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IJC MBT INTERNATIONAL JOURNAL OF CLINICAL MICROBIOLOGY AND BIOCHEMICAL TECHNOLOGY

Research Article

Physicochemical and microbiological quality of tanker waters in Bengaluru urban for safe water supply

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Abstract

This study investigated the water quality of tanker waters that was collected from Bengaluru urban areas to assess its suitability for domestic purpose. A total of 50 samples were collected in dry (March 2019) season. All samples were analyzed for various hydrochemical parameters, such as pH, total dissolved solids (TDS), electrical conductivity (EC), turbidity, dissolved oxygen (DO), total hardness (as $CaCO_3$), calcium (Ca^{2+}), chloride (Cl^-) and nitrate (NO_3^-). Bacteriological analyses of water samples were analyzed for total coliform count. A very high level of total hardness (186 - 434.6 mg L^{-1}) was determined in 27 water samples tested in this study indicating the necessity of water treatment before used for domestic purpose. Of the 50 samples tested, 7 showed a most probable number (MPN) index of < 23 and 9 showed < 240 and the remaining 34 were unsatisfactory with an MPN index of > 1600 per 100 ml. In some locations, the presence of high MPN index, in particular, rings the bell before using the tanker water in houses and restaurants. Exploration of the mechanisms by which water quality deteriorates during supply chain and potential implication for regulatory policy for monitoring of tanker water while distribution is the need of the hour.

More Information

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Submitted: 18 April 2020
Approved: 08 May 2020
Published: 11 May 2020

How to cite this article: Joseph J, Sibi G. Physicochemical and microbiological quality of tanker waters in Bengaluru urban for safe water supply. Int J Clin Microbiol Biochem Technol. 2020; 3: 021-025.

DOI: 10.29328/journal.ijcmbt.1001011

Keywords: Tanker water; Pumping wells; Water scarcity; Water quality; Urban water supply

Introduction

Water is an essential vital source for the sustainability of life, without which life is not possible. Increased population growth and economic development has caused excessive exploitation of water resources [1-3]. As a result of water demand spurred by population growth, urban water distribution systems are increasingly under stress [4,5]. Point sources of water such as bore wells, dug wells and protected springs represent a significant proportion of water supplies in water scarcity areas. Many people around the world rely on water supplied by tankers [6] and in many cases, the consumer will not be aware of the source of the water [7]. Water must be free of contamination at the time of sampling, as well as free from risk of future contamination [8]. Private water tankers have become more prominent in the water delivery supply chain which makes it especially challenging to ensure water quality and prevent the spread of waterborne illness. Previous studies considered the impact of water quality on human health [9,10]. Presence of coliform bacteria were detected in tanker water supplied water in earlier studies.

With the population of Bengaluru city growing rapidly from 8.3 million in 2010 to 12.3 million in 2020 with a growth rate of 3.5% annually. Ground water is the main water resource along with Kaveri water in Bengaluru urban. The aquifer is intensively exploited through lakhs of pumping wells in Bengaluru. As a result of intensive exploitation, groundwater table level has rapidly decreased. Water tankers are a common mean of transporting water in Bengaluru urban areas lacking infrastructure or deprived of water sources. Limited water supply, apartments, multistory buildings, commercial areas, restaurants, shopping malls, function halls and areas that do not receive water from the public network purchase water through water tankers which remains a common practice in urban areas. Water tankers transport the water from unregulated private wells as well as lakes located mostly at the outskirt of the city. Water distribution by tankers due to water shortages is largely unregulated causing health risks and economic burdens. Bacterial contamination in tanker water could be attributed to inadequate water disinfection treatments [11]. Evaluation of tanker water quality can act as a monitoring tool for safe water quality for domestic purposes. The main intentions of this study are (1) to present the physicochemical characteristics of tanker water (2) evaluate the water quality in terms of coliforms.

Materials and methods

Study area and sample collection

Bengaluru has a total geographical area of 709 km^2

extending between Coordinates 12.9716° N, 77.5946° E. Tankers carrying water from various sources during dry season (March) of 2019 were included in the study and the samples were collected at the time of water distribution to various localities of Bengaluru urban. Dry season was considered as there is a huge demand for tanker water supply due to shortage of water in Bangalore during the period. Sample collection points were chosen based on high population, commercial and residential areas. A total of 50 water samples were taken from water tankers at different sample locations (SL-1 to SL-50) and for sample collection, autoclaved 1 L plastic bottles were used.

Water sample analysis

All samples were analyzed for various hydrochemical parameters, such as pH, total dissolved solids (TDS), electrical conductivity (EC), turbidity, dissolved oxygen (DO), total hardness (as $CaCO_3$), calcium (Ca^{2+}), chloride (Cl^-) and nitrate (NO_3^-). Electrical conductivity and pH were measured directly using the conductivity meter and pH meter (Elico). NO_3^- was determined by ion chromatography, and HCO_3^- was determined by alkalinity titration. For dissolved oxygen (DO), Winkler's method was followed and chloride was determined through Argentometric method. The Total hardness, and Ca^{2+} were analyzed by a titrimetric method using EDTA [12]. Nitrates were estimated by Brucine method [13]. Bacteriological analyses of water samples were analyzed for total coliform in duplicate samples by most probable number (MPN) method.

Statistical analysis

Student's t-test was used to test for statistically significant differences in the physicochemical parameters of water samples. All data were expressed as means ± standard deviations. The p-values were checked to analyze whether the parameters differed significantly by using Graphpad Instat software. A p – value < 0.05 was considered to be statistically significant.

Results and discussion

Assessment of water quality is a timely requirement where availability of safe water is at risk due to tanker water supply. The present work is an exploratory study contributing to improving tanker water quality in Bengaluru. Water samples were collected from tanker waters at the time of distribution at different sample locations (SL-1 to SL-50). The study findings revealed that the tanker water was slightly alkaline as 26 out of 50 tested samples were above pH 7. The increased pH of the water could be due to as most of the water tankers collect water from tube wells which contain dissolved minerals from the soil and rocks [14]. Water with high and low pH causes irritation in eyes, skin and mucous membranes [15].

Conductivity values of the ground water samples are presented in tables 1,2. Electrical conductivity gives an indication of the amount of total dissolved substitution in water [16]. Values recorded ranged from 58 - 1660 μS cm^{-1}, meanwhile, the least conductivity values were observed for sample collected

Table 1: Physicochemical characteristics of tanker water (SL-1 to SL-25). Data expressed as mean ± SD.

Sample	pH	EC μs cm^{-1}	Turbidity NTU	TDS mg L^{-1}	DO mg L^{-1}	Hardness mg L^{-1}	Calcium mg L^{-1}	Chloride mg L^{-1}	Nitrate mg L^{-1}
SL-1	7.76	825	0	400	6.1744	186.9	74.928	123.507	0.92
SL-2	6.82	861	0	200	6.9008	169.1	67.928	114.007	2.88
SL-3	5.82	1266	0	400	6.5376	311.5	17.84	237.515	1.4
SL-4	6.2	176	0	Trace	5.8112	44.5	124.88	19.001	1.36
SL-5	6.62	148.8	0	200	6.5376	35.6	14.272	19.001	1.38
SL-6	6.69	201	0	200	6.1744	44.5	17.84	28.502	1.06
SL-7	7.41	701	0	200	4.8	187.32	74.92	73.876	0.58
SL-8	7.89	657	1	600	5.91	151.64	60.65	73.86	0.46
SL-9	7.23	364	0	400	6.28	71.36	28.54	46.163	2.24
SL-10	7.33	207	0	400	7.392	44.6	17.84	27.697	0.78
SL-11	7.61	907	0	600	5.54	214.08	85.63	92.326	4.24
SL-12	7.24	1174	1	1000	3.32	169.48	67.79	203.117	0.72
SL-13	7.61	1289	1	800	3.872	312.2	124.88	142.509	2.28
SL-14	7.06	193	1	Trace	4.928	35.68	14.27	28.501	0.62
SL-15	6.78	275	2	Trace	4.928	62.44	24.97	28.501	0.78
SL-16	7.05	1501	0	800	4.224	276.52	110.6	171.01	13.12
SL-17	8.33	614	0	200	5.632	124.88	49.95	47.503	6.16
SL-18	6.94	1660	4	1600	3.872	258.68	103.47	199.512	5.84
SL-19	7.46	478	1	400	4.634	98.12	39.24	96.3	0.037
SL-20	7.03	473	0	200	5.517	107.04	42.81	50.76	0.097
SL-21	6.88	976	0	600	3.589	187.32	74.92	128.56	0.213
SL-22	7.41	324	0	200	1.56	62.44	24.97	140.56	0.065
SL-23	6.82	913	0	Trace	4.227	231.92	92.76	129.54	0.07
SL-24	6.88	487	0	200	2.562	115.96	46.38	486.8	0.055
SL-25	7.36	836	1	600	3.946	223	89.2	160.4	0.43

SL1- Indira Nagar; SL2- Koramangala; SL3- Kudlu Gate; SL4- Richmond Town; SL5- B.T.M 2nd Stage; SL6- Double Road; SL7- Forum Mall, White Field ; SL8- Koramangala Water Tank; SL9- BBMP Neelasandra; SL10- Koramangala 5th Block; SL11- Sarjapur; SL12- Sadaramangala Lake; SL13- Marathalli; SL14- Majestic; SL15- Richmond Road; SL16- White Field ; SL17- B.T.M 1st Stage; SL18- Silk Board; SL19- Wilson Garden; SL20- Lalbagh West Gate; SL21-Cottonpet; SL22-8th Cross Nanjappa Circle; SL23-Shamanna Garden; SL24- Berlie's Street ; SL25- Tavarekere.

Table 2: Physicochemical characteristics of tanker water (SL-26 to SL-50). Data expressed as mean ± SD.

Sample	pH	EC µs cm-1	Turbidity NTU	TDS mg L-1	DO mg L-1	Hardness mg L-1	Calcium mg L-1	Chloride mg L-1	Nitrate mg L-1
SL-26	7.17	1120	0	600	5.906	240.84	96.33	111.23	0.083
SL-27	6.48	566	0	400	1.816	98.12	39.24	76.004	0.11
SL-28	6.58	1134	0	800	3.632	356.8	142.72	133.008	0.3
SL-29	6.82	942	0	600	4.358	240.84	96.33	114.007	0.085
SL-30	7.62	389	1.5	600	2.542	133.8	53.52	475.03	0.052
SL-31	7.34	1131	3	600	6.99	253.16	101.26	161.51	0.64
SL-32	7.67	1278	3.4	1000	2.94	297.463	118.98	152.01	1.94
SL-33	7.41	1497	0	1000	2.57	316.45	126.58	228.02	1.88
SL-34	7.23	1090	0	1000	4.416	371	245.5	382.05	4.16
SL-35	6.54	884	1	600	3.68	243.8	143.9	293.06	10.8
SL-36	6.98	704	1	200	5.888	222.6	167.2	401.3	8.64
SL-37	6.66	822	0	600	4.048	254.4	186.9	398.15	2.02
SL-38	7.4	1217	1.5	800	3.68	434.6	299.4	293.06	1.06
SL-39	6.74	785	0	400	4.048	275.6	154.6	398.15	7.96
SL-40	6.53	90	1	Trace	4.8	37.72	16.6	399.9	1.86
SL-41	5.74	90	0	Trace	5.91	37.72	17.5	154.6	1.64
SL-42	5.57	58	0	Trace	5.54	18.86	8.6	234.7	2.28
SL-43	6.74	988	3	400	3.31	226.32	145.2	169.3	1.92
SL-44	5.79	633	0	400	2.2	75.44	38.6	153.9	0
SL-45	7.56	471	1	200	6.256	103.73	66.2	135.7	1.7
SL-46	7.86	1500	0	5200	2.354	330.05	132.02	199.51	2.08
SL-47	7.78	1250	0	1000	2.041	320.62	128.24	142.5	1.6
SL-48	7.51	1250	0	2400	1.238	235.75	94.3	142.5	Trace
SL-49	6.27	1059	0	Trace	3.782	18.86	7.54	9.5006	2.02
SL-50	5.13	355	0	Trace	5.923	Trace	Trace	19.001	1.7

SL26- Nanjappa Circle; SL27- Cox Town; SL28- Kammannahalli; SL29- Brigade Road; SL30- ITC Garden; SL31- Sakra World Hospital; SL32- Bellandur Outer Ring Road; SL33- Bellandur Main Road; SL34- Majestic; SL35- Residency Road; SL36- Vijayanagar; SL37- Malleshwaram Circle; SL38- Nagarabhavi 2nd Stage; SL39- Koramangala 6th Block; SL40- Ejipura Signal; SL41- Ejipura 14th Cross; SL42- Ejipura Main Road; SL43- Lingarajapuram; SL44- Thimmaiah Garden; SL45- Adugodi; SL46- Kudlu Road; SL47- Agara Lake; SL48- HSR Layout; SL49- Food World, Nanjappa Circle; SL50- Anepalya.

at SL-42. Turbidity levels of the water samples were within the range of recommended levels. Water containing TDS less than 1000 mg L^{-1} could be considered good enough both for drinking and irrigational purposes [17,18]. In this study, most of the water samples tested were within the limits except SL-46, SL-48 and SL-18 which recorded 5200, 2400 and 1600 mg L^{-1} respectively.

Dissolved oxygen (DO) assesses the waste assimilative capacity of the waters [19]. The estimation of DO content in water samples tested revealed that 20 out of 50 samples were having very low DO level (< 4 mg L^{-1}). In general, DO should be between 4 and 6 mg L^{-1} [20,21] however environmental impact of dissolved oxygen concentration in water should not exceed above 13-14 mg L^{-1} [22] as it varies from place, time and temperature. Lower DO levels in the tested samples indicated the water pollution at the source point.

The concentration of urinary calcium increases when the intake of hardwater increases [23]. Among the other adverse effects of hard water are sensory properties, formation of coatings on the surface, and the loss of aromatic substances caused by binding with Ca carbonate [24]. Water containing calcium carbonate at concentrations more than 180 mg L^{-1} is generally considered as very hard [25]. A very high level of total hardness (186 - 434.6 mg L^{-1}) was determined in 27 water samples tested in this study indicating the necessity of water treatment before used for domestic purpose.

Groundwater contains Ca mainly by rock weathering and ion exchange [26]. A wide range of Ca^{2+} content of the water samples was observed in this study with a lowest content of 7.54 mg L^{-1} in SL-49 and 299.4 mg L^{-1} in SL-38. Chlorides resulting from combination of chlorine gas with metals may get into surface water from several sources and the public drinking water standards require chloride level not to exceed 250 mg L^{-1} [22]. Higher content of chlorides can corrode metals and affect the taste of food products. In this study, 9 out of 50 samples (18%) had higher chloride content in the range of 293.06 - 486.8 mg L^{-1} indicating that those sample locations cannot use the water for drinking purpose. Nitrate is one of the ground water pollutants due to chemical fertilizers and excessive nitrate has been reported to cause health implications [27-29]. Nitrate levels of water samples varied from 0.037-13.12 mg L^{-1} with a mean of 2.08 mg L^{-1}. According to the levels of nitrate risk defined by Adimalla and Qian [30], nitrate levels of the tested samples were at very low risk levels.

Human health and development depend on the access to safe water [31,32]. The presence of large number of coliforms in water is an indication of fecal contamination and is a matter of concern to consumers, water suppliers and public health authorities. The microbiological quality of water samples was therefore analyzed using MPN (most probable number) test and the results were depicted in table 3. MPN index of water samples which tested satisfactory was < 23 per

Table 3: MPN Analysis of Water Samples.

Sample	+ve tubes	MPN Index	Sample	+ve tubes	MPN Index
SL-1	5 – 5 – 5	≥ 1600	SL-26	5 – 5 – 5	≥ 1600
SL-2	5 – 5 – 5	≥ 1600	SL-27	5 – 5 – 5	≥ 1600
SL-3	5 – 5 – 0	240	SL-28	5 – 5 – 5	≥ 1600
SL-4	5 – 5 – 5	≥ 1600	SL-29	5 – 5 – 0	240
SL-5	5 – 0 – 0	23	SL-30	5 – 5 – 5	≥ 1600
SL-6	5 – 5 – 5	≥ 1600	SL-31	5 – 0 – 0	23
SL-7	5 – 5 – 5	≥ 1600	SL-32	5 – 5 – 5	≥ 1600
SL-8	5 – 5 – 5	≥ 1600	SL-33	5 – 5 – 5	≥ 1600
SL-9	5 – 5 – 5	≥ 1600	SL-34	5 – 5 – 5	≥ 1600
SL-10	5 – 0 – 0	23	SL-35	5 – 5 – 0	240
SL-11	5 – 0 – 0	23	SL-36	5 – 5 – 5	≥1600
SL-12	5 – 5 – 5	≥ 1600	SL-37	5 – 5 – 5	≥ 1600
SL-13	5 – 5 – 0	≥ 1600	SL-38	5 – 5 – 5	≥ 1600
SL-14	5 – 5 – 5	≥ 1600	SL-39	5 – 5 – 5	≥ 1600
SL-15	5 – 5 – 5	≥ 1600	SL-40	5 – 5 – 0	240
SL-16	5 – 5 – 5	≥ 1600	SL-41	5 – 0 – 0	23
SL-17	5 – 5 – 0	240	SL-42	5 – 5 – 5	≥ 1600
SL-18	5 – 0 – 0	23	SL-43	5 – 5 – 5	≥ 1600
SL-19	5 – 5 – 0	240	SL-44	5 – 0 – 0	23
SL-20	5 – 5 – 5	≥ 1600	SL-45	5 – 5 – 5	≥ 1600
SL-21	5 – 5 – 0	240	SL-46	5 – 5 – 5	≥ 1600
SL-22	5 – 5 – 5	≥ 1600	SL-47	5 – 5 – 5	≥ 1600
SL-23	5 – 5 – 0	240	SL-48	5 – 5 – 5	≥ 1600
SL-24	5 – 5 – 5	≥ 1600	SL-49	5 – 5 – 0	240
SL-25	5 – 5 – 5	≥ 1600	SL-50	5 – 5 – 5	≥ 1600

100 ml and MPN index of water samples which were graded as unsatisfactory ranged from 23 to > 1600 per 100 ml. Of the 50 samples tested, 7 showed an MPN index of < 23 and 9 showed < 240 and the remaining 34 were unsatisfactory with an MPN index of > 1600 per 100 ml. In Bengaluru, tanker waters are purchased for various purposes such as household, domestic, restaurants, commercial complexes and construction purposes. Considering the use of tanker waters in houses and restaurants, the observation of high MPN index in the tested water samples necessities its restricted use. Further supply of tanker water should be stringent towards safe distribution from sample point to the receiving end as the water is used for various purposes without any limitations.

Conclusion

In conclusion, most of the water samples collected from various sample locations were satisfactory for domestic use and the physicochemical properties were within the permissible limits. However, in some locations, the presence of high MPN index, in particular, rings the bell before using the tanker water in houses and restaurants. Though the water is of good quality at the time of collection, there are chances for contamination during the supply chain. Exploration of the mechanisms by which water quality deteriorates and potential implication for regulatory policy for monitoring of tanker water while distribution is the need of the hour. Such policies should be developed and implemented in a manner that takes into account the safety of tanker waters for consumption while expanding the water supple area.

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