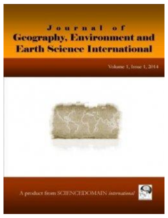

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Flowing Water of Three Major Rivers of the Pune City in Spring Season: A Physico-Chemical Analysis

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Authors' contributions

This work was carried out in collaboration between both authors. Author MVSV designed the study and formulated the research objectives. She has prepared the first draft of the manuscript. Author SG finalized the draft and incorporated certain elements in the study which have added scientific value to the article, besides helping in the interpretation and analysis of the results.

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ABSTRACT

In the present study, an attempt has been made to assess the flowing water quality of different rivers flowing through Pune during the spring season, i.e., prior to summer and monsoon. Physico-Chemical monitoring of these rivers of Pune was done from Jan-Mar 2015 to analyse various parameters. A total of 18 Physico-Chemical parameters were analysed for water samples of the rivers at nine different locations. The study revealed the presence of less organic matter in almost all the samples except those from Mula-Mutha rivers. Electrical conductivity measured for these water samples, which is dependent on total dissolved solids (TDS) showed a good correlation between the two quantities. Also, from the present study, it could be concluded that water quality does have a strong bearing on the seasons; as almost all parameters are a function of the climatic conditions in the environment. It may further be inferred that water contamination levels in river waters of Pune were within the limits of pollution level during the spring season.

Keywords: Mula-Mutha river; physicochemical parameters; water pollution; water quality; dissolved Oxygen.

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1. INTRODUCTION

Pune is one of the emerging smart cities of modern India. Three significant rivers like Pavana, Mula and Mutha flow through this city [1]. Mutha River flows from Khadakwasla dam towards Pune city. Another river Mula meets Mutha River which comes from Mulshi dam towards Pune city. The intersection of Mula-Mutha rivers is known as "Sangam Bridge". Pavana River comes from Pavana dam. These three rivers cover the rural areas of Pune in the initial stages, and they receive agricultural run-off in a significant proportion.

Also, the disposal of wastes from burning fossil fuels, discharge of domestic wastes from hospitals, industrial effluents from small & large scale industries located at the river banks add to their pollution problem [2-4]. In view of the above, systematic analysis of various Physico-Chemical parameters of water is imperative and indispensable to evaluate the water quality of these rivers at various locations. Such regular auditing of different Physico-Chemical parameters of the river waters is very essential due to increasing levels of water pollution.

Various research groups have already studied and analysed the run-off water quality of these waters for almost two decades and expressed great concern [5-6]. It has been reported earlier that, the water quality does get affected by the seasonal variations [7]. Such a season-specific study helps in the maintenance of quality of water. In the present work, studies have been carried out to evaluate the physico-Chemical characteristics of these rivers. Also, inferences are drawn from the analysis of these results with respect to the water quality with special reference to spring season.

2. MATERIALS AND METHODS

2.1 Collection of Water Samples

Water samples were collected from different sampling sites of the rivers Mula, Mutha and Pavana (Table 1, Fig. 1) during spring season of 2015 to study various physico-chemical parameters. Sampling was done three times during the season and the presented results are average values obtained for each of the parameters. Of these temperatures and pH of the water,, samples were recorded during their collection using a mercury thermometer and a pH meter.

2.2 Physico – Chemical Analysis of Water Samples

Key parameters such as pH and temperature, electrical conductivity, Chemical Oxygen Demand (COD), Total Hardness, Alkalinity, Total dissolved solids, Total suspended solids, Phosphate, Nitrate, Sulphate, Chlorides, Turbidity, Sodium(Na), Calcium (Ca), Most Probable Number(MPN), Dissolved Oxygen (DO) and Biological Oxygen demand (BOD) were determined using standard protocol prescribed by American public health Association, (1995) [8]. All the solutions were prepared using distilled water, and the reagents were of Analytical grade (AR) grade.

The results were compared with the standards of water quality as per World Health Organization [9] and BIS (IS 10500 – 1991) [10] to assess the quality of water in Mula, Mutha and Pavana Rivers.

From all the three rivers, sampling locations were selected in such a way to give a reasonable comparison of river water quality in Pune. For the present study, nine sample stations were considered as in Table 1.

Table 1. Sampling stations

Station no	Name of the sampling station	Name of the river
S1	Panshet Dam	Mutha River
S2	Khadakwasla Upstream	Mutha River
S3	Khadakwasla Downstream dam	Mutha River
S4	Mulshi Dam	Mula River
S5	Paud	Mula River
S6	Pavana Dam	Pavana River
S7	Bevad Ovhal	Pavana River
S8	Aundh	Mula River
S9	Yerwada	Mula-Mutha

Table 2. Physico-chemical parameters and methods

S. no	Parameters of water analysis	Methods
1	pH	Electrometric
2	Temperature (̊C)	Thermometer
3	DO	Winkler's method
4	BOD	BOD 5 days incubation at 20 ̊C followed by Titration
5	COD	Digestion followed by Titration
6	Chloride	Titration by $AgNO_3$
7	Sulphate	UV - VIS Spectrophotometer
8	Phosphate	UV - VIS Spectrophotometer
9	Nitrate	UV - VIS Spectrophotometer
10	Calcium (Ca)	Titration by EDTA
11	Total Dissolved Solids	Gravimetric Method
12	Total Suspended Solids	Gravimetric Method
13	Total Hardness	Titration by EDTA
14	Alkalinity	Titration by H_2SO_4
15	Turbidity	Nephelometric Method
16	MPN	Most Probable Number Method/Test
17	Electrical Conductivity	Electrometric
18	Sodium (Na)	Flame Emission

Note 1: - All results are in mg/L except pH, EC in µS/cm, MPN is a number, BOD in ppm& Temperature in degree centigrade

The water samples were collected in the month of January, February and March 2015 (first week of all months). The investigative parameters studied from Nine specified locations and Methods as stated earlier are tabulated in Table 2.

3. RESULTS AND DISCUSSION

The data revealed that there were considerable variations in the examined samples. The results of analysis of various Physico-Chemical Parameters of water of Mula, Mutha & Pavana river are summarized in Table 3.

3.1 pH

If pH of water is too high or low, aquatic organisms or living within it will die. pH also affects the solubility and toxicity of chemicals in water. The value of pH was found within limits as per WHO standards. Greater pH (7-8) was recorded in water samples collected from Aundh (Mula river).

3.2 Temperature

Temperatures of the samples from S1 to S9 were recorded and ranged between 21^{O}C to 23^{O}C. Temperature is one of the most important factors in the aquatic environment. Temperature also affects the solubility of Oxygen in water. The solubility of Oxygen in water increases with decreasing temperature [11]. Water temperatures fluctuate naturally both daily and seasonally.

Aquatic organisms often have narrow temperature tolerances. Thus, although water bodies have the ability to buffer against atmospheric temperature variations, extreme conditions have severe impacts on aquatic life, including bacteria, algae, invertebrates and fish [12]. In the present investigation, almost all the samples were in the same temperature range besides being low in magnitude hence, no considerable impact of this parameter is apparently recorded.

3.3 Dissolved Oxygen (DO)

The amount of dissolved oxygen often determines the number and types of organisms living in that body of water. Dissolved Oxygen is an important parameter in assessing water quality and reflects the physical and biological processes prevailing in the water.

Good water should have the solubility of Oxygen at mg/L 7.7 and 7.0 mg/L at 30^{o} C and 35^{o} C respectively. Oxygen saturated water have a pleasant taste. Fig. 1 shows the graphical representation of DO at various sample stations against the WHO standards. The DO of the samples in the study ranged from 5.04 mg/L to 6.56 mg/L which is within the acceptable limits of the WHO,2003 standards (8)except S8 and S9 which were below this standard. In general, the DO levels are less during spring or pre-monsoon periods due to declined aeration of water during this time.

Table 3. Physico-chemical parameters of the water samples

S.No	Parameter	S1	S2	S3	S4	S5	S6	S7	S8	S9	WHO standards	Desirable limits	Permissible limits
1	pH	7.2	7	7	7.2	7.5	7.6	7.4	7.8	7.2	7.0-8.5	6.5-8.5	No Relaxation
2	Temperature (C)	23	22	23	21	22	21	22	22	22	25-30		
3	DO	6.56	6.24	6.13	6.05	5.43	5.04	5.61	4.51	4.32	>6	5	
4	BOD	2.13	2.32	2.41	2.25	2.93	2.71	2.41	3.42	3.61		1.0-2.0	3.0-5.0
5	COD	3.2	5.6	4	3.2	5.6	1.6	0.8	5.6	4.8	10		250
6	Chloride	35.5	35.5	28.4	28.4	35.5	28.4	35.5	85.2	78.1	250	250	1000
7	Sulphate	11.2	8.6	13.4	9.6	12.2	11.6	15.8	20.1	25.5	250	200	400
8	Phosphate	2.8	1.2	0.8	0.2	1.6	0.6	1.2	3.1	4.3	5		
9	Nitrate	8.4	7.6	10.2	8.7	9.2	13.8	9.3	10.5	13.8	50	45	100
10	Calcium	17.9	36.9	38.1	40.1	15.9	32.8	36.8	30.7	50.1	75	200	
11	Total Dissolved Solids	415	230	380	120	345	323	465	219	200	500-1000	500	2000
12	Total Suspended Solids	134	67	102	48	172	175	209	170	112			
13	Total Hardness	32	72	44	40	36	48	44	292	25	200 - 600	300	600
14	Alkalinity	309	253	261	48	102	67	87	102	38	120	200	600
15	Turbidity	0.05	0.3	0.4	0.5	0.3	0.5	0.2	0.1	0.9	5 NTU	10 NTU	
16	MPN	`-	`-	`-	`-	`-	`-	`-	10	15			
17	Electrical Conductivity	603	401	556	320	523	333	398	468	225	300		
18	Sodium	22.1	51	42	16.4	35.6	48.6	41.6	70.9	51.8	200		

3.4 Biological Oxygen Demand (BOD)

Biological oxygen demand quantifies the amount of dissolved oxygen needed by aerobic biological organisms to breakdown organic material present in given water sample at certain temperature over specific time. It is often used as an alternative of the degree of organic pollution of water. BOD is also used as a gauge of the effectiveness of wastewater treatment plants.

Higher BOD levels, in general, correspond to decline in DO levels. This is because, if the amount of organic waste in the water sample is less, bacteria present to decompose it and thus the BOD will be lower resulting in an enhanced level of DO in it. Fig. 2 shows the graphical representation of BOD at various sample stations against the WHO standards. A minimum value of 2.13mg/Lof BOD was reported in the sample collected from Panshet Dam, and maximum of 3.61mg/L in the sample collected from Yerwada. The BOD levels are little above the standards set by WHO,2003 standard. As the biological activity is low and organic wastes are minimal during the spring season, the recorded BOD levels are justifiable [13].

3.5 Chemical Oxygen Demand of Water (C.O.D)

Chemical Oxygen demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as Ammonia and nitrite. Chemical Oxygen demand is an important water quality parameter and being similar to BOD, it provides an index to assess the effect discharged wastewater have on the receiving environment. Higher COD levels mean a more considerable amount of oxidizable organic material in the sample which reduces dissolved Oxygen (DO) levels. A reduction in DO can lead to anaerobic conditions which are deleterious to higher aquatic life forms.

The COD test is often used as an alternate to BOD due to the shorter length of testing time. COD is a parameter used to widely determine the amounts of organic pollutants in wastewater [14] .COD is a valuable water quality parameter. COD values convey the amount of dissolved oxidised organic matter including non-biodegradable matters present in it. The value of COD was found in the range of 0.8 mg/L to 5.6 mg/L and the values for all samples are under permissible limits given by WHO [15]. The lower values indicate the lesser contents of organic matter in the investigated samples. [16].

3.6 Chlorides (Cl^-)

Chlorides are present in both fresh and salt water and are essential elements of life. Chloride concentrations between 1 and 100 ppm are normal in fresh water. Fig. 3 shows the graphical representation of chloride at various sample stations against the WHO standards. The concentration of Cl was found in the range of 28.4mg/L – 85.2mg/L. The value of Cl was found within the permissible limits as per the WHO standards. The lower values of chloride concentrations are deviation from the regularly shown trends during winters and summers in respect of chloride levels. Such a show up requires further investigations. Lower chloride

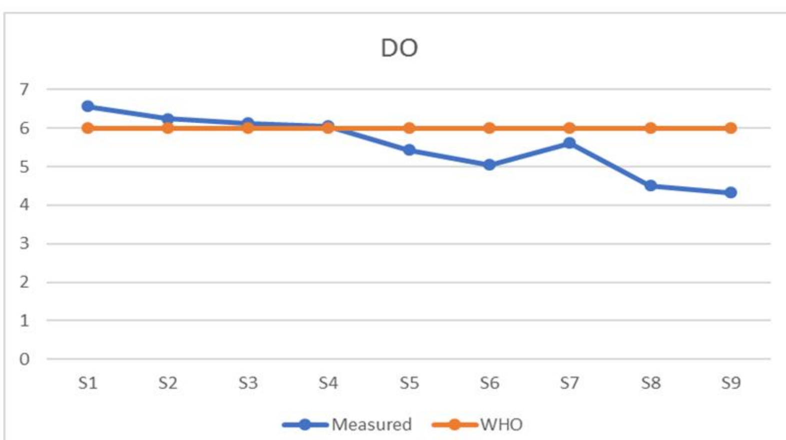

Fig. 1. Extent of DO at various sampling stations

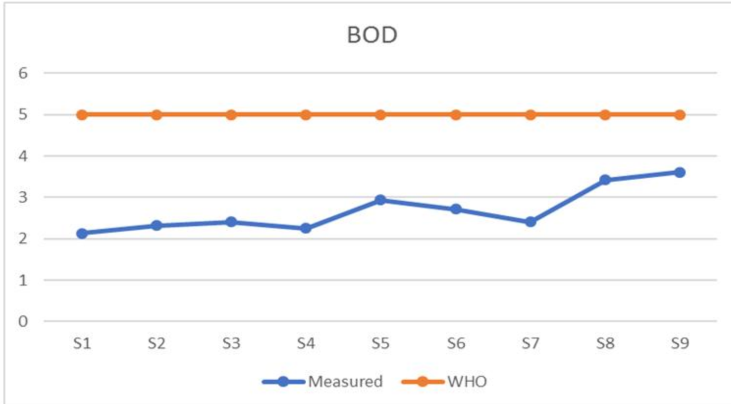

Fig. 2. Extent of BOD at various sampling stations

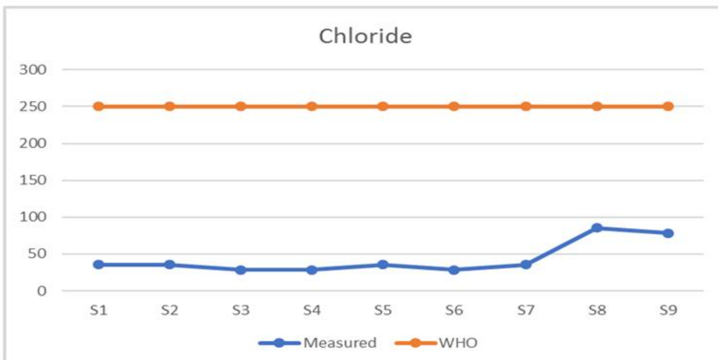

Fig. 3. Extent of chloride at various sampling stations

levels infer presence of lesser amount of organic wastes in the waters analyzed which is in good agreement with the COD values recorded [17]

3.7 Sulphate (SO_4^{2-})

Sulphates occur naturally in drinking water, usually as a combination of Sulphur and Oxygen. Some minerals present in soil also get dissolved and are ultimately released to ground water as Sulphates. Many health concerns regarding Sulphate in drinking water have been raised. There are reports that, diarrhea may be associated with the ingestion of water containing high levels of Sulphate [18]. Sulphate levels in the present water varied from 8.6 mg/L at Khadakwasla to 25.5 mg/L at Yerwada. Samples are well within the standard limits as prescribed by WHO.

3.8 Phosphate (PO_4^{3-})

Phosphates are chemicals containing the element Phosphorous and they affect water quality by causing excess growth of algae. About 3.5 pounds of phosphates per person enter the environment in the United States annually from farms.

All plants need Phosphates to grow but Phosphorous is normally present in surface water at a rate of only 0.002 parts per million. In rivers, lakes and streams they cause problems such as algal blooms, hypoxia, fish deaths, loss of bio diversity and species composition, loss of adequate plants, coral reefs and other problems. Sewage and agricultural activities contribute mainly for the phosphates in the water. However, low phosphates values are recorded during winters [2]. Fig. 4 shows the graphical representation of phosphates at various sample stations against the WHO standards. This was observed among S1-S9 with minimum of 0.2 mg/L at Khadakwasla upstream and a maximum of 4.3 mg/L phosphate at Yerwada. But, the levels of phosphates in all the samples are within the limits set by WHO.

3.9 Nitrates (NO_3^-)

Nitrate is a common contaminant of surface water and ground water and it can cause health problems in infants and animals as well as eutrophication of water bodies. Many studies have shown that agricultural activities are significant source of surface and ground water pollution due to long term and excessive fertilizers use.

Fig. 5 shows the graphical representation of nitrate at various sample stations against the WHO standards The samples collected from Pavana dam and Yerwarda showed maximum nitrate contents (13.8 mg/L) whereas least content (7.6 mg/L) was measured in samples collected from Khadakwasla up stream. Land drainage and plant, animal debris besides igneous rocks are source of nitrates. Samples S8 and S9 are apparently unhygienic and are rich in animal and plant debris leading to relatively greater values of nitrates at these places. Though the water may be used for general use, not fit as potable water due to nitrate contamination levels [19].

3.10 Calcium Hardness

Calcium, one of the components of hard water, can be protective because it makes water less corrosive and less likely to reach toxic trace minerals, such as Cadmium and Lead out of metal pipes. According to US National Academy of sciences by 1977 there had been more than 50 studies in nine countries that indicated a

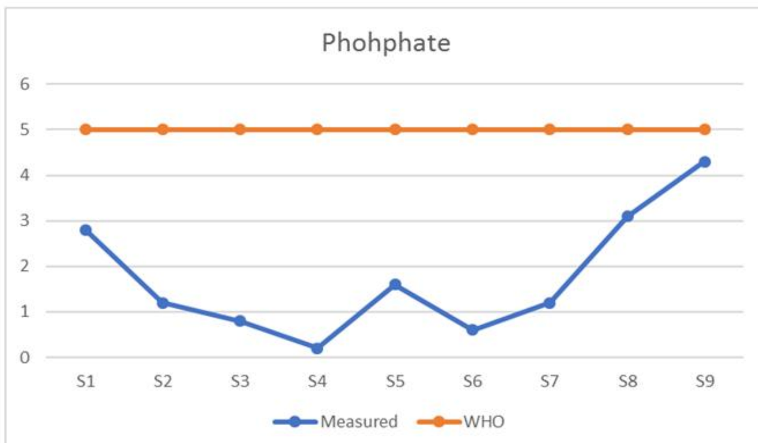

Fig. 4. Extent of phosphate at various sampling stations

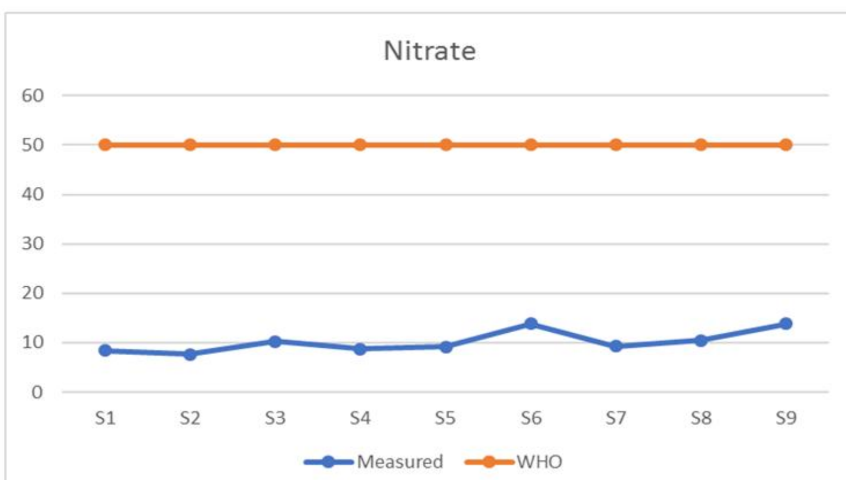

Fig. 5. Extent of nitrate at various sampling stations

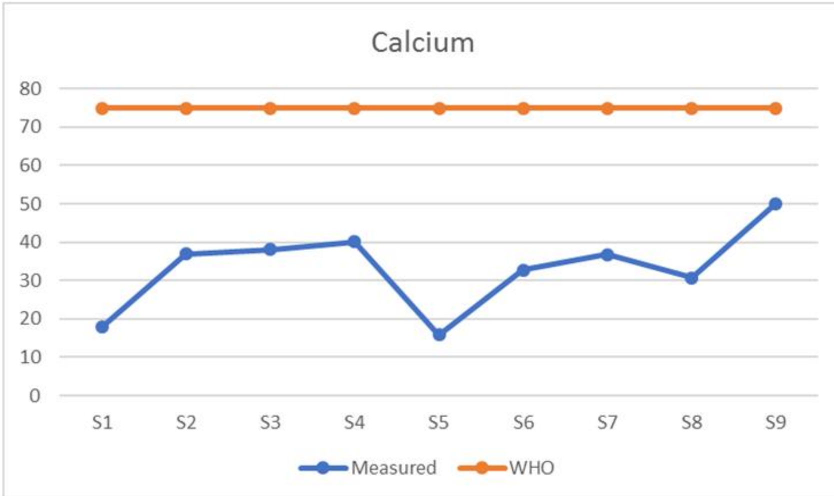

Fig. 6. Extent of Calcium at various sampling stations

universal relationship between water hardness and mortality from cardiovascular disease [20].

Most of the scientists have indicated a negative statistical association of various types of cancer morbidity / mortality with the hardness of water and Calcium. Some studies correlate domestic hardwater usage with increased eczema in children [21]. Fig. 6 shows the graphical representation of calcium at various sample stations against the WHO standards. Calcium hardness for collected water samples were within the permissible limits given by WHO standards and it ranged from 15.9 mg/L to 50.1 mg/L.

3.11 Total Dissolved Solids (TDS)

Total dissolved solids concentration is the sum of the cations and anions in the water. The Total Dissolved Solids test is used as an indicator test to determine the general quality of the water. TDS comprise importantly, Chlorides, Carbonates, Bicarbonates, Phosphates and Magnesium. Excess dissolved solids generally affect the potability of water [22]. This variation is because of pollutants which come along with the effluents of nearby industries and other inlets.

In the samples S1 to S9, the TDS was recorded in the range of 120 mg/L-465 mg/L. The value of TDS was found to be within the limits as per the WHO standards [23].

3.12 Total Suspended Solids

Total suspended Solids (TSS) is the dry weight of suspended particles that are not dissolved in water can be trapped by a filter paper . TSS can include a wide variety of material such as silt, decaying plant matter, animal matter, industrial wastes and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life [24]. TSS ranged from 48 mg/L to 209 mg/L. The maximum value of total suspended solids (209 mg/L) was found at S8 sampling station of Aundh (Mula River). The least value of total suspended solids was recorded at S4 sampling station of Mulshi dam (Mula River). It is established from the earlier studies that greater values of TSS are recorded during monsoon season due to heavy water flow as it may also enhance the erosion leading to increased TSS [25]. However, in the pre-monsoon periods TSS values are low at all sample sites as observed in the present investigation.

3.13 Total Hardness (TH)

The simple definition of water hardness is the amount of dissolved calcium and magnesium in the water. Hard water is high in dissolved minerals both calcium and magnesium [26]. General guidelines for classification of waters [27] are as below.

- 0 to 60 mg/L as calcium carbonate is classified as soft
- 61 to 120 mg/L as moderately hard
- 121 to 180 mg/L as hard
- More than 180 mg/L as very hard.

Hard water can shorten the life of fabrics and clothes. In areas of the country where the water is relatively hard, industries might have to spend money to soften their water as hard water can damage equipment. Long term movement of hard water through a pipe can result in what is called scale buildup.

In addition, several epidemiological investigations have demonstrated the relation between risk for cardiovascular disease, growth retardation, reproductive failure and other health problems due to its content of magnesium and calcium in hard water. The values of TH for all the water samples were found to be within the limits as per standards provided by WHO and are in the range of 25 mg/L to 292 mg/L.

The values within the limits may be attributed to the winter season. As the rate of evaporation is low in the spring season TH is observed to be low. Also, flowing waters are generally less hard than the ground water.

3.14 Alkalinity

Alkalinity refers to the capability of water to neutralize acid. Alkalinity of natural water is determined by the soil and bedrock through which it passes. Higher Alkalinity levels in surface waters will buffer acid rain and other acid wastes and prevent pH changes that are harmful to aquatic life. The lowest Alkalinity (38 mg/L) was recorded in water samples collected from Yerawada whereas the highest alkalinity i.e,309 mg/L was recorded in case of Panshet dam which is very high as compared to permissible limits given by WHO Standards. In fact, S1-S3 have shown high levels of alkalinity which may be attributed to presence of excess of CO_2 produced because of degradation of organic matter.

3.15 Turbidity (NTU)

Turbidity in open water may be caused by growth of phytoplankton. Human activities that disturb land such as construction, mining and agriculture can lead to high sediment levels entering water bodies during rain storms due to storm water runoff. In drinking water the higher the turbidity level, the higher the risk that people may develop gastrointestinal diseases. Turbidity was found in the range of 0.02 to 0.10 and these values are under the permissible limits given by BIS i.e. 10 NTU [28].

3.16 Most Probable Number (MPN)

It is a parameter that is very frequently used or applied for testing the quality of water. It is an index used to know the presence of bacterial matter present in water. It indicates the presence of disease causing bacteria like fecal coliforms. Greater the MPN, greater is the amount of this disease producing organism in the water leading to enhanced levels of health risks. An MPN index of 15 or more should not be permitted in consecutive samples. If the MPN index is consistently 20 or greater, application of treatment to the water supply should be considered. S1-S7 did not show any results and S8 and S9 were within the stipulated limits.

3.17 Electrical Conductivity

The electrical conductivity of water is a measure of salinity. The Electrical conductivity (EC) of water estimates the total amount of solids dissolved in the water and depends on the water temperature. Total dissolved solids and electrical conductivity exists for fresh water with a correlation ratio of 0.65, whereas, there is a nonlinear relationship of TDS and EC for sea water.

Interestingly, there was a good correlation observed for almost all the samples between EC and TDS. As observed in the literature, increased TDS has indeed increased the EC of almost all the samples. S9 with lowest TDS has recorded the lowest EC. Electrical Conductivity of water samples was found to be in the range 225-603 µS /cm of which all the samples except that of S9 have shown greater values compared to WHO standards. The conductivity for the sample S1 is more than double the requisite standard. Enhanced conductivities in the water samples may also be attributed to ions generated by the decomposition and mineralization of organic contents present.

Finally, it is concluded that TDS-EC correlation ratio may not be same for all natural waters and it varies widely within themselves.

3.18 Sodium

Elevated levels of Sodium in drinking water may have adverse health effect on normal, healthy persons. High School sophomores residing in a community with elevated levels of Sodium in the drinking water (109 mg/l) exhibited a marked upward shift in blood pressure distribution patterns for systolic and diastolic pressure than compared with students in an approximate matched community (8 mg/l). Females exhibited a blood pressure distribution pattern characteristic of persons 10 year older while for males the upshift was similar to that of a group approximately 2 year older.

Sodium value was found in the range of 16.4mg/l to 70.9 mg/l. The maximum value of sodium 70.9mg/l was found at S8 Sampling Station of Aundh (Mula River). The least value of 16.4mg/l sodium was recorded at S4 Sampling station of Mulshi Dam (Mula River). All samples showed sodium within the permissible limits.

4. CONCLUSION

As the biological activity is low and organic wastes are minimal during the spring season lower values of BOD and COD were observed in all the samples studied. The recorded BOD and COD levels indicate the presence of lesser contents of organic matter in the investigated samples. Chloride levels in them also hint at the same inference justifying the BOD and COD levels acquired. Sites of samples S8 and S9 are unhygienic and are rich in animal and plant debris leading to relatively greater values of nitrates at these places. Though the Mula Mutha river waters of these regions may be used for general use, as per the results of the present study it is not advisable to use these waters for drinking without treatment due to their enhanced contamination levels. In the pre-monsoon periods, TSS values are low at all sample sites as also observed in the present investigation. It is important to remark that S1-S3 have shown high levels of alkalinity which may be attributed to the presence of an excess of CO_2 produced because of degradation of organic matter. Another result that is worth noting herein is the correlation obtained between TDS and EC as established in the earlier reports. Rest of the physico-chemical parameters studied were within the limits of the standard values prescribed. It may also be concluded form the present work that, water quality during spring season or pre-monsoon period is better vis-à-vis other seasons in view of the lower magnitudes manifested for almost all the studied parameters.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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