International Conference "Water, Environment, Energy and Society" (WEES–2009)
New Delhi, 12–16 January 2009

Assessment of Drinking Water Quality in Delhi City

R.K. Gupta[1], M.K. Chaturvedi and J.K. Bassin
National Environmental Engineering Research Institute, Delhi Zonal Laboratory
A-93/94, Naraina Industrial Area, Phase-I, New Delhi - 110 028, INDIA
E-mail: [1]rk_gupta@neeri.res.in

ABSTRACT: Assessment of water quality at treatment plant and consumer ends in Delhi city was undertaken during June to November 2006 to assess the quality as per BIS 10500:1991. Physicochemical and microbiological quality of treated water from five treatment plants was assessed fortnightly during the survey period. Water samples were also collected from private taps and public hydrants used by consumers from 900 identified locations from distribution network. Samples from distribution system were analyzed for total and feacal coliforms, along with free residual chlorine. It is observed from assessment of treated water quality at treatment plants that essential characteristics such as pH, turbidity, total hardness and chloride are well within the desired limits as per BIS norms. Free residual chlorine ranged between 1.5 to >2.0 mg/L and no sample was found to contain total or feacal coliform. It is observed form analysis of water sample at consumer ends that free residual chlorine was less than 0.2 mg/L in 13.4% samples. Coliform were detected in 10% of the samples and their count was found to exceed 10 in 3.9% samples. Faecal Coliforms were detected in 4.1% samples. It is observed that water gets contaminated in distribution network, even if treated adequately at treatment works to render it safe and acceptable. This could be attributed to intermittent mode of water supply, use of inline booster pump by consumers and leakages in service pipelines. It is desired that quality of water be safeguarded especially during distribution phase to protect the public heath.

INTRODUCTION

Water is one of the most essential commodities which man has exploited than any other resource for sustenance of his life. In most developing countries water supplies are intermittent due to the prevailing water scarcity that results from depletion of existing water sources. Intermittent systems are those in which there are no supplies for long periods of time. In addition to the inadequate supply of water, other major shortcomings of such systems are the inequitable distribution of supply and the risk of contamination resulting from insufficient pressures when the distribution system is empty. The importance of water supply with sufficient quantity and acceptable quality has been emphasized in the Millennium Development Goals (MDGs), drawn from the United Nations Millennium Declaration. Goal 7 of the MDGs says, 'Ensure Environmental Sustainability,' and one of the Targets of Goal 7 says: 'Reduce by half the proportion of people without sustainable access to safe drinking water by 2015' (http://www.un.org/millenniumgoals).

An adequate supply of the safe drinking water is one of the major prerequisites for a healthy life, which according to the World Health Organization (WHO), poses a continual challenge (WHO, 2004). Water borne diseases are still a major cause of death in many parts of the world, particularly of children in developing countries. Thus, while chemical quality is important, microbial quality assumes greater importance. This can be attributed to the fact that the manifestations of bacterial contamination are quicker (at times can cause an epidemic) as compared to those due to chemical contamination. And also the fact that the water is usually already consumed by the time the bactcrial contamination is even detected, because by far the consumers largely depend on only their visual sense & tasting. Contamination of drinking water is often only detected when people have fallen ill or even died because of it. Pathogens are often considered to be a higher health risk issue for municipal water supplies than chemicals, even if arsenic or fluoride content is high (Craun, 1993, Downs, *et al.*, 1999).

About 2855 MLD water is treated in six treatment plant complexes comprising of total fourteen plants. The treated water is then distributed through a complex network comprising of overhead service reservoirs and more than 9000 km long pipeline network spread over an area of 1483 sq. km. In addition, bore wells/tube wells water supply amounts to 322 MLD which is supplied directly after chlorination. The surface water is treated by conventional treatment process (coagulation, flocculation, rapid sand filtration and chlorination).

[1]Conference speaker

This paper presents the data on water quality from four treatment plants and consumer ends in distribution network with respect to physico-chemical and microbiological parameters, viz. faecal coliform and total coliform monitored over a period of six months during May 2006 to November 2006.

STUDY AREA, SAMPLING SCHEDULE AND PROTOCOL

Surveillance was undertaken to assess the microbial quality of drinking water at consumer ends in selected areas in Delhi city from May to November 2006. Locations of areas where consumer end sampling points were monitored during the study are indicated in Figure 1.

There are five different sources of raw water from which water is drawn for supply in Delhi city for treatment. Treated water from four Water Treatment Plants (WTP) was analyzed further for physico-chemical and bacteriological parameters. Location of these treatment plants is shown in Figure 1. Raw water source of Chandrawal and Wazirabad WTP were same, hence only Wazirabad plant was selected for assessment of physico-chemical water quality.

The water distribution network is divided in five Zones which are further sub-divided in Emergencies that manage and control the distribution of water throughout the city. There are twenty-four such Emergencies. The consumer end locations were selected from different areas/Emergencies so as to cover the most of the city area over the study period. List of these areas and relevant water treatment plants feeding these areas are given in Table 1. In case contamination was detected in any area, sampling was carried out again in same location additionally to confirm the presence of contamination. In all, more than 900 samples were analyzed from the consumer ends in the distribution network.

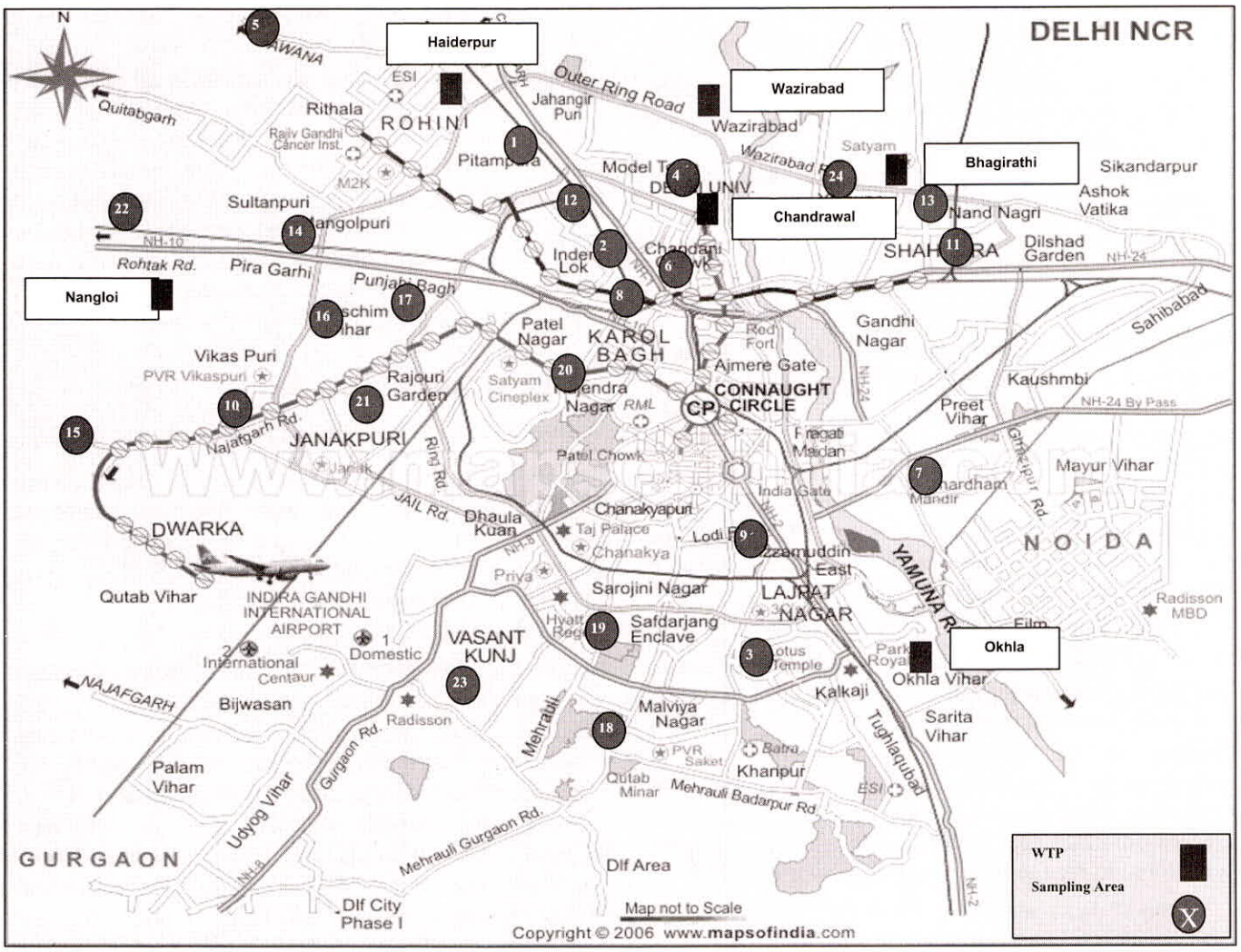

Fig. 1: Map indicating locations of water treatment plants and sampling areas in Delhi City

Table 1: Water Treatment Plants and Areas Selected in Distribution Network

Treatment Plant	*Source of Raw Water*	*Area Covered*
Wazirabad	Yamuna River	Ashok Vihar, Chandrawal , Idgah, Paharganj, Kasturbanagar, Kewal Park, R.K. Puram, Rajinder Nagar
Bhagirathi	Ganga Canal	Greater Kailash, Mandawali, Karkardooma, Giri Nagar, Yamuna Vihar, Kasturba Nagar, Loni Road
Nagloi	Western Yamuna Canal	Najafgarh, Paschim Vihar
Haiderpur	Western Yamuna Canal	Janakpuri D-Block, Mangol Puri, Paschim Vihar, Punjabi Bagh, Mehrauli, Vasant Kunj, R.K. Puram, Rajouri Garden, Holambi, Sarita Vihar
Chandrawal	Yamuna River	Chandrawal, Rajinder Nagar, Punjabi Bagh, R.K. Puram, Najafgarh

The treated water samples were collected from four treatment plants once in a fortnight and analyzed for physio-chemical parameters, viz. pH, turbidity, total dissolved solids, alkalinity, hardness, sulphate, chloride, residual chlorine and bacteriological parameters, viz. total and feacal coliforms.

METHODOLOGY

Based on the information on water supply operations, emergencies, zones, etc. available from Delhi Jal Board, the monitoring schedule was delineated. Different areas were selected in consideration of supply timings and availability of support staff from DJB. Monitoring was started in May 2006 and was continued up to November 2006. It was decided to collect samples from ten households and/or public stand posts in areas with different socio-economic status.

Samples were collected in sterilized glass bottles following the standard method for collection of water samples for bacteriological examination, preserved in ice boxes, and transported to the laboratory within a maximum of four hours of sampling. Analysis was carried out on same day in case of samples collected during morning times and on next day in case of samples collected in the evening times. The samples were stored in refrigerator overnight when necessary.

Samples were analyzed following the Standard Methods for the Examination of Water and Wastewater (APHA, 1998). Temperature of the sample was measured in the filed at the time of taking samples. Residual chlorine was also estimated in the field using ortho-tolidine method. Total coliform and faecal coliforms, were determined employing the membrane filter techniques. Millipore filtration assembly was used to filter the water samples. Membrane filter papers of 0.45 μm pore size with 47 mm diameter were used for filtration throughout the study. Total coliforms and faecal coliforms were determined in 100 mL water sample. For determination of total coliform, the water samples were filtered and filter papers were placed on sterilized Petri plates containing M Endo agar. The plates were incubated at 35 ± 0.5°C for 24 hours. For enumeration of faecal coliform, 100 mL water samples were filtered and filter papers were placed in sterilized Petri plates containing M-FC Media. The plates were incubated at 44.5 ± 0.2°C for 24 hours. Total coliform are indicated by pink to red colonies with metallic sheen, while faecal coliforms are shown by blue colored colonies. All the bacteriological culture media were obtained from Hi-Media Pvt. Ltd., Mumbai. Membrane filter papers and filtration apparatus were obtained from Millipore.

Analysis of samples for physico-chemical parameters were carried out as per Standard Methods. pH was measured using bench top digital pH meter. Turbidity was measured by Turbidimeter using nephelometric principle. Total Dissolved Solid (TDS) was measured by water evaporation in oven and subsequent gravimetric analysis. Total alkalinity, hardness and chloride were estimated using titrimetric methods. Sulphate was measured employing turbidimetric method.

RESULTS AND DISCUSSIONS

Water Quality at Treatment Plants

Results of physiochemical and bacteriological quality of treated water from four water treatment plants are presented in Table 2. These quality characteristics are compared with water quality standards BIS 10500:1991, for relevant parameters given in Table 3.

The Essential characteristics as per the standard such as turbidity, total hardness and chloride of treated water samples are found to range between 0.6 to 2.5 NTU, 60 to 240 mg/L and 10 to 120 mg/L respectively which are within the desirable limits prescribed by the standard. pH is also found to be within desirable range. The Desirable characteristics as per the standard such as Total Dissolved Solids (TDS), alkalinity and sulphate are observed to range between 105 to 450 mg/L, 38 to 160 mg/L and 15 to 90 mg/L respectively, which are also within the prescribed desirable limit prescribed by the standard.

Table 2: Characteristics of Treated Water from Water Treatment Plants

Sl. No.	*Parameters*	*Bhagirathi*	*Haiderpur*	*Wazirabad*	*Nangloi*
1.	pH	7.2–7.8	7.2–7.9	7.3–8.1	7.1–7.9
2.	Turbidity (NTU)	0.6–1.5	0.8–2.0	0.6–2.5	1.0–2.0
3.	Total hardness	60–126	68–142	66–240	70–135
4.	Chloride	10–32	14–36	16–120	16–47
5.	Free Res. chlorine	1.5–>2	1.5–>2	1.5–>2	1.5–>2
6.	TDS	105–191	128–200	161–450	123–200
7.	Sulphate	15–35	29–48.3	37.7–90	22.7–39
8.	Total alkalinity	38–86	52–88	62–160	44–100
9.	Total coliforms	Nil	Nil	Nil	Nil

All results are given in mg/L except pH & turbidity. Total coliforms expressed as CFU/100 ml.

Table 3: Drinking Water Specifications—BIS 10500:1991

Sl. No.	*Characteristics*	*BIS Limit*	
		Desirable	*Permissible*
1.	pH	6.5–8.5	6.5–8.5
2.	Turbidity (NTU)	5	10
3.	Total Hardness	300	600
4.	Chloride	250	1000
5.	Free Res. chlorine (min)	0.2	–
6.	Total Dissolve Solids	500	2000
7.	Sulphate	200	400
8.	Total Alkalinity	200	600
9.	Total Coliform (CFU/100 ml)	Nil	10

All results are given in mg/L except pH, Turbidity and Total Coliform.

The level of residual chlorine indicates the adequacy of protection against bacterial contamination in the distribution pipelines. Free residual chlorine was found to range between 1.5 to >2.0 mg/L in samples of final treated water. Usually this level is found to be adequate to maintain a level of more than 0.2 mg/L free residual chlorine in water at consumer ends.

None of the treated water sample from treatment plants indicated the presence of total or faecal coliforms during the study period.

Water Quality at Consumer Ends in Distribution Network

Drinking water samples collected at consumer ends from house connections and public stands posts from different areas are analyzed for free residual chlorine, total and feacal coliforms. Summary of results of analysis of 900 samples collected from 24 areas are presented in Table 4 while area-wise details are presented in Table 5. It is observed that free residual chlorine was <0.2 mg/L in 13.4% of the collected samples, while 86.6% of the samples contained minimum residual chlorine concentration of 0.2 mg/L, which is desirable limit as per BIS standard.

Total coliforms and feacal coliforms were detected respectively in 10% and 4.1% water samples collected for examination. It was also observed that 4.8% of samples showed more than 10 total coliform/100 mL which is the limit prescribed by the standard.

It is observed that high coliform counts are detected in samples having absence of residual chlorine. However, in some of the samples from areas such as Idgah, Holambi and Todapur Village (under R.K. Puram area) showed presence of coliform although the free residual chlorine level ranged between 0.15 to 1.0 mg/L. This can possibly be attributed to some recent contamination in pipeline in the near vicinity of consumer end which would provide inadequate contact time for disinfection by available free chlorine before reaching the consumer end tap.

It is also observed that the some of the samples collected from areas such as Najafgarh, Punjabi Bagh

and Todapur village under R.K. Puram Emergency have shown substantially high pollution, as indicated by high coliform count, owing to long distances travelled by the water from treatment plant.

In Najafgarh, 32 samples with TC positive and 14 samples with FC positive were detected, as given in Table 5. The sampling locations are at a minimum distance of about 10 km from Chandrawal water treatment plant.

Punjabi Bagh samples have shown TC count positive in 21 samples and FC count positive in 13 samples. The sampling locations in this area are at a distance of about 10 km from the Chandrawal treatment plant.

Similarly, Todapur Village under R.K. Puram area has shown contamination of water samples to the extent of TC positive in 11 samples and FC positive in 1 sample. Water is supplied to this area from three different WTPs viz Chandrawal, Haiderpur and Wazirabad, which are located at approximate distances of 14–17 km from supply area. It is, therefore, evident that more the distance covered by water in distribution pipeline, more the chances of contamination.

Table 4: Summary of Samples from Distribution Network and Water Quality

Sl. No.	*Item/Description*	*Nos.*
1.	Total No. of samples analyzed	900
2.	Samples with <0.2 mg/L residual chlorine	121
3.	Samples with >0.2 mg/L residual chlorine	779
4.	Samples with positive total coliform count	90
5.	Samples with positive faecal coliforms count >10	43
6.	Samples with positive faecal coliforms count	37

Table 5: Residual Chlorine and Coliform Count at Consumer Ends

*Index No.**	*Area*	*No. of Sample Examined*	*Samples with Resi. Chlorine (mg/L)*		*Samples Indicating*		
			<0.2	*>=0.2*	*TC+*	*TC >10*	*FC+*
1.	Ashok Vihar	30	0	30	0	0	0
2.	Giri Nagar	30	0	30	0	0	0
3.	Greater Kailash	37	0	37	0	0	0
4.	Chandrawal	73	0	73	0	0	0
5.	Holambi	40	5	35	3	0	1
6.	Idgah	20	0	20	3	1	1
7.	Mandawali	30	0	30	0	0	0
8.	Paharganj	40	0	40	0	0	0
9.	Kasturba Nagar	20	0	20	1	0	0
10.	Janakpuri D-Block	30	8	22	5	1	0
11.	Karkardooma	20	0	20	0	0	0
12.	Kewal Park	40	2	38	0	0	0
13.	Loni Road	20	0	20	0	0	0
14.	Mangol Puri	30	0	30	0	0	0
15.	Najafgarh	62	40	22	32	15	14
16.	Paschim Vihar	50	7	43	4	0	2
17.	Pujabi Bagh	83	14	69	21	11	13
18.	Mehrauli	35	7	28	4	4	4
19.	R.K Puram	70	11	59	11	6	1
20.	Rajender Nagar	20	1	19	0	0	0
21.	Rajouri Garden	50	1	49	1	0	1
22.	Sarita Vihar	40	21	19	3	3	0
23.	Vasant Kunj	20	2	18	2	2	0
24.	Yamuna Vihar	10	2	8	0	0	0

* The areas are indicated by these Nos. on the map in Figure 1

TC+ - indicates presence of total coliforms; FC+ - indicates presence of faecal coliforms.

It can be concluded from the assessment that even though water is treated and disinfected adequately at treatment plant, it can get contaminated in the distribution networks. This can be attributed to intermittent mode of water supply, use of inline booster pumps by consumers and leakage in service pipelines. It is, therefore, desirable that the water be protected, especially during distribution phase. This could be achieved through regular monitoring and necessary controls such as implementing appropriate water safety plans as per WHO Guidelines 3rd Edition (WHO, 2004), regular leak detection and pipeline repair and maintenance, etc. Continuous mode of water supply is desirable to maintain a positive pressure in the pipeline to avoid contamination from surrounding area. However, this is not achievable at present due to inadequate availability of raw water supply.

The safe level of residual chlorine depends on several factors which include the length of pipeline travelled by water, material and condition of the pipeline, presence of THM pre-cursors, etc. Therefore, a check of residual chlorine levels of more than 0.2 mg/L at consumer ends was considered necessary through monitoring the consumer ends water quality.

REFERENCES

APHA (1998). "Standard methods for the examination of water and wastewater". 20th Edition. Published by APHA, AWWA, WEF.

Craun, G.F. (1993). "Safety of water disinfection: Balancing chemicals and microbial risks". International life Science Institute, Washington, DC.

Downs, T.J. Cifuentes-Garcia, E. and Suffet, I.M. (1999). "Risk screening for exposure to groundwater pollution in a wastewater irrigation district of the Mexico City region". *Environmental Health Perspectives*, 107(7), 533–561.

WHO (2004). "Guidelines for drinking water quality". 3rd Edition, Vol. 1, Recommendations.

http://www.un.org/millenniumgoals/ accessed on June 28, 2007.