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PHYSICO-CHEMICAL AND BACTERIAL STATUS OF DRINKING WATER SOURCES HARBORING HOSPITAL AREAS: A CASE STUDY OF TEZPUR HOSPITAL AREAS

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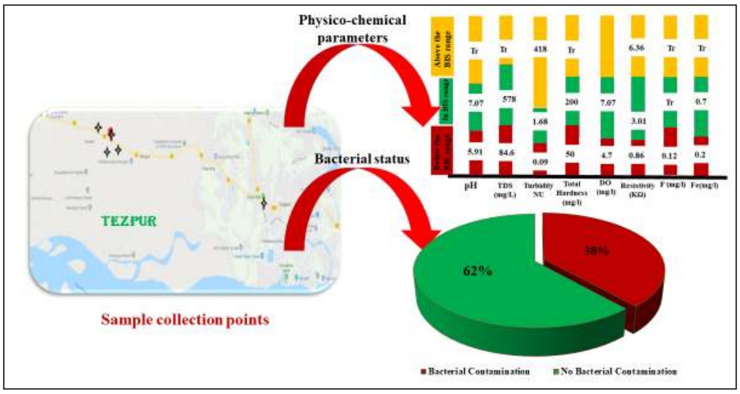
Abstract
Access to potable water is one of the major concerns in the rural parts of North East India. Additionally, the water sources in and around the areas harbouring operational hospitals are prone to a plethora of organic and inorganic contaminants, and therefore the likelihood of any deterioration in their quality cannot be negated. To investigate such a possibility, samples were collected from 13 different potential areas surrounding the hospitals of in and around Tezpur town, Assam, India and several physico-chemical parameters were determined. The total hardness of 12 out of 13 samples was found to be significantly lesser than the standard range of Bureau of Indian Standards (BIS). Similarly, TDS of 11 samples, resistivity of 7 and pH of 2 samples were found to be out of the acceptable range. Salinity and conductivity of 2 out of 13 samples were found to be very high. Analysis for turbidity revealed a vast range of data (0.09-418 NTU), which is way out of the permitted range. The amount of dissolved oxygen was lowest for the sample collected from hand pumps. Furthermore, only 3 samples showed any significant presence of Iron. Surprisingly, only 4 samples indicated the presence of bacterial contamination. Therefore, this study will be useful in taking proper remedial measures for water decontamination.

Keywords
Physico-chemical parameters, Bacterial analysis, WHO, BIS, NE (North-East).



Graphic abstract

INTRODUCTION

Water is a vital component for the sustainability of human life. But undertaking optimum measures for sustainably good water quality for human use is a matter of high serendipity and entropy [1]. Drinking water should be clear, odorless and preferably free from all harmful micro-organisms, especially bacteria.As per a report published by WHO, nearly 80% of harmful diseases in human beings are caused due to polluted drinking water[2][3].Poor sanitation, food sources are becoming intrinsic to the occurrence of pathogens exposure. Poor water quality, sanitation and hygiene are the reasons for 1.7 million deaths a year worldwide [4]. According to theWorld

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Health Organization (WHO) 90% of such deaths are reported in children and effectively all are in developing countries [5][6].

In several states of a developing country like India, more than 90% of the population depends on ground water for drinking and other purpose [7]. It is a herculean task to restore back the optimum quality of water, once it gets contaminated–[8]. The decisive reasons behind the deterioration of urban water, primarily are agricultural, urban conducts, input of untreated industrial as well as hospital effluents, domestic wastewater (like used detergent, excreta and faecal sludge), even uncontrolled landfills, thereby posing tremendous threat to human health [9].The unbalanced physico-chemical parameters and presence of harmful micro-organisms in drinking water are reasons behind causing several adverse effects in human body [10]. The ground water in North-Eastern states of India (especially Arunachal Pradesh, Assam and Nagaland), are usually found to be high on the iron and fluoride contents [11].The people from several parts of Assam are facing lots of struggles for a drop of good quality water [12]. The microbial contaminations of water sources are occurring manly due to the industrial waste and domestic waste, except the educated people the rural people are consuming this contaminated water without testing [13][14]. The different physical, chemical and bacterial parameters of water can affect the water quality and the comparative study of these different parameters can be done by mathematical model called water quality index (WQI) [15][16].

The main aim of this study was to investigate the physico-chemical parameters and bacterial contamination in drinking water samples collected from areas surrounding the hospitals, in and around Tezpur town hospitals, Assam. These parameters were compared limits as mentioned in the BIS.

MATERIALS AND METHODS

Samples were collected from 13 different locations in and around Kanaklata Civil Hospital (KCH), Tezpur and Tezpur Medical College & Hospital (TMCH), Bihaguri, in sterile sample collection amber bottles (1000 ml) and sterile polypropylene centrifuge tubes. Standard procedures were followed while collection & storage of samples, parameters and physical state of water samples such as temperature and pH were measured at the sampling site using a standard thermometer and a portable pH meter (model: EuTech pH610), respectively. The latitude and longitude of all the sampling sites along with the source were recorded (Table-1) using GPS system (model: Garmin GPS72H), sampling location map (fig.1) made by Google earth 6.1 and QGIS 2.12 software. The bottles were then taken to the laboratory in contaminant free ice-boxes in order to avoid the outside contamination and the change in physical,chemical and biological parameters in the samples. Samples were stored at 4°C temperature until further analyses as per standard procedure used for water analysis (APHA, 2005). AR grade reagents and ultrapure de-ionized water were used for all the analyses wherever required. TDS, EC, and Salinity were measured by multi parameter (EuTechCD650). Turbidity was measured using turbidity meter (EuTech TN100) and total hardness was checked by complexometric titration using Erichrome Block –T as indicator (EDTA method). Iron was estimated using colorimetric method in a UV-Vis spectrophotometer (AnalytikjenaSPECORD 205). Fluoride was measured by ion meter (Thermo scientific ORION 4 STAR). Bacteriological analysis was performed using the Bacteriological Field Test Kit (H_2S strip method developed by DefenceResearch Laboratory, DefenceResearch &Development Organization) using mentioned protocol. The bottles containing H_2S strips were filled with 20 ml of test water sample and incubated at 37°C for 72 hours. Any change in colour was monitored and recorded every 24 hours.

RESULTS AND DISCUSSION

Figure 1 describes the map locations from where the samples were collected while Figure 2 on the other hand shows photographs of some sites of collection, giving us an idea of the immediate surroundings various physico-chemical parameters were analyzed and the detailed results are mentioned below. The source, location and physical properties like color and odour of the sample enclosed in Table 1. The light brown color was observed in some samples (GN3, GN4, GN9 and GN13) and sample GN8 had dark brown color. None of the collected samples have odour.

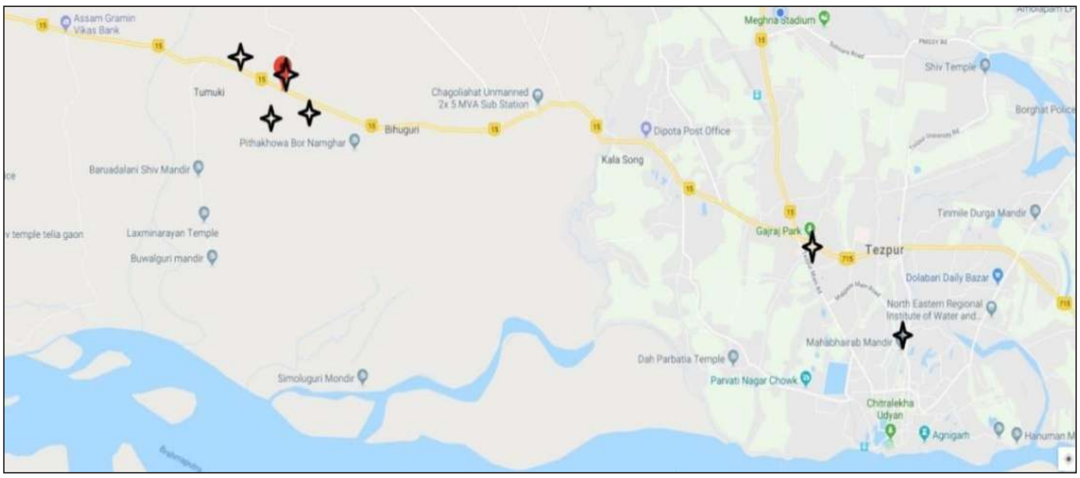

Figure 1: Location map of water collection points.

Figure 2: Photographs of some collection sites. (a-h) in and around TMCH; and (i) inside KCH.

Five types of water sources, i.e. tap, hand pump, well, bore well, filter tank), were selected in and around the operational hospitals in Tezpur town. The preliminary observations like latitude, longitude, color and odour were recorded and the same is presented in table .1. Some samples viz., GN3, GN4, GN9 & GN13 showed a light brown colour while GN8 appeared as dark brown in colour; nonetheless all samples were found to be odourless (Table. 1). The temperatures recorded at the time collection of water sample was nearly 35°C for all locations. The physico-chemical parameters of the collected water samples are also mentioned in table. 2.

Table 1: Sampling Sites and Sources of Collected Water Samples along with Preliminary Observations*.

Sl. No.	Sample code	Water source/ Locality	GPS Location		Odour	Color
			Latitude	Longitude		
1.	GN 1	Tap water	26.68093	92.65326	NO	NO
2.	GN2	Hand pump	26.68093	92.65326	NO	NO
3.	GN3	Well water	26.68246	92.65020	NO	Light brown
4.	GN4	Bore well water	26.68246	92.65020	NO	Light brown
5.	GN5	Filter Tank water	26.68246	92.65020	NO	NO
6.	GN6	Well water	26.68246	92.65020	NO	NO
7.	GN7	Well water	26.67827	92.65329	NO	NO
8.	GN8	Hand pump	26.67671	92.65361	NO	Dark brown
9.	GN9	Hand pump	26.67678	92.65369	NO	Light brown
10.	GN10	Filter Tank water	26.67678	92.65369	NO	NO
11.	GN11	Well water	26.65266	92.77362	NO	NO
12.	GN12	Well water	26.65268	92.77367	NO	NO
13.	GN13	Tap water	26.62893	92.79705	NO	Light brown

Table 2: Physico-Chemical Parameters of Collected Water Samples*

	Parameters									
	pH	Conductivity (μs/cm)	TDS (mg/L)	Turbidity (NTU)	Salinity (mg/L)	Total Hardness (mg/l)	D.O. (mg/L)	Resistivity (KΩ)	F-(mg/l)	Fe(mg/l)
BIS Standard (desirable-permissible)	6.5-8.5	-	500-2000	1-5	-	200-600	>5	1-5	1.0-1.5	≥0.3
Sample Code										
GN1	7.01	178.8	170.2	3.03	166.6	75	6.30	2.94	0.159	Tr#
GN2	6.57	174.1	166.1	0.94	162.2	87.5	6.62	3.01	0.149	Tr#
GN3	6.44	82.4	78.66	42.7	78.72	25	5.11	6.36	0.125	Tr#
GN4	6.07	94.44	90.09	113	89.5	37.5	3.41	5.55	0.149	Tr#
GN5	6.68	102.2	97.61	1.60	96.60	37.5	7.07	5.12	0.147	Tr#
GN6	6.67	448.8	428.2	15.39	425	75	5.33	1.16	0.114	Tr#
GN7	6.61	601.2	572.5	5.96	573.1	150	5.12	0.87	0.186	Tr#
GN8	6.11	181.2	172.8	418	168.4	62.5	5.02	2.89	0.142	0.35
GN9	6.25	89.87	85.5	54	85.24	37.5	4.74	5.85	0.151	0.72
GN10	6.44	88.75	84.65	0.54	84.45	37.5	7.76	5.90	0.137	Tr#
GN11	5.91	232.9	222.2	0.09	217.2	75	5.55	2.25	0.098	Tr#
GN12	6.96	606.0	578.1	0.66	580	200	7.43	0.86	0.128	Tr#
GN13	7.07	151.7	144.9	4.8	141.5	50	5.70	3.45	0.302	0.23

* Red highlighted texts represent values that are out of BIS standard range
* Tr#- trace amounts (≤0.3)

Dissolved oxygen (DO) of sample GN10, collected from filter tank (Figure 2h), and was found to be the highest (7.76 mg/l) among all collected samples. Total hardness of the sample GN12 was found to be the highest (200 mg/l). Total dissolved solids (TDS) for the sample GN12 was found to be 578 ppm. It was logical that sample GN12 also possess highest electrical conductivity (EC = 606.0 µs) and salinity (580 ppm) and naturally very less resistivity (resistivity =0.865 KΩ). Sample GN7, which was collected from wells, shows nominal variations in the respective parameters, even though they were collected from two distant locations. For example, values of total hardness, TDS, EC, salinity and resistivity for GN7 was measured as 150 mg/l, 572.5 mg/l, 601.2 µs, 573 ppm and 0.8733 KΩ, respectively

Table. 3: Comparison of Physico-Chemical Parameters among Water Samples Collected from Hospitals with Surroundings Areas of Hospitals and BIS standards of water.

Parameters	Water samples from hospitals (GN1, GN2, GN11, GN13)		Samples from surroundings areas of hospitals (GN3, GN4, GN7, GN8, etc.)		BIS Standards	
	maximum	minimum	maximum	minimum	Max.	Min.
pH	7.07(GN18)	5.91(GN11)	6.96(GN12)	6.11(GN8)	8.5	6.5
TDS (mg/l)	222.2(GN11)	144.9(GN13)	578.1(GN12)	78.66(GN3)	2000	500
EC (μs)	232.9(GN11)	51.7(GN13)	606 (GN12)	82.4(GN3)	-	-
Salinity (ppm)	217.2(GN11)	141.5(GN13)	580 (GN12)	78.72(GN3)	5	1
Total hardness (mg/l)	87.5(GN2)	50(GN13)	200 (GN12)	25(GN3)	-	-
DO (mg/l)	6.62(GN2)	5.55(GN11)	7.76 (GN10)	3.41(GN4)	>5	5
Fluoride (mg/l)	0.302(GN13)	0.098(GN11)	0.186 (GN7)	0.114(GN6)	1.0	-
Iron (mg/l)	0.23(GN13)	Tr	0.72 (GN9)	Tr	-	0.3

A comparison of various physico-chemical parameters with that of the BIS standards is presented in Table3 and it was observed that the physico-chemical parameters of the water samples, which are collected from hospitals have fewer amounts of TDS, total hardness, DO, Salinity and less electrical conductivity compared to the samples collected from surrounding areas of hospitals. Few of the analyzed physico-chemical parameters of water samples collected from hospitals are present below the acceptable limit of BIS standard (Fluoride, Iron, Total Hardness, and TDS) (BIS standards). However, resistivity and pH lies in the range of acceptable and permissible limits of BIS standard.

pH

The pH of any water sample is a measure of its acidic or basic property [4]. It is one of the major parameters for determining the quality of water, as it provides information in regard to effects on solubility of various metallic contaminants. pH fluctuation in water bodies are related to the discharge of industrial, hospital, home hold and human waste [16]. Change in pH further leads to change in physico-chemical and biological parameters of water. Higher pH contributes to the formation of tri-halo-methane which are toxic [4]. Alkaline pH value is witnessed due to presence of alkaline earth metals like sodium andpotassiumwhich interact with soluble CO forming carbonates and bicarbonates resulting in shifting of the pH above 7.0 (BIS standards). The highest value of pH among all the samples was recorded as 7.07 (assumed in the neutral pH range) for GN13 and the lowest value came up as 5.91 (acidic pH) for the sample GN11 (table 2).

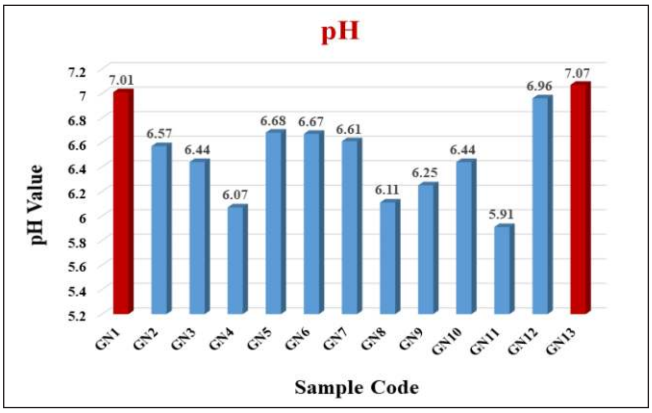

Figure 3: pH values of the samples collected from different location.

Electrical Conductivity

Electrical conductivity (EC)represents the ability of water to conduct electrical current which in return provides a general indication of water quality with respect to amount of total dissolved solids like presence of cations and anions, their concentration, mobility,etc [17]. Therefore, an augmentation in EC is evident usually with an increase in the concentration of dissolved salts in a particular water sample [2]. Conductivity of water also varies with changes in temperature. The highest EC value among all the collected samples was recorded as 606 µs for GN12, whereas the lowest came as 82.4 µs for GN3 (table 2).

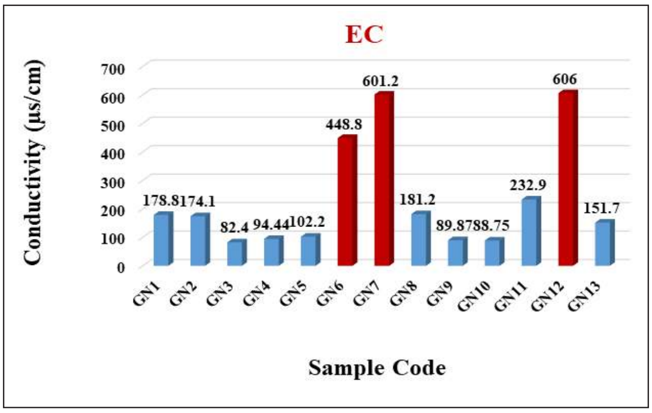

Figure 4: Electrical conductive values of the collected samples.

Total Dissolve Solids (TDS)

TDS is general proportional to degree of pollution. It is considered as an indicator of salinity of water and describes all solids dissolved in water [18] [19]. TDS comprise inorganic salts (Ca, Mg, Na, K, HCO_3, Cl, and SO_4) and some small amounts of organic matter dissolved in water. TDS can be influenced by changes in pH because it leads to precipitation of some of the solutes as well as affects solubility of suspended matter. Water containing more 500 mg/L of TDS is not considered desirable for drinking [10]. The highest value of TDS among all collected samples was measured as 578 mg/l (GN12), and the lowest one was 84.65 mg/l (GN10). TDS will effects the Electrical Conductivity of water that is why the sample GN12 with higher TDS causes high EC and the sample GN10 has lower TDS with less EC (table 2).

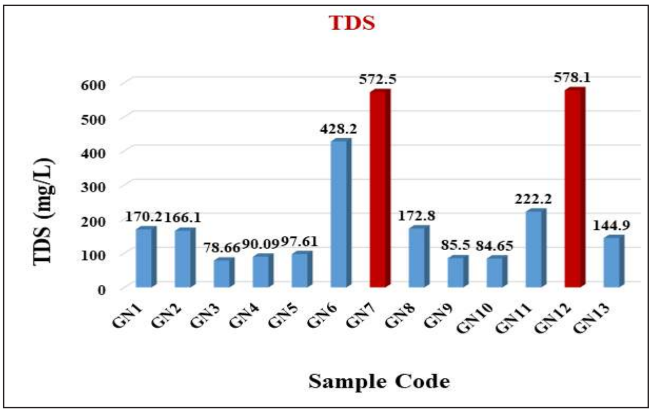

Figure 5: Total Dissolved Solids (TDS) values of the samples (Red column- within the BIS limit and Blue column-below the BIS limit).

Turbidity

Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates

[20][15]. It is caused due to presence of suspended particles and/or colloidal matter which reduce the transmittance of light through water. It may be caused by inorganic or organic matter or a combination of both. High turbidity being an indicator of presence of large number of suspended solids, significantly reduces the aesthetic quality of water source [20]. It increases the cost of water treatment for drinking and food processing. Generally, turbidity causing factors can be either natural or human induced. Human activities can also cause erosion resulting in an increase in turbidity. Although substances resulting in high turbidity may not be intrinsically harmful, but significantly interfere with any disinfection process during water treatment and may provide a medium for microbial growth[2]. These microbes include bacteria, viruses and parasites which cause symptoms such as nausea, cramps, diarrhea etc. Among all the collected water samples, the highest value of Turbidity was found to be 418 TNTU for GN8 and lowest value was 0.09 TNTU for GN11 (table 2).

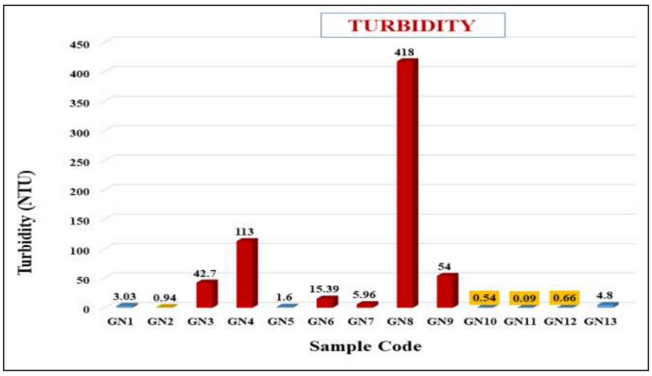

Figure 6: Turbidity values of the samples (Red column-high values above the limit and Blue column-within the limit, Yellow column- below the limit).

Salinity

Salinity of any water body is correlated to its TDS, since it indicates the presence of dissolved salts [7]. Small amounts of dissolved salts in natural waters are required for the life of aquatic plants and animals but higher quantities lead to severe health issue like increased blood pressure or hypertension leading way to cardiovascular diseases [7][21]. Among the collected water samples, the maximum value of salinity is 580ppm for GN12 and minimum value is 78.72 ppm for GN3. Salinity is related to EC&TDS-if salinity will increase then EC&TDS of water will also increase.

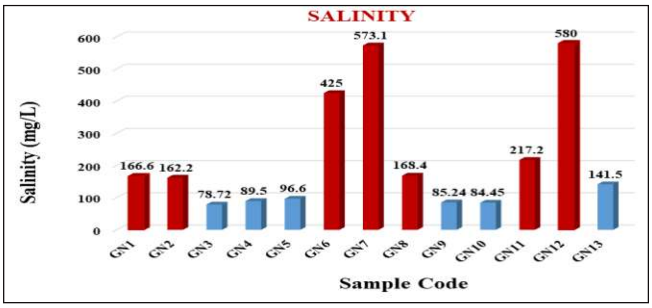

Figure 7: Salinity values of the samples (Red column- high values above 150 mg/L and Blue column-below 150 mg/L).

Fluoride

Fluoride is required in low concentration by human body to prevent dental diseases but very high concentration of fluoride causes fluorosis which affects the teeth and bones [22][23]. Moderate amounts lead to dental effect but long-term ingestion of large amount of fluoride results in skeletal disorders[22]. The highest amount of fluoride content was found for the sample GN13 (from civil hospital) and was found to be 0.302 mg/l. The lowest amount was found for the sample GN11 (from CHRISTIAN HOSPITALS, 0.09 mg/l).

Fluoride content in all the samples was found to be quite similar and within the range of 0.09-0.302 mg/l although, below the desirable limits prescribed by WHO and Indian BIS standards Fluoride content in all the samples was found to be quite similar and within the range of 0.09-0.302 mg/l although, below the desirable limits prescribed by WHO and Indian BIS standards (WHO standards 2011) (BIS standards 2010). Iron content in all the samples were in negligible amount, except for the samples GN8, GN9 and GN13. Iron content for these samples were determined as 0.35 mg/l, 0.72 mg/l and 0.23 mg/l respectively. Comparing the values with BIS standards, it can be ascertained that the amount of iron present in sample GN13lies within the limits of BIS standards, but the same for GN8 and GN9 lies above the limits of BIS standards. The pH of the sample GN18 was found to be 7.07 and was the highest among all collected samples. Highest Turbidity was obtained for the sample GN8 which was measured
as 418 NTU.

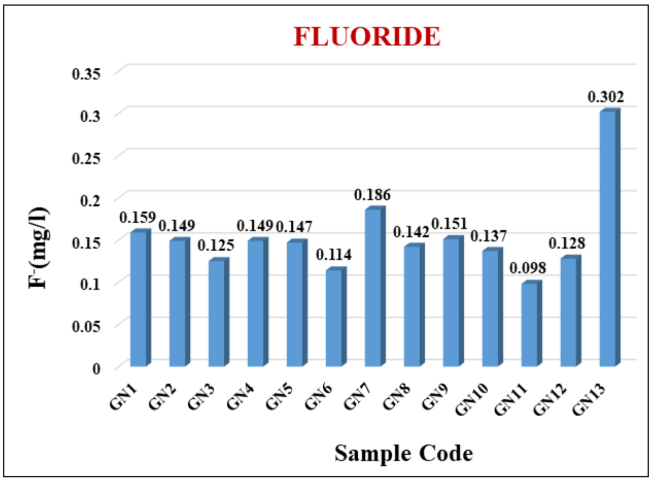

Figure 8: Fluoride content of the samples (all samples have below the lower limit of BIS standards).

Iron

Iron is an important element in human nutrition. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status, and iron bio-availability and ranges from 10 to 50 mg/day [24][25]. Groundwater may hold iron (II) at concentrations up to several milligrams per liter without discoloration or turbidity in the water when directly pumped from a well [26]. Taste is not usually noticeable at iron concentrations below 0.3 mg/liter, although turbidity and color may develop in piped systems at levels above 0.05–0.1

mg/L[27]. Laundry and sanitary ware tends to stain at iron concentrations above 0.3 mg/L. In drinking-water supplies, iron (II) salts are unstable and are precipitated as insoluble iron (III) hydroxide, which settles out as a rust-colored silt. During the study, maximum amount of iron was found in GN9 (0.72 mg/l) and minimum amount was found in GN13 (0.23 mg/l).

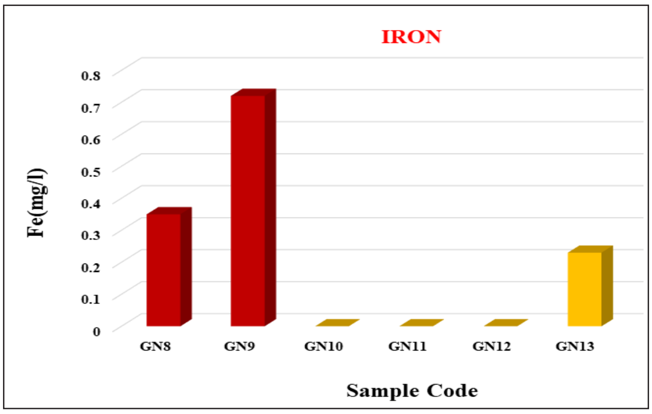

Figure 9: Iron content of the samples (Red column- in limit of BIS standards and, Yellow column- below the limit).

Screening for bacterial contamination

According to the recent BIS slandered reports [15] and literatures [28][29] the microbial contamination is the main reason for water borne diseases like diarrhea. Likewise, as per the reports it is anticipated that in 2015, an estimated 1.3 million people lost their lives from diarrheal diseases and among them 499,000 were children, younger than five years old [28]. So, Microbial contamination, which is reducing water quality is linked to causing inflammation, anemia, stunting and it's becoming the matter of concern [29][30].

The analysis of bacterial contamination can be seen from the images provided in Figure 10. This test was carried out by using the water testing field kit which was designed by DRDO-DRL Tezpur. The kit is provided with testing facilities for both physio-chemical and bacteriological parameters. The test is semi quantitative and are based on accept/reject basis.No bacterial contamination was detected in the first 24 hours of incubation as all samples maintained the characteristic yellow colour. Only after 48 hours of incubation, samples GN10 and GN12 showed a transition to the colour black (Table. 4). Post 72 hours incubation bacterial contamination was detected in 2 more samples (i.e., GN5 & GN6). This concludes that the remaining samples are free from bacteria, and also we can say that the The analysis of bacterial contamination can be seen from the images provided in Figure 10. This test was carried out by using the water testing field kit which was designed by DRDO-DRL Tezpur. The kit is provided with testing facilities for both physio-chemical and bacteriological parameters. The test is semi quantitative and are based on accept/reject basis.No bacterial contamination was detected in the first 24 hours of incubation as all samples maintained the characteristic yellow colour. Only after 48 hours of incubation, samples GN10 and GN12 showed a transition to the colour black (Table. 4). Post 72 hours incubation bacterial contamination was detected in 2 more samples (i.e., GN5 & GN6). This concludes that the remaining samples are free from bacteria, and also we can say that the water samples (GN1, GN2, GN11 and GN18) which are collected from hospitals were free from bacterial

Figure 10: Analyses for Bacterial contamination using DRDO Water Testing Kit: (a) No Bacterial contamination after 24 hours incubation; (b) Contamination in sample GN10 and GN12 after 48 hours; and (c) Bacteria contamination observed in GN5 and GN6 after 72 hours.

contamination, due to the presence of less turbidity inbecause those samples which were collected from hospitals have less turbidity this is one of the reason for absence of bacteria in those samples. It is interesting to find that samples like GN3 and GN4, although having high turbidity did not display any bacterial contamination, whereas samples like GN10 and GN12 having very less turbidity did show the presence of bacterial contamination. A probable reason may be attributed to the location of the samples' sources where certain inconsistent external factors might have played a role.

Table 4: Results of bacterial contamination analysis.

S. No.	Time taken for incubation	Sample with bacterial contamination
1.	24 hours	None
2.	48 hours	GN10,GN12
3.	72 hours	GN5,GN6

CONCLUSION

From this present study it can be concluded that, the physico-chemical parameters of different water samples which were collected from in and around the hospitals in Tezpur town, Assam, had substantial variation. Samples GN7 and GN12 have greater amounts of TDS and DO in comparison with other samples. Because of this greater amount of DO, the metal ions present in the water sample get oxidized with accompanying increase in pH value. That is why these two samples have slightly higher value ofpH.

Samples GN5, GN6, GN10, and GN12 showed the presence of bacterial contamination. Compared to other samples, the water samples which are contaminated with bacteria, have significantly very high value of DO. Because of this higher amount of DO in water, bacteria in the water samples can have a chance to sustain for longer time as we have observed for the samples GN5, GN6, GN10, and GN12. Since there was no substantial uniformity of values obtained from all the undertaken parameters that could virtually connect the influence of hospitals on its nearby biota. Therefore, from this study it can be concluded that the hospitals may have minimum to nil influence on the quality of drinking water surrounding hospital areas.

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REFERENCES

1. **Rameshkumar**, **S., Radhakrishnan, K., Aanand, S. & Rajaram, R**. Influence of physicochemical water quality on aquatic macrophyte diversity in seasonal wetlands. *Appl. Water Sci.***9**, 1–8 (2019).
2. **Ashbolt**, **N. J**. Microbial contamination of drinking water and disease outcomes in developing regions. *Toxicology***198**, 229–238 (2004).
3. **Spangler**, **J. G. & Reid, J. C**. Environmental manganese and cancer mortality rates by county in north carolina: An ecological study. *Biol. Trace Elem. Res.***133**, 128–135 (2010).
4. **Sunil Kumar Tank & R. C. Chippa**. Analysis of Water Quality of Bharatpur. *Http://Www.Ijeijournal.Com/Pages/V2I10.Html***2**, 06–11 (2013).
5. **Herschy, R. W.** Water quality for drinking: WHO guidelines. *Encycl. Earth Sci. Ser.* 876–883 (2012) doi:10.1007/978-1-4020-4410-6_184.
6. **Gopalkrushna, M**. Determination of Physico-Chemical parameters of Surface Water Samples in and around Akot City. *Int. J. Res. Chem. Environ.***1**, 183–187 (2011).
7. **Srinivas, P., Huggi, M. S., Engineering, P. D. a C. & State, K**. Study on the physico-chemical characteristics of ground water of bidar city and its industrial area g . N . D . College of Engineering , Bidar , Karnataka State , India . ISSN 0976-4550 Figure 1 . 1/ : Bidar City Map Figure No . 1/ : Showing the Location of. 359–367 (2012).
8. **Jacks, G., Bhattacharya, P., Chaudhary, V. & Singh, K. P**. Controls on the genesis of some high-fluoride groundwaters in India. *Appl. Geochemistry***20**, 221–228 (2005).
9. **Kilunga, P. I. *et al*.** The impact of hospital and urban wastewaters on the bacteriological contamination of the water resources in Kinshasa, Democratic Republic of Congo. *J. Environ. Sci. Heal. - Part A Toxic/Hazardous Subst. Environ. Eng.***51**, 1034–1042 (2016).
10. **Kalhor, K., Ghasemizadeh, R., Rajic, L. & Alshawabkeh, A**. Assessment of groundwater quality and remediation in karst aquifers: A review. *Groundw. Sustain. Dev.***8**, 104–121 (2019).
11. **Singh, A. K. *et al.*** Assessment of Arsenic , Fluoride , Iron , Nitrate and Heavy Metals in Drinking Water of Northeastern. (2008).
12. **Puzari, A., Khan, P., Thakur, D., Kumar, M. & Shanu, K**. Quality Assessment of Drinking Water from Dimapur District of Nagaland and Karbi-Anglong District of Assam for Possible Related Health Hazards. *Curr. World Environ.***10**, 634–640 (2015).
13. **Dhawde, R. *et al.*** Physicochemical and bacteriological analysis of water quality in drought prone areas of pune and satara districts of maharashtra, india. *Environ. - MDPI***5**, 1–20 (2018).
14. **Obioma, A., Chikanka, A. T. & Wereloobari Loveth, N**. Evaluation of Bacteriological Quality of Surface, Well, Borehole and River Water in Khana Local Government Area of Rivers State, Niger Delta. *Ann. Clin. Lab. Res.***05**, 1–5 (2017).

15. Standards, I. Indian Standard DRINKING WATER — SPECIFICATION (Second Revision) IS 10500 (2012): Drinking water. *Water Supply*__25__, 1–3 (2012).

16. **Jain, C. K., Bandyopadhyay, A. & Bhadra, A**. Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India. *Environ. Monit. Assess.*__166__, 663–676 (2010).

17. **Kapupara, P. P., Dholakia, S. P., Patel, V. P. & Suhagia, B. N**. Journal of Chemical and Pharmaceutical Research preparations. *J. Chem. Pharm. Res.*__3__, 287–294 (2011).

18. **Patil, V. T. & Patil, P. R**. Physicochemical analysis of selected groundwater samples of Amalner town in Jalgaon District, Maharashtra, India. *E-Journal Chem.*__7__, 111–116 (2010).

19. **Abtahi, M. *et al***. A modified drinking water quality index (DWQI) for assessing drinking source water quality in rural communities of Khuzestan Province, Iran. *Ecol. Indic.*__53__, 283–291 (2015).

20. **Aghzar, N., Berdai, H., Bellouti, A. & Soudi, B**. Ground water nitrate pollution in Tadla (Morocco). *Rev. des Sci. l'Eau*__15__, 459–492 (2002).

21. **Pradeep, V., Deepika, C., Urvi, G. & Hitesh, S**. Water Quality Analysis of an Organically Polluted Lake by Investigating Different Physical and Chemical Parameters. *Int. J. Res. Chem. Environ.*__2__, 105–111 (2012).

22. **Ali, S. *et al.*** Concentration of fluoride in groundwater of India: A systematic review, meta-analysis and risk assessment. *Groundw. Sustain. Dev.*__9__, 100224 (2019).

23. **Yadav, K. K. *et al***. Fluoride contamination, health problems and remediation methods in Asian groundwater: A comprehensive review. *Ecotoxicol. Environ. Saf.*__182__, 109362 (2019).

24. **Saxena, V. K. & Ahmed, S**. Inferring the chemical parameters for the dissolution of fluoride in groundwater. *Environ. Geol.*__43__, 731–736 (2003).

25. **Dutta, D. *et al***. Comparative Analysis of Physico-Chemical Parameters for Snow, Ground and River Water of Leh District. *Int. J. Sci. Res. Publ.*__8__, (2018).

26. **Fewtrell, L**. Drinking-water nitrate, methemoglobinemia, and global burden of disease: A discussion. *Environ. Health Perspect.*__112__, 1371–1374 (2004).

27. **Reddy, A. G. S., Reddy, D. V., Rao, P. N. & Prasad, K. M**. Hydrogeochemical characterization of fluoride rich groundwater of Wailpalli watershed, Nalgonda District, Andhra Pradesh, India. *Environ. Monit. Assess.*__171__, 561–577 (2010).

28. **Lydia Abebe, Andrew J. Karon, Andrew J. Koltun, Ryan D. Cronk, Robert E. S. Bain,Jamie Bartram**; Microbial contamination of non-household drinking water sources: a systematic review. *Journal of Water, Sanitation and Hygiene for Development* 1 September 2018; 8 (3): 374–385. doi: https://doi.org/10.2166/washdev.2018.080.

29.**Pu J, Fukushi K**. Bacterial water quality and risk evaluation of bottled drinking water in China. . Int J Food Saf Nutr Public Health 2016; 6(1): 1-3.

30. **Majumder AK, Islam NK, Nite RN, Noor R**. Evaluation of microbiological quality of commercially available bottled water in the city of Dhaka, Bangladesh. Stamford J Microbiol 2011; 1(1): 24-30. [http://dx.doi.org/10.3329/sjm.v1i1.9099].