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Surveillance of drinking water quality for safe water supply in urban area

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A B S T R A C T

To ascertain the quality of drinking water being supplied, water quality monitoring and surveillance was conducted in Shimla city for seven consecutive days in three seasons. It was observed that the physicochemical water quality parameters were within the permissible limits of BIS standard and the treated water quality hardly changed during all the seasons. The bacteriological quality of the water from sumps indicated the presence of total coliform (TC) up to 20 cfu/100 ml and faecal coliform (FC) up to 4 cfu/100 ml during winter. During summer, the TC and FC were found in the range of 20–244 cfu/100 ml and 2–56 cfu/100 ml respectively. During monsoon, the TC was detected in the range of 8–20 cfu/100 ml, but no FC was detected. The city had an intermittent water supply, therefore during non-supply hours, due to back suction through leakages/damages/faulty joints in the supply lines, some insanitary material might be entering into the pipelines and carried up to the consumer ends, when supply resumes. The proper maintenance of the distribution network, awareness about the hygienic and sanitary conditions around the public taps and proper storage of water are prerequisites in maintaining safe water supply in city.

Introduction

Drinking water supply and sanitation are critical water uses for human survival, health and prosperity (WHO, 2004, Marobhe *et al.*, 2007). Almost 900 million people lack access to an improved water supply and 2.6 billion to basic sanitation (WHO & UNICEF 2010). The adverse impacts on public health from poor water supply have long been recognized in both developing and developed countries and take the form of disease outbreaks (Esrey *et al.*, 1991; Ford, 1999; Payment and Hunter, 2001). Water supply access in most developing countries is complex comparable to those in developed countries (Howard and Bartram, 2005) Initiatives to manage the safety of water do not only support public health, but often promote socioeconomic development and well-being as well (WHO, 2013). Inspite of significance achievements in water supply and sanitation coverage, many factors render good quality water unsafe by the time it reaches the consumer. The main problems related to drinking water quality are associated with the conditions of the water supply network (Lehtola *et al.*, 2004; Karavoltsosa *et al.*, 2008; Farooq *et al.*, 2008; Antonio Proto *et al.*, 2014), during collection and storage (Andrew *et al.*, 2005), poor operation management and unsatisfactory sanitary practices, so it becomes obligatory to monitor water quality at each stage of delivery (Khadse *et al.*, 2011a,b,c). Water quality management and surveillance practices ensure safe water supply to consumers.

It is essential that the service provider and the consumers shoulder combined responsibility to see that needed programs and policies are taken up to achieve objectives and missions of “providing safe and sufficient water to one and all at minimum cost in terms of optimum utilization of available resources, adequate maintenance of existing infrastructures, self sustenance, reduction and loss due to leakage and environmental protections from degradation and pollutions” (WSSP, 2004). Surveillance of Drinking Water Quality (SDWQ) is the continuous and vigilant public health assessment and overview of the safety and acceptability of drinking water supplies (WHO, 1993).

SDWQ at drinking water treatment plant is necessary to avoid risk from chemical and bacteriological pollutants and to assure consumers that drinking water is safe and can be consumed without any risk (Leeuwen, 2000). The elements of surveillance include water quality surveillance, study of institutional setup and examination of water for physico-chemical and bacteriological parameters. Analysis of these parameters constitutes a risk to human health, others affect the aesthetic quality of the water supplied and others relate to treatment issues (Ratnayaka *et al.*, 2009). SDWQ programs identify those interventions that will result in improvements in water supply that will be protective of public health (Lloyd and Bartram, 1991; Lloyd *et al.*, 1991; WHO, 1997; Howard, 2002).

In the present paper the intake water quality of treatment plants, water quality at different treatment stages and at consumer end was monitored for three different seasons to assess the drinking water quality status for the Shimla city.

Study area

The hilly region has its own unique peculiarities due to geographical set-up therefore Shimla, the famous tourist place being a hill station and the capital of Himachal Pradesh, was selected for the study of surveillance of urban water supply. The city is situated at 30^0 6" N latitude and 77^0 11" E longitude 2434 m altitude. There are seven surface water sources which supply raw water to four water treatment plants (WTPs).

The total designed capacity of the four WTPs is 46.71 MLD (Table 1). The total water supply to the city is 40 MLD. There is an intermittent water supply through distribution network. The treated water of Dhalli water works and Gumma water works is carried over to the sump at Carignano. The treated water of Chairh water works is brought to the sump at Lambhidhar. The sump at Kusumpti receives the treated water of Ashwanikhad water works. The water is disinfected at sump by bleaching powder solution and is then supplied for distribution. 80% of the population is served by these water supplies.

Materials and Methods

Criteria for selecting sampling locations is envisaged with a view to examine water quality starting from raw water at source to consumers end including all the intermediate stages of treatment units and distribution network. The samples of raw water, settled water, filtered water and treated water after chlorination, were collected during three seasons for seven consecutive days from all the WTP's for examining the plant performance.

The raw water and treated water samples were collected and analyzed for physico-chemical bacteriological parameters. The settled water was collected from the overflow of the clariflocculator/ settling tank of the WTPs and examined for turbidity and sulphate. The filtered water was collected from the combined channel of the filters after filtration and analyzed for turbidity, sulphate and bacteriological quality. Final treated water after chlorination was collected from sump of each WTP. To assess the en-route bacteriological contamination in distribution network, samples were collected from service reservoirs and distribution network for bacteriological analysis. The samples were also collected from consumer end to see the quality of water supplied to the consumer. The seasonal water quality data is depicted in table 2. The pH, conductivity and DO were analyzed at site. The analysis of remaining parameters was carried out as per the standard methods (APHA, AWWA, WPCF, 1998 &, 2005).

Results and Discussion

The raw water quality data for all the WTPs are presented in table 2 whereas the water quality of sump is presented in table 3 for all the three seasons. In winter, the total dissolved solids (TDS) in water samples at the sumps at Carignano, Lambhidhar and Kusumpti were reported in the ranges of 191–201 mg/L, 174–180 mg/L, 128–141 mg/L respectively. In summer, these ranges were 190–200 mg/L, 100–135 mg/L, and 140–150 mg/L respectively. While in monsoon, the TDS ranged between 155–170 mg/L; 85–95 mg/L and 100–125 mg/L respectively. The other water quality parameters were within the permissible limits of drinking water quality standards (BIS: 10500: 1991) and can be used for drinking purposes after conventional treatment followed by disinfection.

The bacteriological quality of the water samples from sumps indicated the presence of TC up to 20 CFU/100 ml and FC up to 4 CFU/100ml during winter. In summer, the TC and FC were found in the range of 20-244 CFU/100 ml and 2-56 CFU/100 ml respectively. While, in monsoon, the TC were detected in the range of 8-20 CFU/100 ml, but no FC was detected. This may be attributed to the complete disinfection due to chlorination non-contamination of faecal origin matter in the sump water.

The salient findings of the water quality at consumer ends during different seasons were:

During winter,

- At two sampling locations no TC or FC was observed
- At ten sampling locations, the TC was observed occasionally but no FC was detected
- At six other places, the presence of TC and FC was observed on some occasions during the sampling period

During summer,

- No TC or FC was observed at 4 sampling locations

- At eight sampling points, the presence of TC and FC was observed
- At remaining sampling locations, only the TC were detected

During monsoon,

- Three locations were contaminated only by TC
- At two locations, no TC and FC were detected, and
- At remaining locations, mostly the samples were found contaminated by TC and FC.

The residual chlorine in tap water was estimated on the spot during sampling. It was observed that even in the presence of sufficient residual chlorine in the sample, there was the presence of total coliform. This may be due to the insufficient contact time (30 to 45 minutes) between chlorine and water in the supply lines. Due to hilly terrain, it may be possible that high velocity gravitational flow of water from supply pipe lines results into insufficient contact time.

The city has an intermittent water supply. Therefore, it is quite possible that during non-supply hours due to back suction through leakages / damages / faulty joints in the supply lines, some insanitary material might be entering into the pipelines and when supply resumes the same material might be carried up to the consumer ends. The insanitary conditions around supply lines are also responsible for carrying the pathogens to consumer ends.

About 35 to 40% uncollected garbage lies on the hill slope which may block the drainage channel. Due to leachate or improper solid waste disposal practices, there can be a possibility that the raw water sources and water quality in the distribution system may get affected. The main reason for indiscriminate disposal of garbage was due to lack of public awareness and inadequate infrastructure facilities. Such practices may result into health hazards. However, the contamination of raw water sources and distribution system due to leachate and other solid waste material was not reported.

Table.1 Details of the water treatment plants at Shimla

S. N.	Water Treatment Plant	Raw Water Source	Design Capacity (MLD)
1	Dhalli water works	Spring sources, Cherot and Kufri nallah	9.35
2	Ashwanikhad water works	Ashwani khad	10.8
3	Chairh water works	Chairh nallah	2.5
4	Gumma water works	Nauti khad and Kalyan nallah	24.06

Table.2 Raw water quality of treatment plants

S. No.	Parameters	Winter				Summer				Monsoon			
		Dhalli	Ashwanikhad	Chairh	Gumma	Dhalli	Ashwanikhad	Chairh	Gumma	Dhalli	Ashwanikhad	Chairh	Gumma
1.	Temperature (^{O}C)	17 - 18	14 - 17	15 - 17	17 - 19	20	23 - 28	19 - 22	26	20 - 21	20 - 22	18 - 21	20 - 21
2.	pH	7.4 - 7.9	7.9 - 8.1	7.2 - 7.8	7.2 - 8.1	6.8 - 8.2	7.5 - 8.7	6.8 - 7.7	8.2 - 8.6	7.4 - 7.8	7.4 - 7.5	7.4 - 7.8	7.9 - 8.1
3.	Turbidity (NTU)	0.2 - 0.3	0.15 - 0.18	0.15 - 0.20	0.29 - 0.34	0.2 - 0.4	0.2 - 1.1	0.1 - 0.5	0.4 - 1.0	0.1 - 0.4	0.05 - 0.40	0.1 - 0.3	0.1 - 0.2
4.	TDS	85 - 91	102 - 114	85 - 95	186 - 199	100 - 105	130 - 140	120 - 125	175 - 185	75 - 90	95 - 110	80 - 90	155 - 190
5.	T.Alkalinity as $CaCO_3$	64 - 72	72 - 84	68 - 72	134 - 150	68 - 70	72 - 76	68 - 80	140 - 156	66 - 76	67 - 75	56 - 68	124 - 148
6.	T.Hardness as $CaCO_3$	44 - 60	48 - 52	44 - 48	122 - 136	70 - 75	84 - 100	76 - 96	152 - 160	65 - 80	74 - 92	70 - 77	140 - 184
7.	Calcium as Ca	11 - 15	11 - 14	11 - 18	34 - 38	19 - 21	22 - 27	22 - 30	38 - 40	16 - 24	18 - 22	18 - 23	36 - 40
8.	Magnesium as Mg	3 - 6	4 - 6	1.1 - 4.8	8.3 - 11.9	4.7 - 6.0	5.9 - 8.5	4.0 - 5.0	12.6 -16.5	4 - 6	5 - 8	5 - 6	9 - 15
9.	Chloride as Cl	6 - 10	4 - 8	2 - 8	6 - 10	10	12 - 20	10	10	10	14 - 16	12 - 14	10
10.	Sulphate as SO_4	14 - 18	20 - 22	14 - 16	25 - 28	25 - 27	35 - 39	29 - 36	22 - 25	7 - 10	11 - 15	9 - 13	21 - 30
11.	Nitrate as NO_3	6 - 10	17 - 20	21 - 25	10 - 12	2 - 3	8 - 13	2 - 3	1.0	2 - 3	6 - 8	5 - 8	4 - 5
12.	Phosphate as PO_4	ND-0.18	ND - 0.08	0.05 - 0.14	0.03 - 0.32	ND	0.1	ND - 0.03	ND	ND	0.1	ND - 0.03	ND
13.	Fluoride as F	0.04 -0.05	0.06	0.06 - 0.07	0.10 - 0.12	0.1	0.1	0.1	0.16	0.1	0.2	0.2	0.2
14.	Sodium as Na	8 - 10	10	5 - 6	7 - 8	12	16 - 17	9 - 10	5 - 6	8	10	6	16
15.	Potassium as K	1	1	0.2 - 0.4	1	1.0	2.0	1.0	1.0	1	1	1	2
16.	DO (mg/L)	7.5 - 8.2	7.1 - 8.6	7.4 - 8.1	7.8 - 8.0	7.0 - 7.5	7.1 - 7.6	6.8 - 7.0	8.0 - 8.4	6.9 - 7.3	7.2 - 7.3	6.9 - 7.3	7.5 - 8.0
Bacteriology													
1.	TC (CFU/100 mL)	115 - 510	90 - 260	160 - 270	230 - 630	ND - 248	48 - 272	28 - 336	16 - 180	80 - 280	192 - 600	224 - 292	160 - 360
2.	FC (CFU/100 mL)	ND - 88	6 - 54	10 - 54	4 - 52	ND - 10	ND - 48	ND - 42	ND - 54	10 - 88	ND - 100	4 - 160	44 - 106

ND: Not Detected; Units for parameters from S.N. 4 to 16 is mg/L

Table.3 Treated water quality at sump

S. N.	Parameters	Winter			Summer			Monsoon		
		Carignano (Dhalli & Gumma)	Lambhidhar (Chairh)	Kusumpti (Ashwanikhad)	Carignano (Dhalli & Gumma)	Lambhidhar (Chairh)	Kusumpti (Ashwanikhad)	Carignano (Dhalli & Gumma)	Lambhidhar (Chairh)	Kusumpti (Ashwanikhad)
1.	Temperature (^{O}C)	16 – 18	17 - 19	16 - 18	23 – 26	21 - 24	23 - 28	20 -21	20 - 22	20 - 22
2.	pH	7.7 - 8.4	7.8 - 8.1	8 - 8.5	7.9 - 8.3	6.5 - 7.1	7.0 - 8.5	7.6 - 7.9	7.5 - 8.5	7.5 - 8.7
3.	Turbidity (NTU)	0.20 - 0.30	0.15 - 0.24	0.15 - 0.20	0.3 - 1.2	0.2 - 0.8	0.1 - 1.0	0.1 - 0.2	0.1 - 0.3	0.1 - 0.4
4.	TDS	191 - 201	174 - 180	128 - 141	190 – 200	100 - 135	140 - 150	155 - 170	85 - 95	100 - 125
5.	T. Alkalinity as $CaCO_3$	140 - 154	144 - 154	64 - 82	148 - 156	72 - 84	73 - 77	118 - 134	58 - 62	72 - 81
6.	T. Hardness as $CaCO_3$	132 - 156	120 - 130	64 - 76	168 - 176	72 - 92	88 - 112	138 - 162	69 - 82	69 - 94
7.	Calcium as Ca	37 - 48	33 - 38	19 - 22	45 - 48	19 - 25	24 - 27	38 - 46	24 - 27	20 - 27
8.	Magnesium as Mg	7.6 - 10.6	7.3 - 11.1	2.8 - 5.0	10.8 - 15.4	4.0 - 8.9	4.9 - 11.4	10 - 11	2 - 4	4 - 8
9.	Chloride as Cl	8 - 10	8 - 12	4 - 10	10	10	18 - 20	10	12 - 14	14 - 24
10.	Sulphate as SO_4	24 - 28	23 - 28	14 - 23	25 - 26	23 - 27	36 - 39	18 - 26	10 - 13	12 - 15
11.	Nitrate as NO_3	11 - 13	10 - 12	19 -21	1.0	2.0 - 3.0	8.0 - 12.0	3 - 4	7 - 8	7 - 9
12.	Phosphate as PO_4	ND - 0.07	ND - 0.27	ND - 0.16	ND	ND	ND	ND	ND	ND
13.	Fluoride as F	0.09 - 0.10	0.06 - 0.09	0.06 - 0.07	0.15 - 0.17	0.1	0.1	0.2	0.2	0.2
14.	Sodium as Na	7 - 8	7 - 8	10	6.0	9.0	16.0	16	6	10
15.	Potassium as K	1.0 - 1.3	1	1	1.0	1.0	2.0	2	1	1
Bacteriology										
1.	TC (CFU/100 mL)	ND - 20	ND - 20	ND	ND – 60	ND - 20	ND - 244	ND - 20	ND - 16	ND - 8
2.	FC (CFU/100 mL)	ND	ND - 4	ND	ND – 18	ND - 2	ND - 56	ND	ND	ND

ND: Not Detected; Units for parameters from S.N. 4 to 15 is mg/L

Table.4 Bacteriological water quality at consumer end

Sl. No.	Location	Monsoon			Winter			Summer		
		Res.Cl (mg/L)	TC (CFU/100ml)	FC	Res.Cl (mg/L)	TC (CFU/100ml)	FC	Res.Cl (mg/L)	TC (CFU/100ml)	FC
1	Dhalli – Public Tap, Main Bazar, Near Banta	Nil -0.1	4-44	ND - 30	Nil – 0.2	ND - 20	ND	Nil –1.5	ND - 120	ND
2	Sanjauli – Public Tap, Sanjauli Square near Bus-Stop	Nil – 1.5	ND - 100	ND - 4	1.0 -2.0	ND -10	ND	0.1 – 0.2	ND -16	ND -6
3	Snowdon – Pump House W.S. & S.D.M.C.	Nil – 1.0	ND - 40	ND - 6	1.5 -2.0	ND	ND	0.2 – 0.5	ND	ND
4	Kaithu – Bazar, Water Supply Tank	Traces – 0.1	ND - 40	ND -12	Nil – 1.5	ND -10	ND	Nil – 0.2	ND - 140	ND -16
5	Summer Hill, H.P.	Nil - Traces	ND - 120	ND - 30	0.1 -0.3	ND -70	ND	Nil -0.2	ND -9	ND -2
6	Kasumpti, Public Tap	0.2 – 0.6	ND -60	ND - 20	Nil – 1.5	ND -20	ND	Nil – 0.5	ND - 16	ND
7	Chakkar -Jai Murari	Nil – 0,4	ND - 8	ND	Nil	ND -60	ND -38	Nil	ND - 108	ND -28
8	Tutikandi – Gita Mandir	Nil – 0.4	ND - 108	ND	Nil -0.1	ND - 10	ND	Nil -0.2	ND - 8	ND
9	103 – Invesam Rly. Tunnel, Rly.	Nil – 0.4	ND - 140	ND - 4	0.1 0.3	ND	ND	NWS -0.2	ND - NWS	ND -NWS
10	Indian Instt. of Advance Studies	Traces – 0.2	ND -32	ND - 6	0.1 1.5	ND	ND	Traces – 0.2	ND	ND
11	Chaura Maidan, Shyamlal Medical Store,	Nil - 0.2	ND - 40	ND -10	0.2 - 0.5	ND - 30	ND - 12	Traces – 0.5	ND	ND
12	Circular Road, H.P.S.I.D.C.	Traces – 0.2	ND - 40	ND -6	Nil - 0.2	ND - 5	ND - 2	Nil	ND - 12	ND
13	Ashwani Khad, New Shimla,	Nil – 0.4	ND - 108	ND	Nil - 0.2	ND - 30	ND - 20	Nil - 0.2	ND - 12	ND
14	Chhota – Shimla, H.P	Traces – 0.3	ND	ND	Nil - 0.2	ND	ND	Nil - 0.2	ND -12	ND
15	Public Tap - Bus Stand	Nil – 0.2	ND - 332	ND - 50	Nil - 0.2	ND - 50	ND - 20	Nil	ND - 52	ND - 8
16	Bharari School	Nil	ND - 148	ND -30	Nil - 0.1	ND - 40	ND	Nil -0.2	ND -	ND
17	Ridge – Maidan,	0.1 – 1.5	ND	ND	1.5 - 2.0	ND - 10	ND - 6	0.2 – 0.5	ND	ND
18	Kufri – Public Tap	1.0 – 2.0	ND -16	ND-16	0.1 – 0.2	ND - 220	ND - 40	0.2 – 0.3	ND - 8	ND

Conclusion

From the present study, it is observed that water supplied through the distribution network is of good physico-chemical and bacterial quality. No significant change in physico-chemical parameters of raw water quality was observed on day-to-day basis. The city had an intermittent water supply. Therefore during non-supply hours, due to back suction through leakages/ damages/ faulty joints in the supply lines, some insanitary material might be entering into the pipelines and carried up to the consumer ends, when supply resumes. The places where the faecal contamination was present at the consumer end, the necessary precautionary measures need to be undertaken to avoid any adverse impact on health. The proper maintenance of the distribution network, awareness about the hygienic and sanitary conditions around the public taps and proper storage of water will definitely help in maintaining water quality within the limits of potable water standards. Thus, the surveillance of water supply and in time measures to control the contamination along with people's participation will lead to safety and better health of the community.

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