Respective minimum values were 126ppm, 89ppm, 547ppm and 30ppm. TDS of the treated water samples were well below the permissible value. TDS level exceeding the limit value in around 20% water samples from Route-1 could be due to cross-contamination within the distribution system.

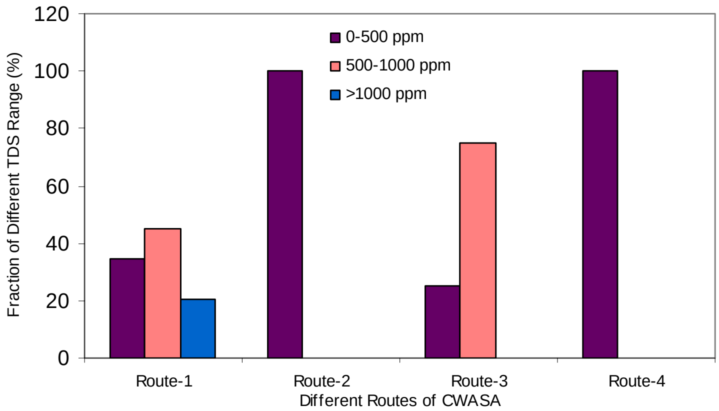

Figure-3. TDS in water samples in different CWASA distribution routes.

Chloride

Chloride concentration of water samples were determined by titration method. Maximum chloride concentration values in collected water samples were 1300ppm, 1050ppm, 145ppm and 82ppm in Route-1, Route-2, Route-3 and Route-4 respectively. Distribution of chloride concentration in water samples collected from different CWASA distribution routes is shown in Figure-4. High chloride concentration values may be due to saline water intrusion problem which is quite frequent in the CWASA's sources of supply now-a-days. Collected groundwater samples also showed high chloride concentration indicating saline water intrusion problem. Most chloride in ground water comes from evaporation, salty connate water and seawater (Nasrin *et. a*l., 2005). Ground water containing significant amount of chloride also tend to have high amount of Na ions indicating the possibility of contacts with water of marine origin (Hem, 1970). At concentration above 250ppm chloride rich water gives a salty test, causes various diseases such as high blood pressure etc. but it depends on individual adaptability (Sawyer and McCarty, 1978).

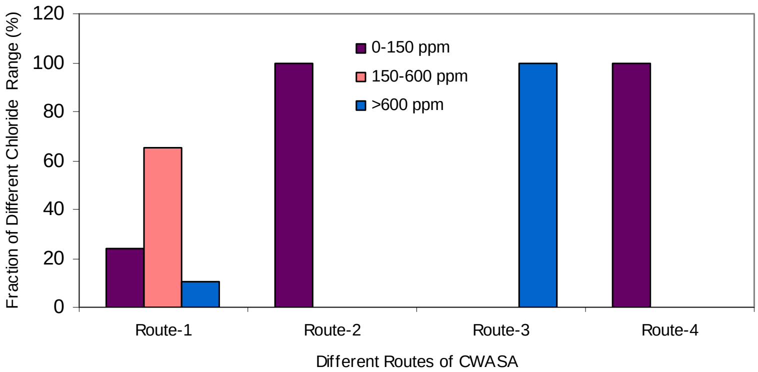

Figure-4. Chloride in water samples in different CWASA distribution routes.

Alkalinity

Alkalinity in water samples was determined by the acid titration method. 97%, 100%, 100% and 79% water samples collected from Route-1, Route-2, Route-3 and Route-4 respectively had the alkalinity concentration within the range of 0-200ppm which is quite satisfactory in accordance with WHO and BECR'97 water quality guideline values. Very few samples had alkalinity in the higher range of 200-400ppm. Nevertheless, all the samples had the concentration within the permissible range 400ppm (Sohel et. al., 2003).

Total Hardness

Total hardness in water samples was determined by titration method. The maximum hardness values were 384ppm, 316ppm, 340ppm and 284ppm in Route-1, Route-2, Route-3 and Route-4 respectively whereas the minimum values at those routes were 20ppm, 58ppm, 191ppm and 34ppm respectively. Total hardness in all water samples were within the permissible limit value.

BOD_5

All the collected water samples from different routes of CWASA distribution had BOD_5 concentration greater than the permissible value of 0.20ppm (according to BECR'97). Around 55% samples of Route-1 showed BOD_5 concentration greater than 1ppm. The maximum BOD_5 concentration was found 3.6ppm and the minimum was 0.20ppm in case of Route-1 while in Route-2, the respective maximum BOD_5 concentration was 5.2ppm. Water samples collected from the outlet of treatment plant had no BOD_5. Therefore, high BOD_5 concentration in the distribution system might be due to cross-contamination through leaking pipes, unauthorized connection, improper domestic storage facilities etc. Distribution of BOD_5 concentration in water samples collected from different routes of CWASA is shown in Figure-5.

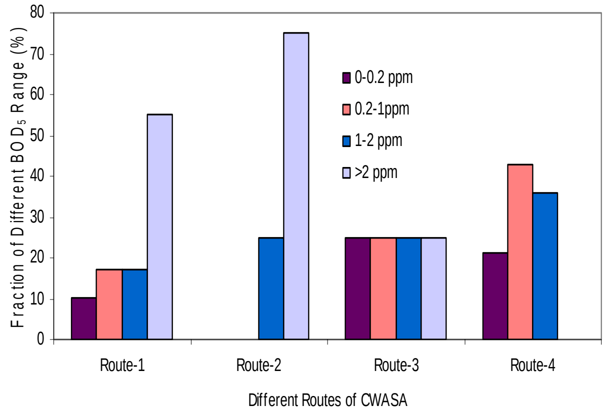

Figure-5. BOD_5 concentration in water samples collected from different routes of CWASA.

Coliform colonies

Among the 56 samples, only 14 selected samples were analyzed for presence of coliform. Test results are given in the following Table-3.

Table-3. Coliform counts in water samples of CWASA distribution routes.

Sample location	1	2	4	5	11	20	22	25	33	37	42	47	50	52
Total Coliform (No/100m)	2800	0	4	0	Un-countable	3	1	0	1	60	8	4	Un-countable	1
Faecal Coliform (No/100m)	200	0	0	0	3	0	0	0	0	0	3	0	1	0

Uncountable total coliforms were found in water samples collected from two houses at Madarbari and Kapasgola. Faecal coliform counts of those samples were 3/100mL and 1/100mL respectively. Therefore, water supply in those areas may not be safe considering the microbiological water quality standard. The water leaving the Mohra treatment plant and Kalurghat Iron removal plant contained neither total coliform nor faecal coliform which indicates that microbial contamination in the distribution system might happen due to cross contamination by leaking pipes, unauthorized connections, improper domestic storage etc. Therefore, it can be said that the supply water of those areas are at risk for domestic uses such as defined by DFID 1998 (Rahman and Mahabub-Un-Nabi, 2002). Immediate measures should be taken to improve the water quality in the distribution system which should include awareness raising among the consumers, proper monitoring, institutional surveillance (Samsuddin, 2002).

OVERALL ASSESSMENT OF THE CWASA SUPPLIED WATER

Test results of water samples collected from the outlet of treatment plants revealed that the water entering the distribution system was of desired chemical and microbial quality. However, good quality drinking water can suffer serious contamination in distribution system because of breaches in the integrity of the pipe work and storage reservoirs. Although the researchers are currently unsure about the exact effect of biofilm produced within a distribution system (Lahlou, 2002), such organisms have been shown to persist within biofilms, thereby presenting a potential underlying health concern to consumers (Szewzyk *et al*., 2000).

Though the concentration of chemical water quality parameters in the distribution routes were higher than the level recorded at the outlet of treatment plants, they were still within the permissible range. During the time of sampling, chloride concentration in water samples was unexpectedly high. The problem was a temporary one due to saline water intrusion problem and the salinity dropped to tolerable limit within a few days. It was found in the study that almost all the water quality parameters were varying along the distribution system. Though only a few samples were analyzed for biological quality, microbial water quality parameters in the CWASA distribution lines were found of utmost concern for the city dwellers. BOD_5 concentration of all the collected water samples from the distribution lines was greater than 0.20ppm. Therefore, it can be concluded from random tests of biological water quality that the people of Chittagong city are at high risk due to microbial contamination of drinking water. Possible sources of microbial contamination of CWASA supply as identified during field study are cross contamination by leaking pipes, unauthorized connection to the main at road sides, lack of maintenance of domestic storage and distribution system etc.

PROBLEMS OF CWASA WATER SUPPLY

CWASA supply of drinking water seems to be quite good at least in terms of chemical water quality parameters. Low levels of microbial indicators in water just leaving the treatment plant also indicate about the treatment or disinfection efficiency in removing or inactivating most pathogens. However, water quality deteriorated as it traveled through the distribution system which clearly indicates that the water distribution system somehow provided a habitat for microorganisms, which were sustained by organic and inorganic nutrients present on the pipe and in the conveyed water. Some of the reasons that were identified for deteriorating water quality in the distribution network are cross-connections, leaking pipes, lack of covering or venting of storage tanks, inadequate separation of supply lines from sewers and roadside ditches, lack of enforcement of applicable building plumbing codes etc.

RECOMMENDATION FOR IMPROVED WATER QUALITY IN CWASA'S DISTRIBUTION SYSTEM

One of the major tasks to ensure improved microbial water quality in the CWASA distribution system is to prevent contamination from faecal material that might build up near pipes or contaminate surface or soil water. Current practice in many countries is to use disinfectant residuals to control the growth of microorganisms in distribution systems and to act as a final barrier, to help maintain the microbial safety of the water. Realistic residual concentrations at least inactivate the least resistant microorganisms such as E. coli and the thermo tolerant coli forms that are used as the main indicators of water safety (Payment, 1999). However, absence of coli forms may create a false sense of security because many viral and parasitic pathogens are resistant to a low level of disinfectant. Therefore, the maintenance of a disinfectant residual or an increase in disinfectant dose should never be regarded as a substitute for the rigorous application of the operational and maintenance practices. In fact, proper system efficiency in order to maintain microbial water quality should be based on all the following:

Microbial monitoring could be achieved by a programme of frequent monitoring at every storage reservoir and service connection throughout the system. However, such a strategy would be prohibitively expensive and could only verify that the water was safe after it was supplied. One way to monitor effectively is to perform 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.

Contamination via cross-connection, leaky pipe joints, or pipe breaks may influence water quality. Pathogens may enter the system through contaminated raw water, in-line reservoirs, or breaks in pipelines. System personnel need to thoroughly perform disinfection procedures following repairs.

From an operations standpoint, network operating conditions - such as slow water velocities, supply sources going on and off-line, and the amount of time that systems store water - greatly affect water quality. System personnel should take measures to prevent such problems.

CONCLUSIONS

Chittagong city dwellers are not only suffering from inadequate water supply but also are they posed to serious threat due to the scarcity of safe water. Water quality test results of random samples collected from four routes of CWASA's distribution system revealed that the microbial water quality deteriorated during its flow from treatment plant through the distribution system. Though the measured value of pH, turbidity, alkalinity, hardness was mostly within the permissible range, BOD_5 value of almost all the selected samples was significantly higher. Faecal coliform as well as total coliform was also found at some locations of the distribution system. Therefore, it can be concluded from the findings of the study that the CWASA should not solely rely upon its treatment plant's efficiency. CWASA's piped water supply systems are generally buried complex reticulations and they are difficult to operate and maintain. Nevertheless, they are as important as water resource and treatment facilities in ensuring the supply of safe dinking-water. 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. 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.

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