Original Article

Water safety planning in India: Assessment of water quality in urban Vadodora

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Abstract

Introduction: According to the World Health Organization, the objectives of a water safety plan are to ensure safe drinking water through good water supply practices.

Objective: The objective of the study was to assess physical, chemical, and bacteriological water quality parameters among water samples from urban Vadodara.

Materials and Methods: A cross-sectional study was carried out at urban Vadodara city. Average three water tanks were selected from north, south, east, and west zone randomly; hence, water sample from 12 water tanks was tested. From the areas supplied by these 12 selected water tanks, two water samples each, one from near tank area, and another from outer limit of water supply were collected from household level for water quality analysis to confirm variation in quality if any. Thus, total 38 samples (12 water tank samples, 24 household water, and 2 from main water supply reservoir) samples were tested for color, odor, total dissolved solids (TDS), total suspended solids (TSS), calcium and total hardness, fluoride, hydrogen sulphide (H2S) strip test, and multiple tube method (maximum coliform and maximum fecal coliform). Analysis was done using MedCalc software.

Results: H2S Strip test was negative in all the water tanks. There was no single coliform in any water tanks. There was no Fecal Coliform in any water tanks. No objectionable color or odor was found in any sample. TDS of water was found to be normal except for one area. The fluoride levels were normal in 3 areas, while it was marginally higher in the rest of areas.

Conclusions: Drinking water available to the people of Vadodara supplied by the Vadodara municipal corporation was bacteriologically safe.

Keywords: Bateriological quality, coliform count, drinking water, hydrogen sulphide strip test

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INTRODUCTION

A safe, reliable, affordable, and easily accessible water supply is essential for good health. Yet, for several decades, about a billion people in developing countries have not had a safe and sustainable water supply. It has been estimated that average 135 L of water per person per day is required

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for drinking, cooking, washing utensils, washing house, washing clothes, toilet flushing, and bathing.[1]

A key target of sustainable development goal (SDG) 6 aims to ensure availability and sustainable management of water and sanitation for all.[2] In poorly served countries, achieving the water supply target as per SDG will involve an increase in water availability for domestic uses, improving water quality, and bringing about changed water-use and water management habits. The quality of water relates to water hardness, pathogens, and chemical constituents in water that can give rise to both diarrhoeal and nondiarrhoeal diseases.[3]

Clean water, basic toilets, and good hygiene practices are essential for the survival and development of children. Every day over 800 children die from preventable diseases caused by poor water and lack of sanitation and hygiene.[4] Diseases spread through contaminated water are cholera, diarrhoeal disease, dysentery, gastroenteritis, giardiasis, Hepatitis E, and typhoid Fever.

Water safety planning is the most effective means of consistently ensuring the safety of a drinking-water supply from catchment to consumer.

To accelerate the efforts to achieve universal sanitation coverage and to put focus on sanitation, the Prime Minister of India launched the Swachh Bharat Mission on October 2, 2014. The Mission Coordinator shall be secretary, Ministry of Drinking Water and Sanitation (MDWS) with two Sub-Missions, the Swachh Bharat Mission (Gramin) and the Swachh Bharat Mission (Urban), which aims to achieve Swachh Bharat by 2019, as a fitting tribute to the 150th Birth Anniversary of Mahatma Gandhi, which in rural areas shall mean improving the levels of cleanliness in rural areas.[5] As per our knowledge, this type of study is not done in India. The purpose of this study is to know the quality of water and the type of purification method used by people.

MATERIALS AND METHODS

Approval of ethics committee and scientific review committee (Institutional Ethics Committee For Human Research, Medical College Baroda and SSG hospital) was taken along with written consent of corporation before initiating the data collection.

A cross-sectional study was conducted in Vadodara district to assess the pPhysical, chemical, and bacteriological water quality of Vadodara municipal corporation water supply.

The study was carried out from November 2016 to August 2017. Data collection was done over a period of November to next August.

Exclusion criteria for the study were those families used bore well water, who lived in slum area and flat/apartment area.

Three water tanks were randomly selected from each zone by computer-generated random number. From each water supplying tank area, two water samples were collected for water quality analysis, one sample nearest to the water tank and one water sample furthest to the water tank. One water sample was taken from Sayajisarovar-Ajwa and one water sample from Mahi river bed which are the main water sources for urban Vadodara. Thus, total 12 water tank samples, 24 household water samples, and 2 from main water source of Vadodara (Ajwa and Mahi river) (38 samples) were tested water samples sent to the public health laboratory (PHL), SSG Hospital, Vadodara for Bacteriological (hydrogen sulphide [H2S] strip test for bacterial contamination, Multiple tube method for coliform organism and residual chlorine) analysis of water and to Gujarat Ecology Society, Vadodara for chemical analysis (color, odor, total dissolved solids [TDS], total suspended solids [TSS], Calcium Hardness, Total Hardness, and Fluoride) of water. Standard operating procedure was followed for water collection and transport for water sampling testing

The sampling bottles were made of plastic of good quality, durable, and screw cap was taken. Containers were washed with distilled water and dried before sampling. These bottles were cleansed and autoclaved as per protocol procured from the PHL. Containers were coded by the name of location, date, time, area/tank from which specimen was delivered to SSG Hospital, which is a part of National Accreditation Board for Hospital and Healthcare Providers accredited Microbiology laboratory. Containers were placed in cold box for transportation to laboratory. Sturdy, insulated wooden or plastic boxes to protect the sample from sun-light and prevent breakage of bottles were used. Temperature was around 4°C, for which ice was added in box. A box of small bottles of preservatives of sulphuric acid and hydrochloric acid was taken. General samples were preserved in the refrigerator but not frozen at the PHL. Before testing, these samples were brought down to room temperature. While the acid preserved, samples were not refrigerated. These procedures were carried out by trained technician at the respective laboratories.

The process of data collection did not pose any potential risk or harm to the participants. Data safety and confidentiality were given due consideration by keeping the file containing identity-related details password protected. The filled Pro forma was kept in lock and key accessible only to researchers.

Bacteriological examination

It was done by multiple tube fermentation test to find the total or presumptive coliform count. The results were interpreted as excellent presumptive total coliform count 0/100 ml of water, satisfactory (1–3), suspicious (4–10), and unsatisfactory (more than 10).[6]

Drinking water (bacteriological quality of drinking water) criteria:

1. All water intended for drinking– *Escherichia coli* or thermotolerant coliform bacteria must not be detectable in 100 ml sample
2. Treated water entering the distribution system-*E. coli* or thermotolerant coliform bacteria, total coliform bacteria must not be detectable in 100 ml sample
3. Treated water in the distribution system-*E. coli* or thermotolerant coliform bacteria, Total coliform bacteria must not be present in 100 ml sample.

Data were entered in Microsoft Excel worksheet 2007 using strict check files. Water quality parameters were measured in predefined measures.

Chi-square and Fisher's exact test was used for categorical data using Epi_Info Version 7_d. A word processing database and statistical programme for public health on IBMcompatible Microcomputers. Centers for Disease Control and Prevention. Atlanta, Georgia, USA. The outcome variable was drinking water quality standards compared with World Health Organization (WHO) water quality standards.

RESULTS

Table 1 shows the physical and chemical analysis of the water from the 12 areas compared with WHO standards. Color and odor of the water from all the water tanks were comparable with WHO standards. Normal TDS value is <600 mg/L. TDS value in all the water tanks was below 600 except Manjalpur water tank, in which TDS value was >600 mg/L. Calcium Hardness in all the water tanks was within normal range. Normal value total hardness of water is 500 mg/L. Total hardness of water was below 500 mg/L in all water tanks. Normal fluoride value is <1.5 mg/L. Fluoride value was highest in Ajwa water tank followed by Jail Road, Lalbaug, Manjalpur, Vadivadi, T. P. 13, North Harni, Gorwa, Subhanpura, Gujarat Industrial Development Corporation (GIDC), Tarsali.

Color and odor of all the water samples near and far from the water tanks were comparable with WHO standards. Normal TDS value is <600 mg/L, all the sample near and far from water tank area contain TDS value <600 mg/L. Calcium hardness in all the household samples was within normal range. Normal value of total hardness is 500 mg/L; all the samples near and far from water tank area contain total Hardness value <500 mg/L. Normal fluoride value is <1.5 mg/L. All the samples near and far from water tank contain higher fluoride level [Table 2].

Table 3 shows the bacteriological parameters of the water sample collected from the 12 tanks of urban Vadodara and compares with standard. H2S Strip test was negative in all the water tanks. There was no single coliform in any water tanks. There was no fecal coliform in any water tanks. Free chlorine was 1.940 ppm in Lalbaug water tank, 0.5 ppm in North Harni and Ajwa, and 1 ppm in all the remaining all water tanks.

Free chlorine was 2.0 ppm in Gorwa, Manjalpur, GIDC water tanks area and 1 ppm in all the remaining water tanks area [Table 3]. H2S Strip test was Negative at user level (near and far from the water tank). There was no single coliform at user level. There was no Faecal Coliform in any sample level [Table 4].

DISCUSSION

Safe drinking water is a basic human right. Contaminated water supply and poor sanitary conditions lead to public

Table 1: Physical and chemical analysis of water tank

Parameters	Normal value (mg/l)	Gorwa	Subhanapura	Vadivadi	Jail road	Lalbaug	T.P. 13	Tarsali	Manjalpur	GIDC	Panigate	N.Harni	Ajwa
Colour		+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve
Odour		+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve
TDS	<600	224	143	231	230	291	245	164	786	234	137	157	183
TSS		24	42	38	18	46	84	22	34	58	60	76	74
Ca hardness	75	67	65	60	73	59	62	84	68	62	70	74	72
Total hardness	500	114	116	132	126	132	140	320	118	106	104	122	120
Fluoride	1.5	1.725	1.676	1.856	1.994	1.940	1.779	0.384	1.987	1.475	1.274	1.731	2.054

+ve: Normal, −ve: Abnormal, TDS: Total dissolved solids, TSS: Total suspended solids, Ca: Calcium, GIDC: Gujarat Industrial Development Corporation

Table 2: Physical and chemical analysis of water at user level (near and far from water tank)

Parameters	Normal value (mg/l)	Gorwa		Subhanapura		Vadivadi		Jail road		Lalbaug		T.P. 13		Tarsali		Manjalpur		GIDC		Panigate		N.Harni		Ajwa	
		Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far
Colour		+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve
Odour		+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve
TDS	<600 mg/l	119	129	37	112	93	131	374	131	256	458	173	415	177	355	190	188	363	242	51	145	43	133	34	87
TSS		26	12	44	6	24	30	34	20	18	22	56	24	32	38	10	14	16	22	30	26	16	6	12	46
Ca hardness	75	62	60	70	62	74	62	66	70	74	70	68	64	62	72	68	74	86	75	72	68	64	60	68	64
Total hardness	500 mg/l	170	140	144	138	134	136	144	136	140	122	138	134	102	138	128	120	140	134	140	134	136	156	96	112
Fluoride	1.5 mg/l	1.773	1.796	1.937	1.940	1.884	1.908	1.854	1.742	1.748	1.894	2.244	1.700	1.954	0.625	1.899	1.866	1.828	1.819	1.733	1.852	1.957	1.949	1.347	1.321

+ve: Normal, −ve: Abnormal, TDS: Total dissolved solids, TSS: Total suspended solids, Ca: Calcium, GIDC: Gujarat Industrial Development Corporation

health hazards like typhoid fever, viral hepatitis A and E, worm infections, etc.[7]

The present study was carried to know the physical, chemical, and bacteriological water quality parameters among water samples from urban Vadodara. Water safety planning includes the use of a comprehensive risk assessment and management approach that encompasses all steps in the water supply.

In all total 38 samples of water were checked, they have no objectional color or odor. TDS of water was found to be normal except for one area (Manjalpur water tank, which was 786 mg/L), TSS ranged from 18 to 84 mg/L, calcium hardness of water ranged from 40 to 84 mg/L, total hardness of water ranged from 104 to 320 mg/L, and fluoride level of water ranged from 0.384 to 2.054 mg/L. The fluoride levels were normal in three areas (Tarsali, Panigate, and GIDC), while it was marginally higher in the rest of areas.

Fluoride content in our study ranged from 0.384 to 2.054 mg/L. The study conducted by Kotecha and Patel *et al.* at Vadodara district of Gujarat show that the prevalence of dental fluorosis in high fluoride are was 59.31%, while in normal fluoride area, it was 39.21%.[8]

Fernando García-Ávila *et al.* in a study in Ecuador showed that 45.2% of nodes maintain residual chlorine below what the WHO recommends.[9]

H2S Strip test was negative, maximum coliform count was zero, maximum fecal coliform count was zero, and free chlorine ranged from 0.5 to 1.940 parts per mol (ppm). The study showed that all the samples of water (from the source of the water up to user level) were bacteriologically safe for drinking purpose; this is good for the population of Vadodara that there is a good water supply and it met the WHO drinking water criteria. Thus the 6th goal of SDG has been fulfilled as citizens of urban Vadodara have equitable and sustainable access to safe drinking water.

There may be a seasonal variation in the bacteriological quality of water which needs to be studied later. All the households were using corporation water supply. Due to lack of sufficiency of water, 208 households were using bore well water also. People using corporation water for drinking purpose and bore well water for domestic use. Corporation water supply was 1 h/day.

Disinfection with chlorine is important to prevent the spread of waterborne diseases as a result of bacteria

Table 3: Bacteriological analysis of water- samples from the 12 tanks of urban vadodara

Parameters	Normal value	Gorwa	Subhanapura	Vadivadi	Jail road	Lalbaug	T.P. 13	Tarsali	Manjalpur	GIDC	Panigate	N.Harni	Ajwa
H2S strip test	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve
Maximum coliform	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum faecal coliform	0	0	0	0	0	0	0	0	0	0	0	0	0
Free chlorine (ppm)	0.5	1	1	1	1	1.940	1		1	1	1	0.5	0.5

GIDC: Gujarat Industrial Development Corporation, −ve: Abnormal

and viruses. Therefore, the presence of residual chlorine of 0.5 mg/L, measured at the endpoints of the water distribution system, must be guaranteed.

Water quality testing is only one of the essential requirements for safe drinking water. The water quality can deteriorate in the distribution system after the water leaves the treatment plant.[10] If the concentration of residual chlorine in the water is too low, it may not provide effective protection against recontamination. Too high a chlorine level in drinking water adds disagreeable taste, which forces consumers to use water from alternative sources for drinking purposes. Furthermore, it leads to pipeline corrosion. On the other hand, a lower amount of chlorine causes improper levels of disinfection.[11]

A study conducted in Kanpur by Manish Nigam *et al.* original H2S paper strip correlated with total coliform 83% times, while with fecal coliform 87% of times. H2S strip test correlates better with fecal coliform than total coliform.[12]

A study conducted by T. Wnorowski *et al.* showed that the H2S paper strip test and coliform MPN Colilert® test were equally effective in the detection of bacterial contamination in water samples. An agreement (97.3%) was found between the H2S test and *E. coli* MPN Colilert® method. The H2S test is a sensitive, simple, and inexpensive procedure for screening of water supplies for potential fecal contamination.[13]

A study conducted by Muhammad Sayeed Anwar in Lahore tested during the summer months showed the highest positivity (77.96%) for chlorine ($P < 0.001$) as compared with other months of year. Among chlorinated samples, 12.32% showed bacterial contamination. However, contamination was significantly higher ($P < 0.001$) among non-chlorinated samples.[14]

A study conducted by Amhedabad Municipal Corporation (AMC) showed Total Hardness, 80–280 mg/L, TDS 120–300 mg/L, 97.80% of samples do not contain any coliform organism, At consumer end point Residual free chlorine AMC maintains 0.2 ppm.[15]

Globally, 4 billion episodes of diarrhea were estimated to occur each year, with >90% occurring in developing countries. Diarrheal disease is an important public health problem among under-five children in developing countries. Total diarrhoeal deaths in India among children aged 0–6 years were estimated to be 158,209, and proportionate mortality due to diarrhea in this age group was 9.1%.[16] According to a study conducted by Maria. J Gunnarsdotti observed that there was a reduction in the incidence of diarrhea after implementation of water safety plan.[17]

Residual chlorine using computer modeling for a small water supply system located in La Sirena, Cali, Colombia revealed that show that 98% of the time, concentrations below 1.2 mg/L are presented with an average value of 0.985 mg/L, and only 2.41% of the data do not meet the standard because they show concentrations lower than 0.3 mg/L.[11]

The generalizability of above study data is applicable to the whole Vadodara Municipal Corporation area. This study was conducted in summer months; this study may be repeated during monsoon months to study seasonal variation in water quality. To minimize measurement bias in measuring the physical, chemical, and biological quality of water, standardization of the instruments was done before conducting the tests. Further study needs to be conducted for parameters such as pH, dissolved oxygen, sulfates, phosphates, arsenic, and nitrates.

CONCLUSIONS

Water safety planning of Vadodara city appears to be effective in this study.

Drinking water available to the people of Vadodara supplied by the Vadodara Municipal Corporation was physically and bacteriologically safe.

Recommendations

There should be continued monitoring routine monitoring of water supply from source to user level and correlating the findings with gastrointestinal disease prevalence.

Table 4: Bacteriological analysis of water at user level (near and far from water tank)

Parameters	Normal value	Gorwa		Subhanapura		Vadivadi		Jail road		Lalbaug		T.P. 13		Tarsali		Manjalpur		GIDC		Panigate		N.Harni		Ajwa	
		Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far	Near	Far
H2S strip test	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve	−ve
Maximum coliform	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Maximum faecal coliform	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Free chlorine (ppm)	0.5	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0

GIDC: Gujarat Industrial Development Corporation, −ve: Abnormal

The monitoring should document changes due to seasonal variation in water quality.

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PHL (multiple tube method, residual chlorine, and H2S strip test), Gujarat Ecological Society (color, odor, TDS, TSS, calcium and total hardness, and fluoride). All tests were conducted free of cost.

Conflicts of interest

There are no conflicts of interest.

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