Assessment of Physicochemical and Microbiological Qualities of Drinking Water in Ahmedabad Slum, India: A Cross-Sectional Study

Devang Raval[1] Dinesh Rathod[2], Ripal Panchal[3], Jaydeepkumar Ghevariya[3], Kinner Patel[4]

[1]Professor & Head, [2]Ex Assistant Professor, [3]Senior Resident, Dept. of Community Medicine, B J Medical College, Ahmedabad, Gujarat, India, [4]Assistant Professor, Dept. of Community Medicine, Ananya College of Medicine & Research, Kalol, Gujarat, India

Correspondence: Dr. Jaydeepkumar Ghevariya, Email: ghevariya172@gmail.com

Abstract:

Introduction: The quality of drinking water is a public health concern, especially in urban slum areas. Drinking water quality and contamination are seriously threatened by the growing slum population and irregular water supply. **Objective:** To examine the physicochemical and microbiological quality of drinking water in the field practice area of one of the Tertiary-care hospital in Ahmedabad a part of PG teaching activity **Method:** A cross-sectional study was carried out for water quality assessment using stratified random sampling. A total of 139 water samples were collected; samples were collected from different households in different areas of the Asarwa ward of Ahmedabad Corporation. From each ASHA worker's area, according to population of that area, 6 to 10 samples were selected. The samples were analysed using standard methods and compared with WHO and BIS water quality standards. **Results:** TDS and alkalinity are above permissible levels in 42.4% and 46.7% samples respectively. pH, turbidity, conductivity, total hardness, and magnesium were found altered in a few samples. The mean free residual chlorine was 0.05 mg/L. Microbiological analysis of water samples revealed the presence of coliform in 5 (3.6%) samples. **Conclusion:** Except for total alkalinity and TDS, most physicochemical parameters of drinking water were acceptable. By storing water, a low level of free residual chlorine can be justified. A few samples (3.6%) with coliform bacteria indicate water contamination somewhere in the distribution system or at the consumer level.

Keywords: Drinking water quality, Microbiological parameter, Physicochemical parameter, Urban slum.

Introduction:

The quality of the water provided is critical in determining the health of individuals and communities as a whole.[1] Lack of access to clean, safe drinking water is a major contributor to global ill health, especially in developing nations.[2]

Three main elements that significantly affect the quality of drinking water in the water distribution network are the quality of raw water at the source, the purification process employed for water and the distribution system used for water.[3] These three elements affect the physicochemical characteristics as well as the microbial composition of drinking water.[4] Geochemical processes like weathering, dissolution, hydrolysis, precipitation, adsorption, and ion exchange as well as oxidation-reduction and biochemical reactions are major controlling factors for physiochemical changes in drinking water.[5]

Assessment of physicochemical parameters like pH, electrical conductivity (EC), total dissolved solids (TDS), alkalinity, and the levels of fluoride, arsenic, lead, and nitrate is generally considered to set

Quick Response Code	Access this article online
	Website : www.healthlinejournal.org
	DOI : 10.51957/Healthline_ 589_2024

How to cite this article :
Raval D, Rathod D, Panchal R, Ghevariya J, Patel K. Assessment of Physicochemical and Microbiological Qualities of Drinking Water in Ahmedabad Slum, India: A Cross-Sectional Study. 2024; 15 (1): 59-65

guidelines and categorize the physicochemical water quality. On the other hand, coliform count, E. coli in particular, determines the microbiological quality of drinking water.[6]

Drinking water pollution by industrial (Toxic elements) and agricultural (Runoff fertilizers) activities as well as its contamination (Poor sanitation and hygiene) are a major threat to human health. Reports from the Water Aid mentioned that even households that receive drinking water from "improved" sources are also above the permissible limits of WHO standards.[7]

In India, around 200,000 people died annually due to inadequate or unsafe water supplies. In era of rapid urbanisation this problem is worse in urban areas. According to census 2011 data, around 30.8% of India's rural household and 70.6% of Urban household has access to safe drinking water, slum households have better access to tap water compared to non-slum households. Despite of this quality of drinking water is still a concern in Indian cities.[8,9]

In Ahmedabad city, large-scale drinking water purification is done by the municipal corporation. Water is then distributed to households by a well-established network of pipelines followed by routine surveillance and monitoring to be conducted at various levels as per the guideline.[10,11] This study aims to examine the physicochemical and microbiological quality of drinking water in a slum of Ahmedabad city.

Objective:

To examine the physicochemical and microbiological quality of drinking water in the field practice area of one of the Tertiary-care hospital in Ahmedabad a part of PG teaching activity

Method:

This cross-sectional study was conducted at the urban field practice area (Asarwa Urban Health Centre) of the community medicine department, B.J. Medical College, Ahmedabad between September 2020 to July 2021. The approval of the institutional ethical committee and local health authority was obtained prior to the study. Sample size of 139 determined for convenience. As per the data obtained from local health authority there were approximately 15,000 households with 73,000 population in Asarwa Urban Health Centre (UHC). Households in this UHC are distributed among 16 Accredited Social Health Workers (ASHA workers) to cater for the health needs of people, approximately 1000 households for each ASHA. Stratified - proportionate sampling was conducted by considering the population of ASHA worker's areas in relation to the total population of Asarwa ward, subsequently 6 to 10 households from each ASHA worker's area were selected randomly.

After taking informed consent and explaining the purpose of the study, 3 water samples were collected from each household. From the storage containers for drinking water, 1000 ml was collected in a plastic bottle for physicochemical analysis; 200 ml and 20 ml were collected in an air-tight sterile glass container for microbiological examination; by using standard water collection techniques.[12-14] Collected samples were transported in the icebox to medical college. The physicochemical and microbiological analysis was performed on the same day using standard techniques as per available calibrated instruments mentioned in Table-1, available in postgraduate research laboratory in the community medicine department. Parameters such as colour, odour, test, temperature, turbidity, pH, conductivity, TDS, total hardness, calcium, magnesium, chloride, sulphate, total alkalinity, free residual chlorine, and chlorine demand were measured and recorded.

Qualitative bacteriological analysis was done by strip method in the postgraduate research laboratory of the community medicine department. For quantitative bacteriological analysis, samples were sent to the microbiological laboratory of the attached medical college within two hours. Multiple tube test was performed on each sample to detect coliform organisms by the Most Probable Number (MPN) method. Water samples with coliform ≥1 cfu/100 ml were considered non-acceptable for drinking purpose.[15] Water samples which were positive by microbiological method were informed to the Medical Officer and public health supervisor of the respective areas for necessary action.

The microbiological analysis was performed by qualitative and quantitative methods. Results were compared with local guidelines issued by the Water And Sanitation Management Organization (WASMO),[16] W.H.O. water quality standards,[17] European standards[18] and BIS/ICMR guideline.[19]

Table 1: Parameter tested and analytical method[14,19]

Type of Parameters	Parameters	Methods
Physicochemical	Temperature	Thermometer
	Colour	Visual comparison
	Odour	Smelling
	Taste	Tasting
	pH	pH strip
	Turbidity	Turbidity Scale
	TDS	TDS meter
	Conductivity	Digital conductivity
	Total Hardness	Titrimetric method
	Calcium	
	Magnesium	
	Chlorine	
	Total alkalinity	
	Sulphate	Gravimetric method
	Free residual chlorine	Chloroscope
Microbiological	Microbiological	By Strip (Qualitative)
	Microbiological	By MPN (Quantitative)

Results:

Table 2 shows that out of 139 samples, 42% of samples were outside the limit of criteria set by a state authority (WASMO) with a mean TDS value of 456.18±158.53. 47% of samples reported total alkalinity outside the limit with a mean value of 200.8±64.48.

Total hardness is greater than recommended in 5% of samples, while magnesium is higher in 5% of samples. In 5% and 1% of the samples, pH and turbidity were found to be changed, respectively. The colour, odour, and taste are altered in one sample. All the samples' temperature, calcium, chloride, and sulphate levels are within normal limits.

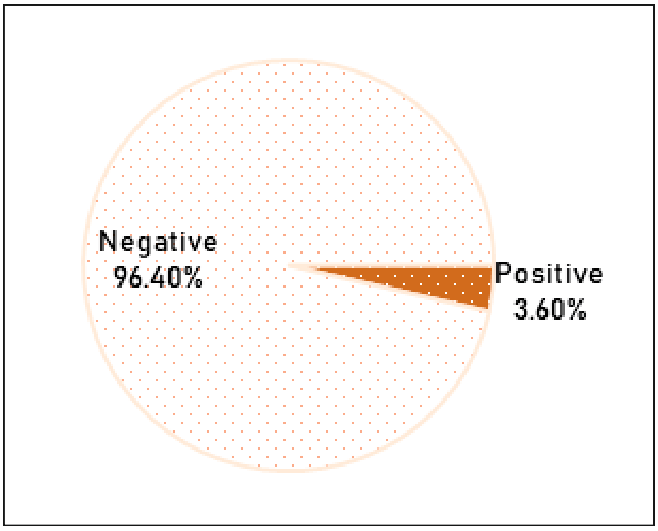
In 91% of samples, the test result of free residual chlorine was less than 0.2 mg/L with a mean value of 0.05±0.08.

Figure 1 shows that out of 139 samples, 5 (3.6%) were positive for the coliform organism. Three samples were positive by qualitative and four by quantitative method while 2 samples were positive by both methods.

Table 2 : Physicochemical analysis of drinking water in study households (N=139)

Sr No	Parameter (Unit)	Range	Mean±SD	Sample outside of the permissible limit of WASMO criteria
1	Temperature (C)	25-31	28.71±1.67	0 (0%)
2	Turbidity (NTU)	0-20.8	0.15±1.77	1 (1%)
3	pH	7-9	7.88±0.46	7 (5%)
4	Conductivity (µS/cm)	287-1540	745.37±259.51	13 (9%)
5	TDS (mg/L)	175-951	456.18±158.53	59 (42%)
6	Total hardness (mg/L)	100-228	158.3±23.44	7 (5%)
7	Calcium (mg/L)	8-48	25.42±8.27	0 (0%)
8	Magnesium (mg/L)	7-87	18.61±8.26	7 (5%)
9	Chloride (mg/L)	48-232	116.87±34.52	0 (0%)
10	Sulphate (mg/L)	17-198	73.72±32.22	0 (0%)
11	Total alkalinity (mg/L)	100-460	200.8±64.48	65 (47%)
12	Free residual chlorine (ppm)	0-0.5	0.05±0.08	126 (91%)

Figure 1 : Microbiological analysis of drinking water in study households (N=139)



Discussion:

A safe water supply is the backbone of a healthy economy, yet is woefully prioritized, globally. Water that can be delivered to a user and is safe for drinking, food preparation, personal hygiene, and washing is known as safe drinking (potable) water.[20] Changes in water quality are reflected in its physical, biological, and chemical conditions; and these, in turn, are influenced by physical and anthropogenic activities.[21]

This study assessed the physicochemical and microbiological qualities of drinking water in the slum of urban field practice area of the community medicine department. In most of the households studied, drinking water was supplied by a municipal corporation on a daily basis and stored in an earthen pot at the household level.

The appearance, taste, and odour of drinking water should be acceptable to the consumer. Aesthetically unacceptable water can lead to the use of water from sources that are aesthetically more acceptable, but potentially less safe.[17] This study found that one sample had an altered appearance, taste, and odour.

All samples in this study had a temperature in the normal range. Cool water is generally preferable to warm water, and temperature influences the acceptability of a variety of other inorganic constituents and chemical contaminants that may affect the taste. High water temperatures promote the growth of microorganisms and may exacerbate issues with taste, odour, colour, and corrosion.[17] One sample was found to be turbid. Visible turbidity reduces the acceptability of drinking water.

Table 3 : Comparison of this study's Findings in Relation to Guidelines from BIS, and the EU(N=139)

Sr No	Parameter (Unit)	Mean	SD	BIS standard (WASMO)[19]	WHO Guideline[17]	EU[18]
1	Temperature (C)	28.71	1.67	-	-	-
2	Turbidity (NTU)	0.15	1.77	1	-	-
3	pH	7.88	0.46	6.5 to 8.5	6.5 – 8.5*	6.5 to 9.5
4	Conductivity (µS/cm)	745.37	259.51	1000	-	2500
5	TDS (mg/L)	456.18	158.53	500	600*	-
6	Total hardness (mg/L)	158.3	23.44	200	500*	-
7	Calcium (mg/L)	25.42	8.27	75	-	-
8	Magnesium (mg/L)	18.61	8.26	30	-	-
9	Chloride (mg/L)	116.87	34.52	250	250*	250
10	Sulphate (mg/L)	73.72	32.22	200	250*	250
11	Total alkalinity (mg/L)	200.8	64.48	200	-	-
12	Free residual chlorine (ppm)	0.05	0.08	0.2 to 0.5		

** No health-based guideline proposed.*

The mean pH of the samples in this study was 7.88. Although pH has no direct impact on water consumers, it is one of the most important operational water quality parameters. The pH should ideally be less than 8.0 for effective chlorine disinfection.[22] The mean TDS was 456.18 mg/L. The presence of high levels of TDS in drinking water may be objectionable to consumers.[17] Total dissolved solids (TDS) are inorganic salts dissolved in water (Primarily calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates) and small amounts of organic matter.[23]

In this study 95% and 58% of samples were within the satisfactory limit for pH and TDS respectively. Palit A et al[24] reported more than 90% of samples did have satisfactory pH and TDS when collected at stored and at the source level.

The mean alkalinity in samples was 200.8 mg/L. Total alkalinity is a measurement of the concentration of all alkaline substances dissolved in the water that can both attract and release Hydrogen ions (H^+). It is primarily bicarbonate, carbonate, and hydroxide, along with a few others like cyanurate alkalinity. When acid is added to water, these alkalis can neutralize some of the acids and resist a reduction in pH. Although alkaline water is generally considered safe to drink, there isn't any evidence to suggest it has health benefits.[17]

Pure water is a good insulator rather than a good conductor of electric current. An increase in ion concentration increases water's electrical conductivity.[25] The mean conductivity was 745.37 µS/cm.

In this study, the level of total hardness, calcium and magnesium were 158.3 mg/L, 25.42 mg/L and 18.61 mg/L respectively. Calcium and magnesium cause hardness. The degree of hardness of water that is acceptable to the general public varies greatly from one community to another. It is significant in household usage; however, no health-based guideline value for hardness in drinking water is proposed.[17]

The mean chloride level in this study was 116.87 mg/L. Chloride in drinking water comes from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt, and saline intrusion. Excessive chloride concentrations, depending on the alkalinity of the water, enhance the rates of corrosion of metals in the distribution system. This can result in higher metal concentrations in the supply. There is no health-based recommendation value of chloride in drinking water but concentrations over 250 mg/L can cause a perceptible taste in water. (Table 3)

Sulphate in drinking water can have a detectable taste, and very high amounts can have a laxative impact on unaccustomed consumers. All samples in this study had sulphate in a normal range. (Table 3)

Chlorination is a very important process of water treatment that decreases the microbial load of drinking water and makes it safer for consumption.[26] The presence of free residual chlorine in water protects against reinfection from the point of chlorination to the point of use.[27] In this study 91% of samples didn't have adequate chlorine level. Palit A et al[24] reported that 30% of stored water didn't have adequate chlorine level. Though the mean value was 0.05 ppm, the lower level in this study could be due to the type of container, and frequency of adding/ removing water into containers. In General, by storage of water, free residual chlorine decreases.

In this study, coliform organisms were detected in 3.6% of the samples. Unsafe water can cause diarrhoeal diseases in consumers. This study didn't differentiate between contamination of drinking water at the source or at point-of-use. A study by Eschol J et al & Palit A et al revealed that dirty hands contaminate drinking water at point-of-use, adding to microbial contamination.[24,28]

A study by Palit A et al and Jensen et al reported that heavy faecal contamination can occur when the water is stored at the household level.[24,29]

This study was done as part of establishing a biophysical and microbiological testing facility for drinking water at a postgraduate research laboratory in Community Medicine Department. This initiative will be very helpful for resident doctors to learn epidemiological skills related to water. The laboratory could also be utilized to train other medical and paramedical workers. It will also supplement ongoing water quality monitoring and surveillance of diarrhoeal disease by a local health authority.

Limitations:

This was a cross-sectional study which didn't check the effect of seasons on the quality of drinking water. Our postgraduate research laboratory is in the developmental phase with limited resources hence lacking the necessary equipment to detect fluorides, nitrates, and arsenic in drinking water.

Conclusion:

Except for total alkalinity and TDS, most physicochemical parameters of drinking water are acceptable. By storing water, a low level of free residual chlorine can be justified. A few samples with coliform bacteria indicate water contamination somewhere in the distribution system or at the consumer level. The study emphasises additional protective measures like proper storage and handling at the household level.

Declaration:

Funding: Nil

Conflict of Interest: Nil

References:

1. Sharma S, Bajracharya RM, Sitaula BK, Merz J. Water quality in the Central Himalaya. Current Science. 2005 Sept; 89(5):774–9.
2. Park K. Park's Textbook of Preventive and Social Medicine. 25th ed. Jabalpur: Bhanot; 2019.
3. Ikonen JM, Hokajärvi AM, Heikkinena J, Pitkänen T, Ciszek R, Kolehmainen M, et al. Drinking water quality in distribution systems of surface and ground waterworks in Finland. Journal of Water Security. 2017;3:1-10. doi:10.15544/jws.2017.004
4. Geldreich EE. Drinking water microbiology—new directions toward water quality enhancement. Int J Food Microbiol 1989 Dec;9(4):295–312. doi:10.1016/0168-1605(89)90098-6
5. Wu J, Li P, Qian H, Duan Z, Zhang X. Using correlation and multivariate statistical analysis to identify hydrogeochemical processes affecting the major ion chemistry of waters: a case study in Laoheba phosphorite mine in Sichuan, China. Arabian Journal of Geosciences. 2013 Aug;7:3973–82. doi:10.1007/s12517-013-1057-4
6. Mostafa AH, Al-Wasify RS, Sayed AM, Haroun BM. Microbiological and Physicochemical Evaluation of Groundwater in Egypt. International Journal of Environment and Sustainability. 2014 Mar;2(2):1-10.

7. Khurana I, Sen R. Drinking water quality in rural India: issues and approaches. WaterAid. 2008.
8. Shah PN. Safe and Secure Water Supply in Slum/Chali. [Internet]. CEPT University; 2024 [cited 2024 Feb 5]. Available from: https://portfolio.cept.ac.in/2021/M/fp/infrastructure-project-studio-ui4001-monsoon-2021/safe-and-secure-water-supply-in-slum-chali-monsoon-2021-pui20233
9. NITI Aayog (India). Composite Water Management Index. New Delhi (India) 2019. Available at: https://social.niti.go v.in/uploads/sample/water_index_report2.pdf.
10. Urban Management Centre. Standard Operating Procedure (SOP) for Routine Water Quality Surveillance in ULBs in Gujarat. Urban Management Centre. n.d.
11. Ahmedabad Municipal Corporation. Central laboratory, Engineering department [cited February 5, 2024] Available from: https://ahmedabadcity.gov.in/StaticPage/viewWaterQuality
12. Cheesbrough M. District Laboratory Practice in Tropical Countries. vol. 2. 2nd ed. Cambridge: Cambridge University Press; 2006.
13. United States Environmental Protection Agency. Quick Guide To Drinking Water Sample Collection. 2nd edition. Denver: United States Environmental Protection Agency; 2016.
14. WHO. Guidelines for drinking-water quality: volume 3: drinking-water quality control in small-community supplies. Geneva: World Health Organization; 1985.
15. Walter WilliamG. Standard methods for the examination of water and wastewater (11th ed.). Am J Public Health Nations Health. 1961 Jun;51(6):940. doi: 10.2105/AJPH.51.6.940-a.
16. WASMO. [Internet] Water and Sanitation Management Organisation [cited 2022 Sept 15]. Available from: https://wasmows.gujarat.gov.in/
17. WHO. Guidelines for Drinking-water Quality. 4th ed. Geneva: World Health Organization; 2022.
18. Directive (EU) 2020/2184 of the European parliament and of the council of 16 December 2020 on the quality of water intended for human consumption (recast). Official Journal of the European Union 2020.
19. Bureau of Indian Standard. Indian Standard - Drinking water – Specification - IS 10500 : 2012. New Delhi: 2012.
20. Bos R, Roaf V, Payen G, J. Rousse M, Latorre C, McCleod N, et al. Manual on the Human Rights to Safe Drinking Water and Sanitation for Practitioners. Water Intelligence Online. 2016 Jul;15:120. doi:10.2166/9781780407449.
21. Diwakar J, Yami KD, Prasai T. Assessment of Drinking Water of Bhaktapur Municipality Area in Pre-Monsoon Season. Scientific World. 2008;6(6):94–8. doi: 10.3126/sw.v6i6.2642
22. Water treatment and testing [Internet]. Centers for Disease Control and Prevention; 2022 [cited 2022 May 20]. Available from: https://www.cdc.gov/zhealthywater/swimming/residential/disinfection-testing.html
23. Total Dissolved Solid - an overview [Internet] ScienceDirect Topics [cited 2022 May 26]. Available from: https://www.sciencedirect.com/ topics/engineering/total-dissolved-solid.
24. Palit A, Batabyal P, Kanungo S, Sur D. In-house contamination of potable water in urban slum of Kolkata, India: a possible transmission route of diarrhea. Water Science and Technology 2012;66(2):299–303. doi: 10.2166/wst.2012.177.
25. Conductivity: Water Quality Assessment. [Internet] IJERT. [cited 2022 May 26] Available from: https://www.ijert.org/conductivity-water-quality-assesment.
26. Centers for Disease Control and Prevention; 2020 [cited 2022 May 26]. Available from: https://www.cdc.gov/healthywater/drinking/public/water_disinfection.html
27. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Chlorinated Drinking-Water; Chlorination by-Products; Some Other Halogenated Compounds; Cobalt and Cobalt Compounds. Lyon (FR): International Agency for Research on Cancer; 1991. (IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, No. 52.) Available from: https://www.ncbi.nlm.nih.gov/books/NBK506913/
28. Eshcol J, Mahapatra P, Keshapagu S. Is fecal contamination of drinking water after collection associated with household water handling and hygiene practices? A study of urban slum households in Hyderabad, India. Journal of Water and Health. 2009 Mar;7(1):145–54. doi: 10.2166/wh.2009.094.
29. Jensen PK, Ensink JH, Jayasinghe G, van der Hoek W, Cairncross S, Dalsgaard A. Domestic transmission routes of pathogens: the problem of in-house contamination of drinking water during storage in developing countries. Trop Med Int Health. 2002 Jul;7(7):604-9. doi: 10.1046/j.1365-3156.2002.00901.x.