



Assessment of Drinking Water Quality of Bangalore West Zone, India - a case Study

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Abstract

Assessment of drinking water quality was carried out at Bangalore city and samples were collected from different parts of Bangalore west zone ward wise namely Rajarajeshwari nagar, Vijayanagar, Rajajinagar, Nagarbhavi. The Results showed that 26% of the samples exceeded with permissible limits for BOD. (Vijaynagar (5.6mg/L), Agrahara Dasarahalli, Manjunatha Nagar (5.0mg/L), Mahalakshmi Layout (6.8mg/L), Jyoti Nagar (4.8mg/L), Kamashipalya (12.0mg/L), Mysore Road (3.0mg/L)). Highest variation of COD values recorded in the study. About 60% of the total samples showed total dissolved solids levels above the desirable limit of 500mg/L. About 60% of the samples showed above desirable limit of drinking water standard values for TDS. This may be due to different topography, water distribution system and impact of domestic water pollution which imparts in water quality. Drinking water contaminated by human or animal waste and also due to breakage of pipelines.

Key words: Drinking water quality, water distribution system, biological oxygen demand, chemical oxygen demand, total dissolved solids

Introduction

Water contamination due to pathogenic agents, chemicals, heavy metals, pesticides, water disinfectants and their by-products as a consequence of industrial and agricultural activities, leaching from soil, rocks and atmospheric deposition and other human activities has become an environmental risk leading to hazard of human health in several regions of the world. Several chemicals are being introduced into water bodies or aquifers usually as a consequence of leaching from soil, rock or via atmospheric deposition, through the dissolution of mineral/ores, industrial effluents and agricultural run off. Due to indiscriminate withdrawal of ground water causes deterioration of groundwater quality (Klimas and Gregorauskas, 2002).

Water quality surveillance is an activity which independently verifies whether the water being supplied to community is in fact, safe or not and whether all aspects relevant to supply of safe water are being considered by supplies, or not. The goal of Millennium Declaration made by UN in September 2000 represents a partnership between the developed and the developing countries. The goal is to ensure environmental sustainability, primarily water and sanitation, the quality that is accepted by WHO and UNICEF (Lodhia, 2006). In India, urban areas access to drinking water considered safe by Government's standards arose from about 82% of the population in 1991 to 90% in 2001, this figure which includes access to non-piped water could rapidly reach 100% by 2007 (Ministry of Urban Development, 2001). Bacteriological examination of drinking water studied at Bhurdwan (India) showed that Municipal tap water was safe for drinking when compared to other source of water like sweet shops, mobile vendors Chatterjee *et al.* (2007). Drinking water distribution system of Bangalore North was studied by Nandini (2006), Assessment of Drinking water quality of Delhi, India was studied by Bisht (2007), physico-chemical properties of ground water studied for Kaithal City (Haryana) India by Gupta *et al.* (2009), and water quality index for ground water was studied by Rajankar *et al.* (2009). The present paper reveals about the drinking water quality of Bangalore Urban district with respect to wardwise water quality with physico-chemical and bacteriological analysis.

Materials and Methods

Study area

Bangalore District is located in the heart of South-Deccan Plateau in Peninsular India to the South-East corner of Karnataka State between the Latitudinal Parallel of 12° 39' N and 13° 18' N and Longitudinal Meridians of 77° 22' E and 77° 52' E at an altitude of 900m average mean sea level covering an area of about 2,191 sq.km. For convenience, Bangalore City, it was divided into 5 phases as North, South, East, West, and Central phases. To start with South-Central Part of the Bangalore City was considered and sampling, surveying of the pipe distribution network was carried out (BWSSB, 2001).

West Zone includes areas like Hosahalli, Chandra Layout, Kengeri, Rajajinagar, Nandini Layout, Kethmaranahalli, Magadi road, Mysore road, West of Chord road, Nagarbhavi (BWSSB Annual Report, 2001). Around 27 samples were collected in different areas of west zone of Bangalore and is classified wardwise includes wards like Vijayanagar (88) around 6 samples, Rajarajeshwarinagar (ward no. 118) around 6 samples, Rajajinagar (ward no. 62) around 10 samples in areas like Manjunathnagar, Mahalakshmi Layout, West of Chord road, Rajajinagar Industrial area, and Nagarbhavi (ward no. 59) around 5 samples as mentioned in Table 1.

Drinking water sampling and Analysis

The Drinking water samples were collected, analysed for various physico-chemical and biological parameters and preserved for further analysis by following

APHA (2005). Air and water temperature, dissolved oxygen (Winkler's Method) were recorded at the site and the samples were brought to the laboratory for further analysis.

Physico-chemical parameters like pH, Conductivity, Dissolved oxygen (DO), Total hardness, Calcium hardness, Alkalinity, Sodium, Potassium Total Dissolved Solids (TDS) , Chloride, Total Residual Chlorine, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD).

Selection of Study Organisms

Microorganisms like *Thiobacillus thioparus*, *Desulfovibrio desulfuricans*, *Pseudomonas aeruginosa*, *Sphaerotilus- Leptothrix species* (iron bacteria) were selected for the study. For the bacteriological examination, *total coliforms* (28° C for 24 h) and *faecal coliforms* (44.5° C for 24 h) were determined by Membrane Filtration (MF) technique, and the average values were recorded. The TC was enumerated by M-Endo Agar, (Hi-Media Mumbai) which appeared as metallic sheen colour colonies, and FC was enumerated by M-FC Agar, (Hi-Media Mumbai) which appeared as blue colour colonies.

Results and Discussion

Physico-chemical characteristics of drinking water

Drinking water samples collected from twenty-seven (27) sampling points in the residential and public layouts showed the mean temperature value of 28.5° C and pH showed in the range of 7.0 - 8.30. Mysore Road recorded highest values of pH compared to other locations, while West of Chord road samples had least pH. Mean values of Electrical Conductivity recorded showed 831.9 µmhos/cm and range from 656–1400 µmhos/cm. Similar values were reported by Gupta *et al.* (2009) in Kaithal city, Haryana. Dissolved oxygen recorded in the range of 6.1 – 7.9 mg/L and found within optimum dissolved oxygen conditions. Similar values of dissolved oxygen were reported by Rajankar *et al.* (2009) in Nagpur region.

Chemical oxygen demand recorded in the Western zone with mean value of 33.9 mg/L and in the range of 13.3 mg/L - 226.0 mg/L (Table 2). The higher variations of chemical oxygen demand due to variation in biological processes in the samples. Biological oxygen demand values recorded in the range of 1.2 mg/L - 12.0 mg/L with mean value of 2.7mg/L. The primary water quality criteria for water does not permit BOD of drinking water source to go above 3mg/L. Results showed 26% of the samples exceeded with permissible limits (Vijaynagar (5.6mg/L), Agrahara Dasarahalli, Manjunatha Nagar (5.0mg/L), Mahalakshmi Layout (6.8mg/L), Jyoti Nagar (4.8mg/L), Kamashipalya (12.0mg/L), Mysore Road (3.0mg/L)). This may be due to the deficiency in improper water supply in the region. Kamashipalya recorded the highest BOD of while Mysore Road had the lowest BOD. Similar range of values was reported by Gupta *et al.* (2009) and Rajankar *et al.* (2009).

Table 1 Ward-wise Sampling points of Bangalore West Zone.

Sl. No.	Name and Ward No.	No. of Samples collected	Sampling Locations
1.	Rajarajeshwari nagar (ward no. 118)	6	<ol style="list-style-type: none"> 1. Haligewaderahalli near R.K.Chicken Centre, Rajarajeshwari nagar. 2. Mysore Public Tap near Bus Stop, Mysore Road in front of Kamala Bakery. 3. Public Tap water sample collected near Anjeneya temple, Mysore Road. 4. Public Tap water at BHEL circle, Mysore road near a storm water drain. 5. Old Guddadahalli, Mysore road, at School. 6. Low level Reservoir (LLR) at RPC layout, Vijayanagar.
2.	Vijayanagar (ward no. 88)	6	<ol style="list-style-type: none"> 7. Corporation ward Office, Vijayanagar. 8. Overhead tank, Vijayanagar. 9. House of Mr. Krishnamurthy, No.482, 1stMain road, Kamashipalya, SBI colony. 10. Tap water, Vijayanagar, Magadi road, Dasarahalli. 11. House at Agrahara Dasarahalli. 12. House at No.2, Tejaswini Nilaya, 13th Cross, Agrahara Dasarahalli.
3.	Rajajinagar (ward no. 62)	10	<ol style="list-style-type: none"> 13. Hotel Akshaya Upahara, at Basveshwara nagar main road. 14. House no.322, opp. to Durga vegetable shop, 3rd street Manjunathnagar 15. LLR, BWSSB, 4th Division, 5th main road, west of chord road. 16. Tap water, House no. 916, at West of Chord road. 17. House no.879, Byraveshwara Nilaya, Mahalakshmi layout. 18. BWSSB, LLR, Mahalakshmi layout. 19. House no.58 opp. to Akshaya Mini bazaar, Rajajinagar. 20. KEB Quarters, Rajajinagar. 21. House Sri. Siddaramana krupa, no. 222, 53rd B Cross, 3rdBlock, Rajajinagar. 22. KSSIDE Quarters, Rajajinagar Industrial Area, Rajajinagar.
4.	Nagarbhavi (ward no. 59)	5	<ol style="list-style-type: none"> 23. House no.82, Choudeshwari Nilaya, Maruthi nagar, Nagarbhavi. 24. BWSSB LLR at Chandra layout. 25. House of Dr. Pushpa Gujar, 3rd Cross, Joythinagar, Chandra layout. 26. BWSSB, LLR, Nagarbhavi. 27. House no.509. Lalitha Nilaya, 2nd stage, Nagarbhavi.

Table 2. Physicochemical characteristics of drinking water at Bangalore West Zone. TH, CaH and MgH as CaCO₃

	Conductivity (µmhos/cm)		DO (mg/L)		COD (mg/L)		BOD (mg/L)		TDS (mg/L)		pH as pH unit		Chloride mg/L		TH (mg/L)		CaH (mg/L)		MgH (mg/L)		Tot. Alk. (mg/L)		Na (mg/L)		K (mg/L)	
	DL	PL	DL	PL	DL	PL	DL	PL	DL	PL	DL	PL	DL	PL	DL	PL	DL	PL	DL	PL	DL	PL	DL	PL	DL	PL
BIS	--	--	4.0	4.0	250	250	--	3.0	500	2100	6.5	8.5	200	400	300	600	75	100	30	75	200	600	--	--	--	--
1	980		6.8		13.3		1.3		646		7.896		40		128		80		48		152		105.2		4.6	
2	1400		7.5		26.6		3.0		812		7.813		48		132		84		48		144		54.5		7.9	
3	896		6.2		13.3		1.3		502		7.846		48		132		88		44		140		93.8		1.2	
4	884		6.9		24		2.8		514		7.883		112		164		116		48		156		94.3		1.6	
5	856		6.5		13.3		1.3		522		7.682		40		136		88		48		140		97.1		1	
6	792		7.0		80		5.6		494		8.136		44		128		88		40		132		93.9		0.8	
7	864		6.6		13.3		1.3		536		8.14		44		128		88		40		132		93.3		1	
8	798		6.9		13.3		1.3		504		8.203		44		136		96		40		144		93.3		1.1	
9	904		7		226		12		552		7.99		52		140		112		28		128		112.6		3.2	
10	892		7.2		13.3		1.3		518		8.09		48		140		108		32		144		112.4		4.1	
11	878		7.1		40		2.8		534		8.046		48		136		100		36		140		112.5		4.1	
12	836		7.3		80		6.4		518		8.1		48		132		88		44		136		109.3		3.2	
13	858		7.9		13.3		1.3		484		8.046		36		140		84		56		148		98.9		4	
14	774		6.9		53.3		4.5		476		8.02		52		136		80		56		144		112.8		4.2	
15	656		6.6		13.3		1.3		394		8.106		48		128		80		48		120		112.5		4.2	
16	876		6.2		40		2.6		544		6.99		44		272		220		56		284		110.9		4.2	
17	786		6.3		13.3		1.3		464		7.876		128		128		84		44		148		107.5		2.5	
18	798		6.5		66.6		6.8		506		8.14		48		148		112		36		152		104.3		2.1	
19	816		6.1		13.3		1.3		526		8.2		44		132		92		40		156		101		2.1	
20	778		6.5		13.3		1.3		492		8.11		48		148		92		56		144		104.6		2.2	
21	876		6.3		13.3		1.3		510		8.1		44		160		84		76		156		115.5		2.2	
22	788		6.4		13.3		1.3		488		8.18		84		124		72		52		144		100		1	
23	826		6.6		13.3		1.3		512		8.23		48		140		96		44		152		89		1.1	
24	832		6.8		13.3		1.3		492		8.06		40		140		92		48		140		92.1		1.1	
25	784		6.9		53.3		4.8		486		7.98		52		136		88		48		152		89		1.2	
26	776		7.1		13.3		1.2		452		8.036		48		124		72		52		132		88.2		1.1	
27	816		7.4		13.3		1.2		506		8.1232		62		156		94		78		156		104.2		2	

TDS values recorded with the mean value of 517.9 mg/L and in the range between 394 mg/L and 812 mg/L and about 60% of the total samples showed above the desirable limit of 500 mg/L and the areas include R. Nagar, Mysore Road, Venkateswara Nagar I and II, Old Guddahalli, Vijaynagar II and III, Kamashipalya, Dasarahalli I, II, III, West of Chord Road, Mahalakshmi Layout II, Rajajinagar I and III, and Nagarbhavi I and III. Mysore Road layout had the highest TDS level of 812 mg/L. The highest values of TDS are due to dissolved salts like sulphates, nitrates, chlorides and also due to the improper treatment of drinking water supply. The total hardness (as CaCO₃) of the Western Zone water samples ranged between 124 and 272mg/L as CaCO₃ with mean value of 142.4mg/L. For calcium hardness (as CaCO₃), the range was 72 - 220mg/L as CaCO₃ with mean value of 95.5mg/L. Magnesium hardness (as CaCO₃) ranged between 28.0 and 78.0mg/L as CaCO₃ (Table 2). This was within the desirable level of 30 mg/L as CaCO₃ as set by BIS. Praveen *et al.* (2005) also studied the drinking water quality in Bangalore City western zone and recorded higher values of TDS, hardness, BOD and COD.

Table 3. Bacteriological characteristics (No. of CFU per 100 ml) of drinking water at different study locations.

Sampling Locations	<i>Pseudomonas aeruginosa</i>	<i>Thiobacillus species</i>	<i>Desulfovibrio desulpuricans</i>	<i>Leptothrix-Sphaerotilus species</i>
1	32	12	23	0
2	24	8	18	5
3	28	13	15	3
4	22	10	12	11
5	18	6	14	6
6	21	4	0	5
7	18	5	10	7
8	21	3	13	3
9	13	6	11	5
10	15	10	8	10
11	22	4	7	6
12	12	5	0	0
13	23	10	12	6
14	17	8	10	5
15	15	12	15	10
16	14	0	15	10
17	12	10	13	11
18	23	0	10	10
19	16	13	12	15
20	21	10	14	11
21	14	11	15	0
22	20	0	14	0
23	12	14	16	10
24	13	12	13	11
25	22	8	11	6
26	20	0	8	5
27	21	6	8	5

Sodium concentrations ranged between 7.9 mg/L and 115.5 mg/L with mean value of 100.1 mg/L. Potassium concentrations ranged between 0.8 mg/L and 7.9 mg/L. Chlorides recorded in the range of 36.0 - 128 mg/L and are below desired limits for drinking water standards. This showed that the drinking water is devoid of contamination from sewage. Total Alkalinity recorded in the range of 120 mg/L - 284 mg/L and found within the BIS desirable limit is 200mg/L, however sample from West of Chord road, Rajajinagar showed the highest value of 284 mg/L which is higher than the BIS desirable limits. Calcium (as Ca) levels ranged from 28.8 - 88.0 mg/L. The highest Ca was recorded in the sample from West of Chord (88.0 mg/L) and found above desirable limits of 75 mg/L. Magnesium (as Mg) levels ranged from 6.8 - 18.5 mg/L and found within desirable limit of 30 mg/L. Similar findings were observed by Bisht (2007).

Biological Characteristics of drinking water

Microorganisms like *Pseudomonas aeruginosa*, *Thiobacillus species*, *Desulfovibrio species*, and *Leptothrix-Sphaerotilus* were isolated from drinking water. The study revealed that Rajarajeswarinagar sample showed highest number of CFU (32) and samples from Vijayanagar (sample no.12) and Nagarabhavi (sample no. 23) showed least CFU (12) of *Pseudomonas aeruginosa* per 100ml. However Nagarabhavi sample (no. 23) showed highest CFU (14) of *Thiobacillus species* and Vijayanagar overhead tank (no. 8) showed least number of CFU (3) per 100ml. Sample no. 1 showed highest (23) CFU/100 ml of *Desulfovibrio species* while sample no.11 showed least CFU (7) per 100ml. Sample no. 19 showed highest CFU (15) per 100 for *Leptothrix-sphaerotilus species* and sample no.3 showed least CFU (3) per 100ml. All the samples showed positive for *Pseudomonas aeruginosa*, however, few samples did not show any growth like *Leptothrix-sphaerotilus* for sample numbers 1, 12, 22 and 23, *Desulfovibrio species* for sample numbers 6 and 12, *Thiobacillus species* for sample numbers 16, 18, 22 and 26 (Table 3). The results confirmed that the overhead tank is devoid of growth of microorganism and other sampling points are at the receiving end and it can be assumed that the contamination might have occurred during the process of supplying. Similar results were reported by Nandini (2006), Chatterjee *et al.* (2007), Rajankar *et al.* (2009), Mazari-Hiriart *et al.* (2005) and Simoes *et al.* (2007).

The presence of *P. aeruginosa* in drinking water might have caused due to the entering of human or animal waste. *P. aeruginosa*, a biofilm forming organism and an opportunistic pathogen which may cause nosocomial infections, urinary tract infections, eye and ear infection, meningitis etc. *P. aeruginosa* associated with *Thiobacillus spp.* *Desulfovibrio spp.* causes corrosion of pipes (biocorrosion) which may affect the water distribution system. *Leptothrix-sphaerotilus spp.*, an iron bacteria, which alters the water quality at micro-level by deteriorating the pipe material by corroding pipes, blackening of water with rotten egg smell, which leads to water borne diseases. These microorganisms might have introduced into the distribution network of drinking water by means of open reservoirs, breakages due to new pipeline construction, main pipe system breaking (old pipes), reduction of water flow pressure in the system, resulting in back siphonage and regrowth of microorganisms (Momba *et al.*, 2005; Chatterjee *et al.*, 2007).

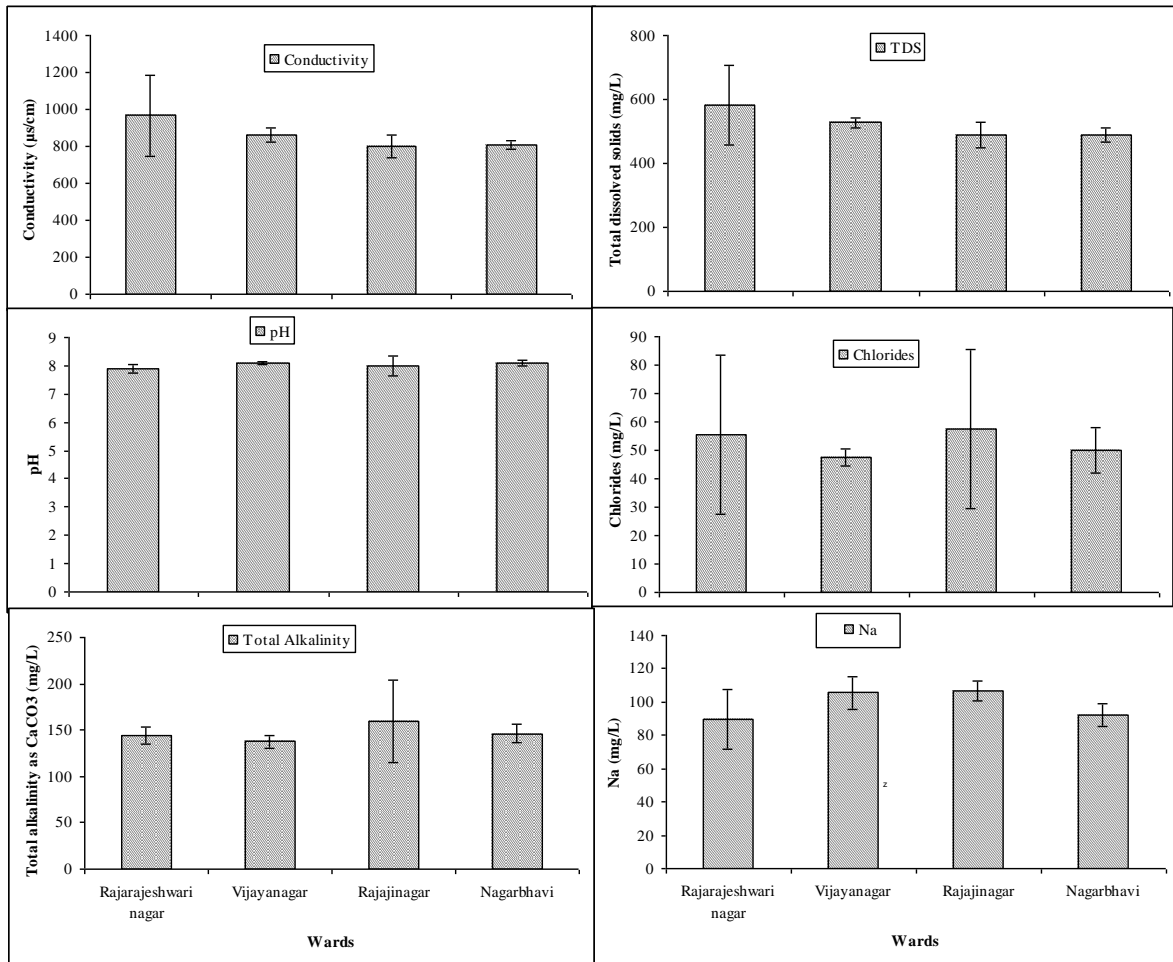


Figure 1 Physicochemical characteristics of drinking in different wards of Bangalore west zone (The values are mean and bars showing standard deviation).

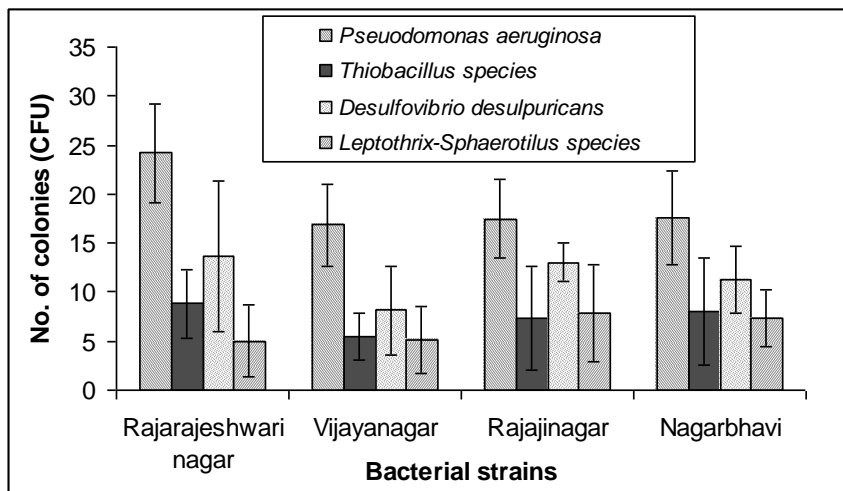


Figure 2 Bacteriological characterization of drinking water in wards of Bangalore west zone.

The micro colonies adhere to other organism, forming a biofilm matrix that protects the interior microbes from harmful chemicals. It also allows the organism to share nutrients besides protection. This cooperation may produce an aggregate with a metabolic potential that is greater than the sum of individual organisms (Momba *et al.*, 2005; Nandini, 2006). This kind of survival, may lead to the recurrence of gastrointestinal diseases (Mazari-Hiriart *et. al.*, 2005).

Conclusion

The results of this investigation provide evidence that physico-chemical characteristics and microorganisms are common constituents of water distribution which are attributed by Biofilms, and their by-product deposition within the water system. Sample collected from different parts of Bangalore west zone, ward wise namely Rajarajeshwari nagar, Vijayanagar, Rajajinagar, Nagarbhavi showed variation in physico-chemical properties of water quality (i.e., pH, conductivity, hardness, alkalinity, chlorides etc.) which may be due to mechanical failure or due to biocorrosion. However, in this study nitrates have not estimated due to some constraints.

Authors' contribution: *Mr. Abdul Khayum* (Research Scholar) contributed in designing the experiment, carried out sampling works and corresponding author of manuscript; **Dr.N. Nandini** (Associate Professor), Chairman and Principal Investigator of the project work; **Dr.J.S. Chandrashekar** (Faculty) contributed in designing the experiment, scientific inputs and final editing of the manuscript; **Mr.R. Durgesh** (Research Scholar), contributed in designing the experiment and carried out sampling works.

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