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Government of India
Ministry of Jal Shakti
Department of Water Resources, River Development &
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REPORTS ON WATER QUALITY SCENARIO OF RIVERS

VOLUME- I

CENTRAL WATER COMMISSION

TABLE OF CONTENTS

Government of India
Ministry of Jal Shakti,
River Development and Ganga Rejuvenation

A CASE STUDY ON RIVER ARKAVATHY WATER QUALITY

(From August 2019 to July 2020)

CAUVERY DIVISION
MONITORING SOUTH ORGANISATION
CENTRAL WATER COMMISSION
BENGALURU

January 2021

FOREWORD

Water is a precious natural resource with almost fixed quantum of availability. Fresh water is becoming a scarce resource day by day worldwide. Besides quantifying the water resources, the work of monitoring the Quality of water is also needed to be done for various usages.

Central Water Commission, a premier technical organization in the field of Water Resources under the Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal shakti, has been monitoring river water quality in the country. Monitoring (South) Organisation was setup in April 1995 as one of the Regional Offices of Central Water Commission with headquarters at Bangalore. This organisation looks after the units of Project monitoring, Project appraisal, Hydrological Observations, Flood Forecasting and Water Quality Monitoring activities in the river basins of Cauvery (Karnataka and Kerala), Upper Krishna namely Malaprabha ,Ghatprabha and Tungabhadra sub-basins(Karnataka & Maharashtra) and West flowing rivers, spread across parts of Maharashtra and Goa.

Upper Cauvery Water Quality Laboratory (NABL accredited) of Cauvery Division, MSO, CWC, Bengaluru analyzes 25 different physio-chemical and biological water quality parameters at 28 WQ stations in Cauvery and Krishna basin rivers. Vrushabhavathy river, which joins Arkavathy river carries pollution load of Bengaluru city and since there is no WQ station on Vrushabhavathy river, hence a case study of river water quality on River Arkavathy for about 50km river stretch, was carried out by the WQ lab under Cauvery Division. The Level –II Water Quality laboratory has been accredited by NABL as per ISO/IEC 17025:2017 and using internationally accepted standard methods for river water analysis [American Public Health Association (APHA), 2017 Edition standards].

The data presented in this report will be useful for the water resources planners, managers and Water Users in Catchment area of Arkavathy basin, and also for R&D institutions, planning, irrigation, industrial and sewage disposal schemes.

I am very thankful to the able guidance of Shri Sushil Kumar, CE, MSO, CWC, B'lore and efforts put in by Shri Jitendra Panwar, the then SE (HO&CC), MSO, CWC, B'lore. I also thank to Shri Guru Prasad J, SE (HO&CC), MSO, CWC, B'lore in bringing out this report titled "The Water Quality Case study on river Arkavathy" for the period from August 2019 to July 2020. The work done by the Officers and staff of UCWQL headed by Shri Narayanaswamy M, ARO with the assistance of Sh. Vijay Kumar, SRA, Sh. Ajay Chaitanya, SRA and staff, for the sampling, analysis, data compilation and preparation of report is highly appreciated. I also put on record special thanks to National River Water Quality Laboratory, New Delhi for helping us in analysis of trace and toxic elements.

06/01/2021

(SHRIHARI SHEKHAR)
Executive Engineer,
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Bengaluru.

List of abbreviations

APHA	-	**American Public Health Association**
CPCB	-	**Central Pollution Control Board**
BIS	-	**Bureau of Indian Standards**
CWC	-	**Central Water Commission**
MSO	-	**Monitoring South Organisation**
CD	-	**Cauvery Division**
UCWQL	-	**Upper Cauvery Water Quality Laboratory**
NRWQL	-	**National River Water Quality Laboratory**
WQ	-	**Water Quality**
HO	-	**Hydrological Observation**
SAR	-	**Sodium Adsorption Ration**
COD	-	**Chemical Oxygen Demand**
BOD	-	**Bio-chemical Oxygen Demand**
DO	-	**Dissolved Oxygen**
TC	-	**Total Coliform**
FC	-	**Fecal Coliform**
TDS	-	**Total Dissolved Solids/ Salts**
MPN	-	**Most Probable Number**
mg/L	-	**milligram/ Litre**
ppm	-	**Parts per million**
GDSQ	-	**Gauge Discharge Sediment and Water Quality**

Executive Summary

Chief Engineer, MSO, CWC, Bangalore visited T Bekuppe and Koggedoddi HO stations and Arkavathi dam on Arkavathy River. It was observed that Vrushabhavathy; a tributary of Arkavathy have its catchment near Bangalore, and hence with a views to analyze the effect of Vrushabhavathy river flow on water quality, the Chief Engineer during the said visit instructed to take up a study on the same river system and its tributaries, along with collection of water samples for water quality analysis before and after confluence of Arkavathi/Vrushabhavathi Rivers. After further discussions with Executive Engineer, Cauvery Division and ARO, WQ lab, the numbers of observation points of study were decided at five locations including two existing HO stations and the frequency of sampling was decided as twice a month. The points were decided as follows:

- Around 5 km upstream of confluence of Arkavathi and Vrushabhavathi rivers, one point on each river.
- One point downstream of confluence and before Kankapura town.
- One point downstream of kanakapura and at T Bekuppe HO station.
- One point at koggedoddi HO station.

Accordingly, Upper Cauvery Water Quality Laboratory conducted sampling and study on Arkavathi River system from August 2019 to July 2020.Twenty five WQ parameters were analysed in UCWQL and seven parameters (trace and toxic) were analyzed in National River Water Quality Laboratory, CWC, New Delhi.

After analysing the samples at designated locations it has been concluded that the oxygen demand parameters like Dissolved Oxygen, Bio-chemical oxygen demand and biological parameters like Total and Fecal coliforms are improved at downstream station Koggedoddy (S-5), before joining River Cauvery due to rejuvenation of river naturally. pH is increased to above 8.3(<9.0) at station Koggedoddy compare to upstream stations due to presence of carbonate rocks in the river bed along the river after Arkavathy dam.

1. Introduction

1.1 The River Arkavathi

The Arkavathi River, a tributary of Cauvery River, originates at Nandi Hills of Chikkaballapura district of Karnataka. It flows 161 Kms southwards to finally join River Cauvery at Sangama. There are two CWC's Hydrological Observation stations situated at **T Bekuppe**, (GDSQ Site), WQ station with level-I lab (Flux), around 30 km U/s of confluence and at **Koggedoddi**, (GDQ site) WQ station with level-I lab (trend), around 2 Km U/s of confluence. Four lakes/ dams are constructed across the Arkavathi River namely **Hesaraghatta Lake, Thippagondanahalli Dam, Manchanabele Dam and Arkavathi Dam**. The River further flows southwards to reach Kanakapura Town. From Kanakapura Town, the River flows southwards for a length of 15 km to reach Arkavathi Dam. Further, the River flows about 17 km to reach Sangam. The total catchment area of entire river system is **4351** Sq.Km. The Arkavathi river runs without any pollution upto Manchanabele Dam because the river passes through Savanadurga Reserve Forest and adjacent to reserve forests like Hulthur Reserve Forest and Handigundi Reserve Forest. The River is primary source of water for wild life of these forests. After Manchanabele dam, sewage generated due to industrial area of Ramanagara town contributes directly to the river. The river Vrushabhavathi, a tributary of River Arkavathi originates at Basavanagudi, Bengaluru and runs for about 65 kms before joining Arkavathi river at Ganalu. River Vishabhavathy carries considerable domestic sewage of Bengaluru city in its route and joins Arkavathi. The Arkavathi River flow is very lean during non-monsoon season upto Ganalu (Confluence point of two rivers). The water quality parameters near the confluence point with Cauvery river is found to be improved. The water near the confluence point looks to be transparent and local people/ domestic animals uses it for their livelihood. Locations of Cauvery River basin and Arkavathy sub basin is given at Plate-1.

1.2 Study area

The study area in this explore encompasses 5 kms upstream of confluence point of river Arkavathi and Vrushabhavathi, 5 km downstream of confluence of above rivers and 3km upstream of kanakpura town with two CWC's H.O stations before confluence of Cauvery and Arkavathi rivers. There are five stations which are taken sampling point in the present study as detailed below.

Geographical details of sampling locations:

Station code	Sampling location	Longitude	Latitude
S1	Doddamudavadi (On river Arkavathi, 5 Km U/S of Confluence of Vrushabhavathy)	77°22'57"E	12°37'11"N
S2	Gogeredoddi (On River Vrushabhavathy, 5 Km U/S of Confluence of Arkavathi)	77°24'24"E	12°37'11"N
S3	Thyamasandra (On River Arkavathi, 3 Km D/S of Confluence point.)	77°24'24"E	12°34'26"N
S4	T Bekuppe (CWC's existing H.O station)	77° 25' 39"E	12° 30'29"N
S5	Koggedoddi (CWC's existing H.O station)	77° 26' 25"E	12°17'46"N

The location of observation stations on map is shown at Plate-2 and Line diagram showing observation stations is at Plate-3

1.3 Sources of pollution:

As the River passes through Reserve Forests, there are no major industries along the Arkavathi River Stretch up to Ramanagara. After Ramanagara the main sources of pollution are as follows.

- **Sewage from Ramanagara Town** :

I. **Domestic sewage from Ramanagara town**

The sewage is being discharged to natural valleys / storm water drains which finally joins the Arkavathi River.

II. **Silk processing / filature units at Ramanagara** :

Ramanagara is famous for its sericulture, and is nicknamed Silk Town & Silk City. The silk produced in this region forms the input for the famous Mysore Silk. Ramanagara is the largest market for silk cocoons in Asia. About 50 tons per day of cocoon arrive at the town. There are more than 1000 silk reeling, twisting and silk waste processing cottage units in Ramanagara Town. The silk processing activity involves cooking of cocoon in Hot water and degumming by using hot water. The process generates considerable quantity of trade effluent with high BOD and COD.

III. **Sewage from Kanakapura Town:**

The sewage is being discharged to natural valleys / storm water drains which finally joins the Arkavathi River.

IV. **Polluted water from Vrushabhavathi River:**

The Vrushabhavathi River which originates in the North western part of Bengaluru, passes through western parts of Bengaluru before joining the Byramangala Reservoir. On the way it carries huge quantity of sewage / sullage from the Bengaluru City and industrial effluents. The river joins Byramangala Reservoir and this is the predominant source of pollution to River Arkavathi.

V. **Dumping of Municipal Solid Wastes:**

The two major towns in the stretch viz., Ramanagar and Kanakapura generate municipal solid waste, which enters into river through storm water drains and by other means.

2.0 Sampling and preservation

Sampling and preservation followed as per standard methods in APHA (2017) as follows. Water samples for physico-chemical analysis were collected in pre-cleaned 2L polythene plastic bottles. Water samples for BOD and COD analysis were collected separately in pre- cleaned 300ml Glass BOD bottles and 100 ml Polythene bottle for COD by adding 1ml of Sulphuric acid as preservative. Dissolved Oxygen fixation was done at site itself by adding DO fixation chemicals by using 300 ml BOD bottle. And other physical parameters like temperature, color, odor, pH and Conductivity analysis done at field only. All the water samples were stored in insulated cooler containing ice and brought on the same day to the laboratory and maintained at 4°C± 2°C until processing and analysis was over. The river water samples also sent for trace and toxic analysis in the month of August 2019 & December 2019 to National River Water Quality Laboratory, CWC, New Delhi and June 2020 to Krishna and Godavari River Water quality laboratory, CWC, Hyderabad for trace and toxic metal analysis.

3.0 Discussion on Water Quality Parameters

Water in its chemically pure form occurs rarely in nature. In fact, water is commonly found to carry a variety of constituents. When water in its precipitate form reaches the surface of the earth, it has already collected a number of substances and properties that characterize natural water. Gases have been absorbed or dissolved, dust particles have been picked up, and it has obtained a certain temperature. In case of a high radioactive washout or high acidity pickup, atmospheric water may not even be clean in the general sense and may not be suitable for some uses. Atmospheric water is subject to further changes of quality both upon reaching the earth's surface and during its travel underground. The ability to dissolve salts is gained in the topsoil where carbon dioxide is released by bacterial action on organic matter. The soil water becomes charged with carbon dioxide resulting in formation of carbonic acid. Under the acidic conditions that develop, many soil and rock constituents are dissolved. Apart from natural factors that affect the quality of water, man's influence on the quality of water is quite apparent and is now a major concern. Mixing with municipal and industrial waste waters may result in drastic changes in the water quality of natural waters. Agriculturally oriented activities such as irrigation, use of fertilizer, pesticides, herbicides, etc., may lead to diffuse pollution of both surface waters and ground water. Irrigation return waters also tend to increase total salts in the receiving water. Construction schemes, such as those connected with river training, flood control, low flow augmentation, etc., considerably influence the quality regime. Mining activities often cause substantial water quality changes. There is a great range of water quality parameters that can be used to characterize waters. Largely the water quality measurement objectives and the previous history of the water body will determine selection of parameters. It is true, however, that some parameters are of special importance and deserve frequent attention.

Table 1.0: List of parameters analyzed in Upper Cauvery Water Quality Laboratory, Methodology and Standard Methods of Analysis.

Sl.No	Parameter	Methodology	Standard method of analysis
1	pH	Electrometric method	APHA- 4500 H^+B
2	Conductivity	Laboratory method	APHA- 2510 B
3	Total Dissolved solids	Total dissolved solids dried at 180^0C	APHA- 2540 C
4	Chemical Oxygen demand	Closed Reflux colorimetric method	APHA- 5220 D
5	Bio-chemical oxygen Demand	5-day BOD test	APHA- 5210 B
6	Dissolved Oxygen	Azide modification method	APHA- 4500 O C
7	Total coli form	Standard total coli form fermentation technique	APHA- 9221B
8	Fecal coli form	Thermotolerant fecal coli form procedure	APHA- 9221 E
9	Iron	Phenathroline method	APHA- 3500 Fe B
10	Fluoride	Ion selective Electrode method	APHA- 4500 F^-C
11	Boron	Curcumin method	APHA- 4500 B B
12	Nitrate	Nitrate Electrode method	APHA- 4500 NO_3^-D
13	Sulphate	Turbidimetric method	APHA-4500 $SO_4^{2-}E$
14	Chloride	Argentometric method	APHA- 4500 Cl^-B
15	Calcium	EDTA titrimetric method	APHA- 3500 Ca B
16	Potassium	Flame photometric method	APHA-3500 K B
17	Total Alkalinity	Titration method	APHA- 2330B
18	Total Hardness	EDTA titrimetric method	APHA- 2340C
19	Sodium	Flame emission photometric method	APHA- 3500 Na B
20	Magnesium	Calculation method	APHA- 3500 Mg B
21	Nitrite	Colorimetric method	APHA- 4500 NO_2^-B
22	Silicate	Heteropoly Blue method	APHA- 4500 SiO_2D
23	Phosphate	Ascorbic acid method	APHA- 4500 P E
24	Carbonate	Titration Method	APHA- 2330B
25	Bi-carbonate	Titration Method	APHA- 2330B

4.0 Water Quality Requirement for Different Uses

For any water body to function adequately in satisfying the desired use, it must have corresponding degree of purity. Drinking water should be of highest purity. As the magnitude of demand for water is fast approaching the available supply, the concept of management of the quality of water is becoming as important as its quantity. Each water use has specific quality need. Therefore, to set the standard for the desire quality of a water body, it is essential to identify the uses of water in that water body. In India, the Central Pollution Control Board (CPCB) has developed a concept of *designated best use*

Table 2.0: Designated Best Uses of Water (Source: CPCB)

Designated Best Use	Class	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	1.Total Coli forms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/L or more 4. Biochemical Oxygen Demand 5 days 20°C, 2mg/L or less
Outdoor bathing (Organized)	B	1.Total Coli forms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/L or more 4. Biochemical Oxygen Demand 5 days 20°C, 3mg/L or less
Drinking water source after conventional treatment and disinfection	C	1. Total Coli forms Organism MPN/100ml shall be 5000 or less 2. pH between 6 and 9 3. Dissolved Oxygen 4mg/L or more 4. Biochemical Oxygen Demand 5 days 20°C, 3mg/L or less
Propagation of Wild life and Fisheries	D	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4mg/L or more 3. Free Ammonia (as N) 4. Biochemical Oxygen Demand 5 days 20°C, 2mg/L or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	1. pH between 6.0 and 8.5 2. Electrical Conductivity at 25°C, 2250 µmohs/cm Max. 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/L
	Below-E	Not meeting any of the A, B, C, D & E criteria

Table 3.0: Surface Water Quality Standards in India (Source IS 2296:1982):

Characteristics	Designated best use				
	A	B	C	D	E
Dissolved Oxygen (DO)mg/L, min	6	5	4	4	-
Biochemical Oxygen demand (BOD)mg/L, max	2	3	3	-	-
Total coli form , MPN/100ml, max	50	500	5,000	-	-
pH value	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.0-8.5
Colour, Hazen units, max.	10	300	300	-	-
Odour	Un-objectionable			-	-
Taste	Tasteless	-	-	-	-
Total dissolved solids, mg/L, max	500	-	1,500	-	2,100
Total hardness (as $CaCO_3$), mg/L, max	300	-	-	-	-
Calcium hardness (as $CaCO_3$), mg/L, max.	200	-	-	-	-
Magnesium hardness (as $CaCO_3$), mg/L, max.	100	-	-	-	-
Copper (as Cu), mg/L, max.	1.5	-	1.5	-	-
Iron (as Fe), mg/L, max.	0.3	-	50	-	-
Manganese (as Mn), mg/L, max.	0.5	-	-	-	-
Cholorides (as Cu), mg/L, max.	250	-	600	-	600
Sulphates (as SO_4), mg/L, max.	400	-	400	-	1,000
Nitrates (as NO_3), mg/L, max.	20	-	50	-	-
Fluorides (as F), mg/L, max.	1.5	1.5	1.5	-	-
Phenolic compounds (as C_2H_5OH), mg/L, max.	0.002	0.005	0.005	-	-
Mercury (as Hg), mg/L, max.	0.001	-	-	-	-
Cadmium (as Cd), mg/L, max.	0.01	-	0.01	-	-
Salenium (as Se), mg/L, max.	0.01	-	0.05	-	-
Arsenic (as As), mg/L, max.	0.05	0.2	0.2	-	-
Cyanide (as Pb), mg/L, max.	0.05	0.05	0.05	-	-
Lead (as Pb), mg/L, max.	0.1	-	0.1	-	-
Zinc (as Zn), mg/L, max.	15	-	15	-	-
Chromium (as Cr^{6+}), mg/L, max.	0.05	-	0.05	-	-
Anionic detergents (as MBAS), mg/L, max.	0.2	1	1	-	-
Barium (as Ba), mg/L, max.	1	-	-	-	-
Free Ammonia (as N), mg/L, max	-	-	-	1.2	-
Electrical conductivity, µmhos/cm, max	-	-	-	1000	2,250
Sodium absorption ratio, max	-	-	-	-	26
Boron, mg/L, max	-	-	-	-	2

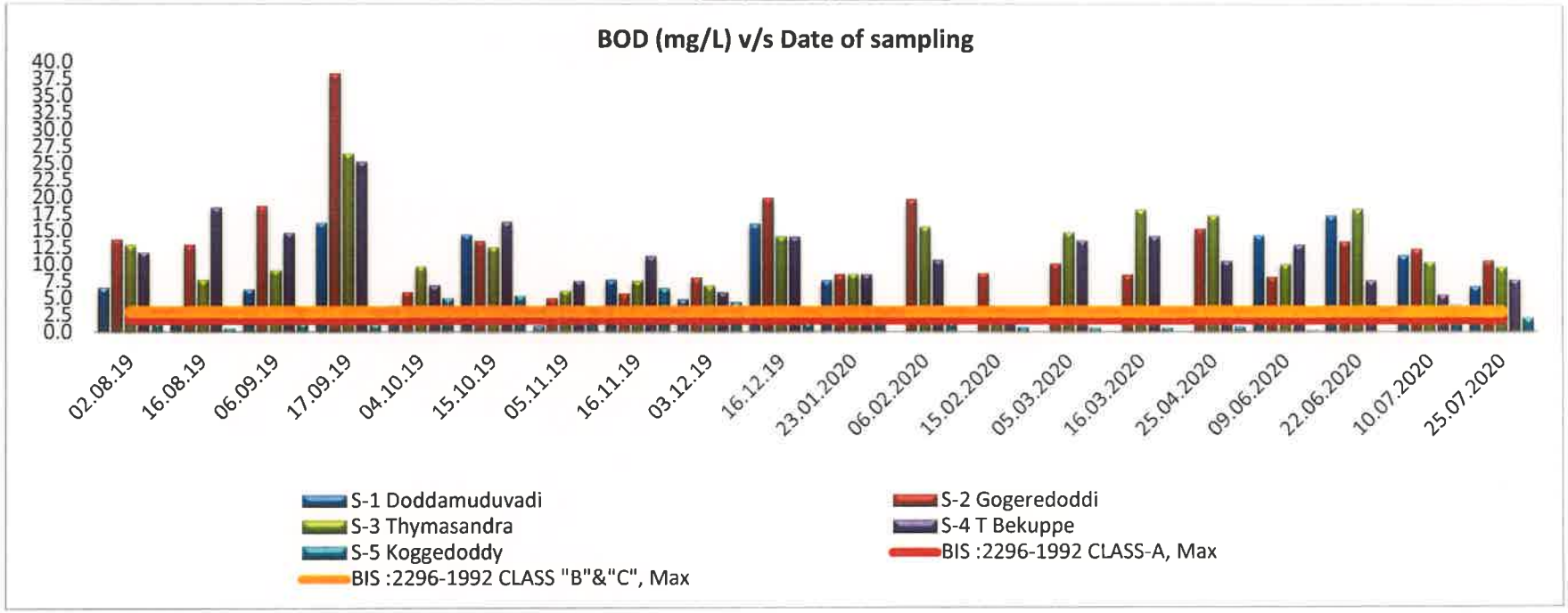
Observed Water Quality data, graphical representation and Discussion

1. Bio-Chemical Oxygen Demand (mg/L)

Observed data

Station Code	Station Name/ Date of sampling	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	6.6	3.1	6.4	16.3	4.0	14.5	0.9	7.8	4.9	16.1	7.7	Dry Bed					14.5	17.4	11.4	6.8
S-2	Gogeredoddi	13.8	13.0	18.8	38.4	6.0	13.6	5.0	5.7	8.1	20.0	8.6	19.8	8.8	10.2	8.5	15.4	8.2	13.5	12.4	10.7
S-3	Thymasandra	13.0	7.8	9.2	26.5	9.8	12.6	6.1	7.6	6.9	14.2	8.6	15.7	3.9	14.9	18.3	17.4	10.1	18.4	10.5	9.7
S-4	T Bekuppe	11.9	18.6	14.9	25.3	7.0	16.5	7.6	11.3	5.9	14.2	8.6	10.8	2.0	13.7	14.3	10.6	13.0	7.7	5.6	7.8
S-5	Koggedoddy	1.5	0.6	1.3	1.2	5.1	5.4	2.2	6.5	4.5	1.5	2.9	1.5	0.8	0.7	0.7	0.8	0.3	0.2	4.0	2.1

Graphical representation



Discussion

BOD plays a vital role in Surface Water Quality as there is more organic wastage in the water body, more BOD level will occurs. Above graph is clearly shows that, the BOD level is increased enormously at the upstream sampling stations it may be due to direct discharge of domestic wastage, industrial wastage and other anthropogenic activities. But the River is naturally recovered for some extent at the point of **Koggedoddy,** due to presence of Dam at the upstream and Water flows from higher level on rocky bed, so the water get saturated by oxygen.

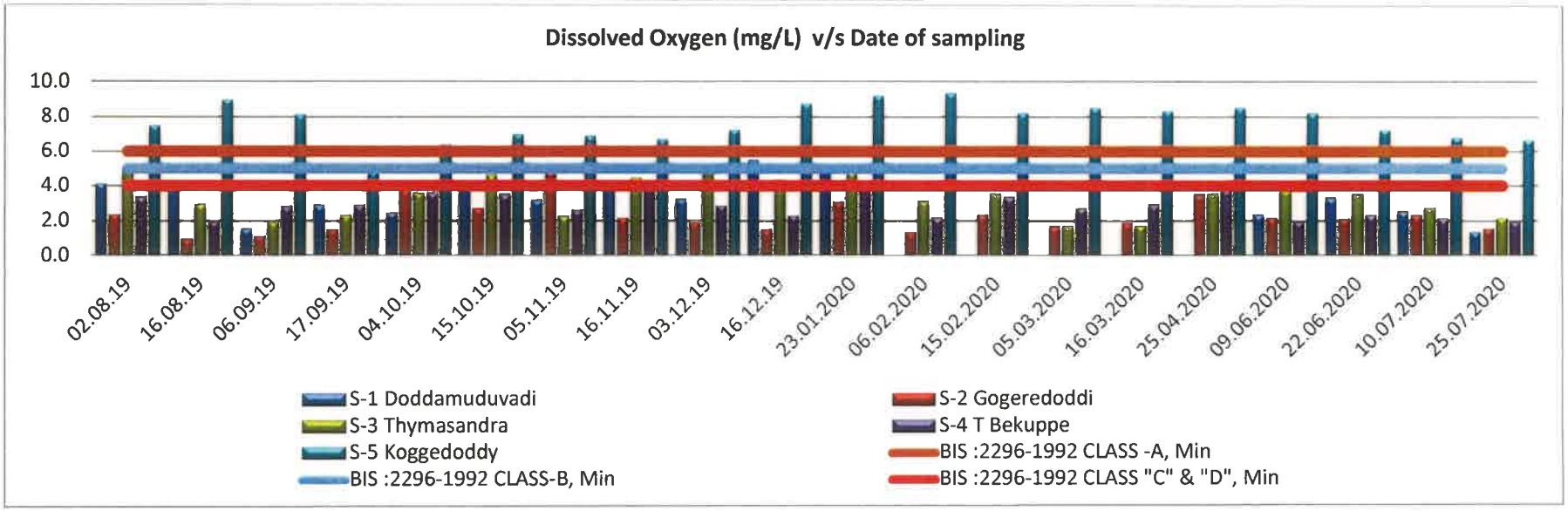
The Maximum BOD observed is **38.4 mg/L** at station **Gogeredoddi (S-2)** of river Arkavathy and minimum BOD observed is **<1.0 mg/L (0.2)** at station **Koggedoddi (S-5). As per BIS 2296:1992 for Inland surface waters , BOD should be less than 2.0 mg/l as per Class A and below 3.0 mg/L as per Class B&C.**

2. Dissolved Oxygen (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	4.1	3.9	1.5	2.9	2.4	4.1	3.2	4.1	3.2	5.5	5.2	Dry bed					2.4	3.3	2.5	1.4
S-2	Gogeredoddi	2.4	1.0	1.2	1.5	3.8	2.7	4.8	2.2	1.9	1.5	3.1	1.4	2.3	1.7	1.9	3.5	2.2	2.1	2.3	1.6
S-3	Thymasandra	4.9	2.9	1.9	2.3	3.6	4.6	2.2	4.5	5.3	4.4	4.8	3.1	3.5	1.7	1.7	3.5	3.7	3.5	2.7	2.1
S-4	T Bekuppe	3.3	2.0	2.8	2.9	3.6	3.5	2.6	4.3	2.9	2.3	4.2	2.1	3.3	2.7	2.9	3.8	2.0	2.3	2.1	2.0
S-5	Koggedoddy	7.5	9.0	8.1	4.8	6.4	7.0	6.9	6.7	7.2	8.7	9.2	9.4	8.2	8.5	8.3	8.5	8.2	7.2	6.8	6.6

Graphical Representation



Discussion

Dissolved Oxygen plays a vital role in Surface Water Quality as the activity of aquatic animals completely depends on it. Dissolved Oxygen deceases with increasing temperature. Above graph clearly shows that, the Dissolved Oxygen is decreased enormously at the upstream sampling stations, it may be due to direct discharge of domestic wastage, industrial wastage and other anthropogenic activity. But the River is naturally recovered at the point of **Koggedoddy**, due to presence of Dam at the upstream and Water flows from higher level on rocky bed, so the water get saturated by oxygen and there is no effect on activities of aquatic animals at this point.

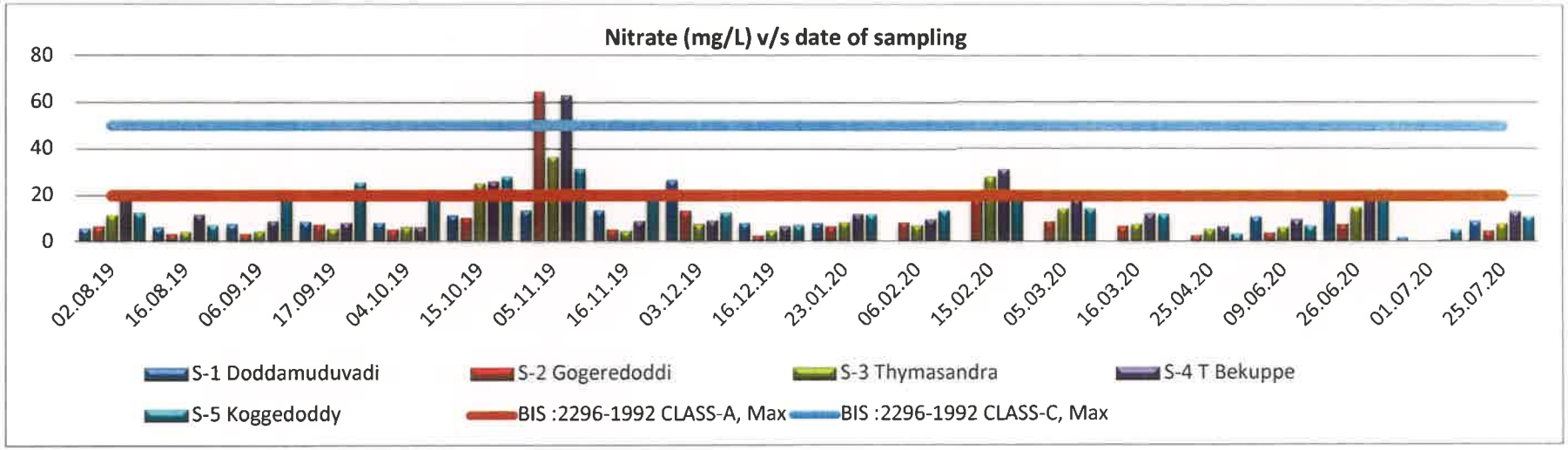
The Maximum DO observed is **9.4 mg/L** at station **Koggedoddi (S-5)** and minimum DO observed is **1.0 mg/L** at station **Gogeredoddi (S-2)**.As per BIS 2296:1992, DO should be minimum 6.0 mg/l as per class A, 5mg/L as per Class B and 4 mg/L as per Class C&D.

3. Nitrate (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.20	06.02.20	15.02.20	05.03.20	16.03.20	25.04.20	09.06.20	26.06.20	01.07.20	25.07.20
S-1	Doddamuduvadi	5.99	6.3	7.89	8.74	8.33	11.4	13.4	13.5	26.5	8.1	8.1	Dry Bed					10.9	19.4	2.1	9.1
S-2	Gogeredoddi	6.89	3.65	3.62	7.62	5.37	10.3	64.5	5.52	13.4	2.9	6.9	8.6	18.6	8.9	7.0	3.2	4.3	7.7	0.5	4.9
S-3	Thymasandra	11.6	4.41	4.61	5.57	6.51	25.3	36.5	4.71	7.76	4.9	8.4	7.2	27.9	14.4	7.8	5.6	6.4	14.9	0.6	7.9
S-4	T Bekuppe	20.6	11.8	9.02	8.3	6.42	25.8	63	9.05	9.24	6.8	12.1	9.7	31.4	18.6	12.2	6.9	9.9	20.9	1.0	13.1
S-5	Koggedoddy	12.4	7.31	19.6	25.5	22.1	28.1	31.2	22.6	12.5	7.2	11.8	13.5	22.6	14.3	11.9	3.5	7.1	22.8	5.4	10.9

Graphical Representation



Discussion

Nitrate generally occurs in trace quantities in surface water but may attain high levels in some ground waters. The rich sources of Nitrates are from fertilizers and domestic wastage and industrial effluents of nitrifying biological treatment plants. In excessive amounts it contributes to the illness known as **Methemoglobinemia** in infants. Above graph are clearly shows that, the Nitrate level is increased enormously on 5th November at Gogeredoddi on River Vrushabhavathy and at T Bekuppe on River Arkavathi it may be due to leaching of fertilizers from agricultural fields, direct discharge of agricultural wastage, industrial wastage and other anthropogenic activities.

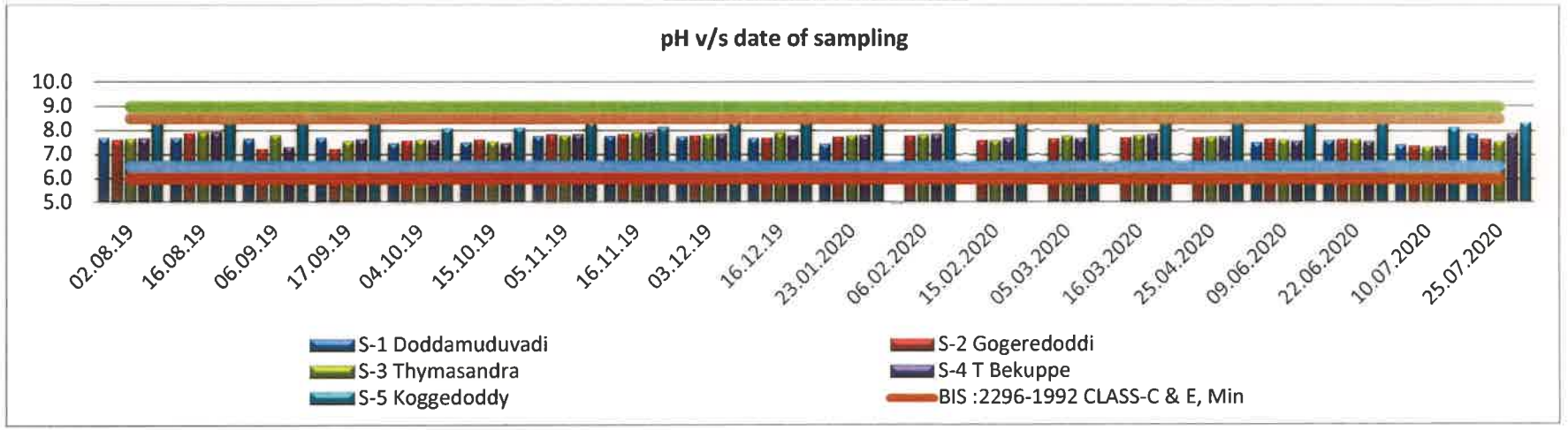
The maximum Nitrate concentration observed is 64.5 mg/L and minimum concentration observed is 0.50 mg/L at station Gogeredoddi (S-2). As per BIS 2296:1992, the nitrate concentration should be maximum 20 mg/l as per class A, and 50 mg/L as per Class C.

4. pH

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	7.7	7.7	7.7	7.7	7.5	7.5	7.8	7.8	7.8	7.7	7.5	DRY BED					7.5	7.6	7.4	7.9
S-2	Gogeredoddi	7.6	7.9	7.3	7.2	7.6	7.6	7.8	7.9	7.8	7.7	7.7	7.8	7.6	7.7	7.7	7.7	7.7	7.7	7.4	7.7
S-3	Thymasandra	7.7	7.9	7.8	7.6	7.6	7.5	7.8	7.9	7.8	7.9	7.8	7.8	7.6	7.8	7.8	7.7	7.6	7.7	7.3	7.6
S-4	T Bekuppe	7.7	7.9	7.3	7.6	7.6	7.5	7.8	7.9	7.9	7.8	7.8	7.9	7.7	7.7	7.9	7.8	7.6	7.6	7.4	7.9
S-5	Koggedoddy	8.6	8.9	8.6	8.6	8.1	8.1	8.4	8.1	8.3	8.5	8.7	8.7	8.6	8.7	8.7	8.6	8.5	8.4	8.1	8.3

Graphical Representation



Discussion

pH is an important parameter to distinguish between acidic and basic nature of water. Above graph clearly shows that, the pH level of River Arkavathi is within the acceptable limit at all the sampling stations as per class C of BIS 2296:1992. The pH level at Koggedoddi is above 8.0 all the time. It may be due to natural interaction with rocky bed and presence of Carbonate in the River water clearly indicates that it's due to leaching of carbonate rocks.

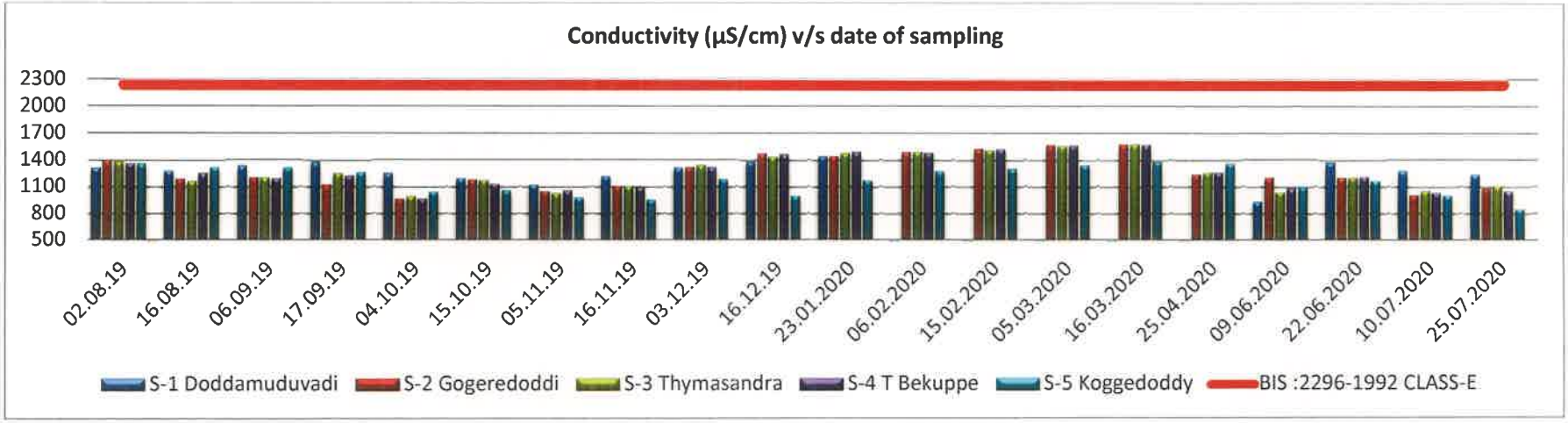
In the current study, maximum pH observed is **8.7 at Koggedoddy (S-5)** and **7.2 at station Gogeredoddi (S-2)**. As per BIS 2296:1992 the pH range should be 6.5-8.5 for Class A, B & D ; 6.0-9.0 as per Class C and 6.0-8.5 as per Class E.

5. Electrical Conductivity(µS/cm)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	1313	1285	1341	1381	1255	1198	1124	1221.0	1322	1382	1447	DRY BED					935.0	1374.0	1282	1241
S-2	Gogeredoddi	1400	1187	1206	1125	967	1186	1048	1109.0	1328	1481	1450	1500	1538	1576	1583	1246	1207	1210	1008	1086
S-3	Thymasandra	1385	1162	1209	1256	996	1180	1029	1111.0	1349	1445	1484	1498	1519	1568	1584	1264	1043	1206	1051	1110
S-4	T Bekuppe	1365	1255	1198	1225	965	1136	1059	1100.0	1325	1471	1497	1486	1531	1572	1579	1262	1093	1215	1034	1053
S-5	Koggedoddy	1360	1320	1319	1261	1044	1059	977	954.0	1188	1000	1172	1275	1305	1347	1382	1364	1103	1168	1006	852

Graphical Representation



Discussion

Electrical conductivity (EC) is used as a basic index to select the suitability of water for agricultural purpose. Conductivity is a measure of water's capability to pass electrical flow. This is directly related to salinity and the ions created as salts dissolve in water.

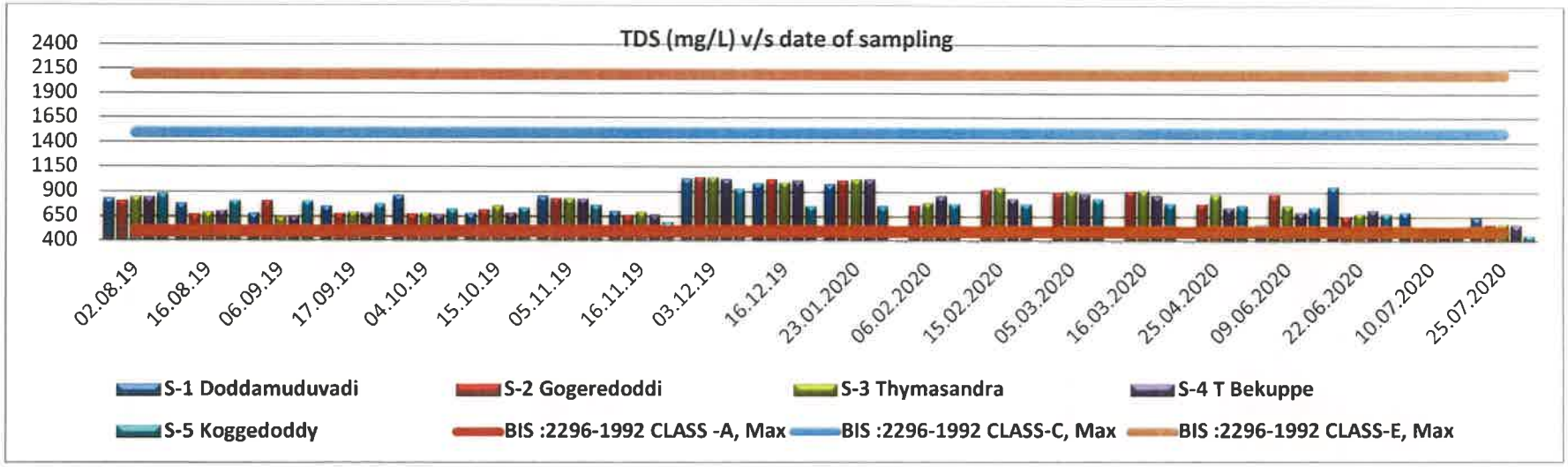
Above graph clearly shows that, the Electrical Conductivity of River Arkavathi is always more than or near to 1000 µmohs/cm from beginning S1 station to S-5 station. The maximum and minimum values are as follows. The maximum EC observed is 1584 µmohs/cm at Station Thymasandra (S-3) and minimum EC observed is 852 µmohs/cm at station Koggedoddy (S-5). As per class E of BIS 2296-1992, the EC should be 2250 µmohs/cm.

6. Total Dissolved Solid (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	834	782	680	758	865	682	856.0	704	1040	987	980	DRY BED					570.0	960.0	700	650
S-2	Gogeredoddi	810	674	811	680	675	720	836.0	666	1050	1030	1020	766	924	904	916	786	882	660	544	576
S-3	Thymasandra	852	696	648	700	690	760	832.0	698	1050	1000	1030	792	946	914	920	876	764	690	548	584
S-4	T Bekuppe	846	712	654	690	668	690	830.0	668	1030	1020	1030	860	836	882	868	746	698	724	540	574
S-5	Koggedoddy	880	812	808	776	725	740	766.0	594	928	758	760	780	778	832	782	764	752	680	558	462

Graphical Representation



Discussion

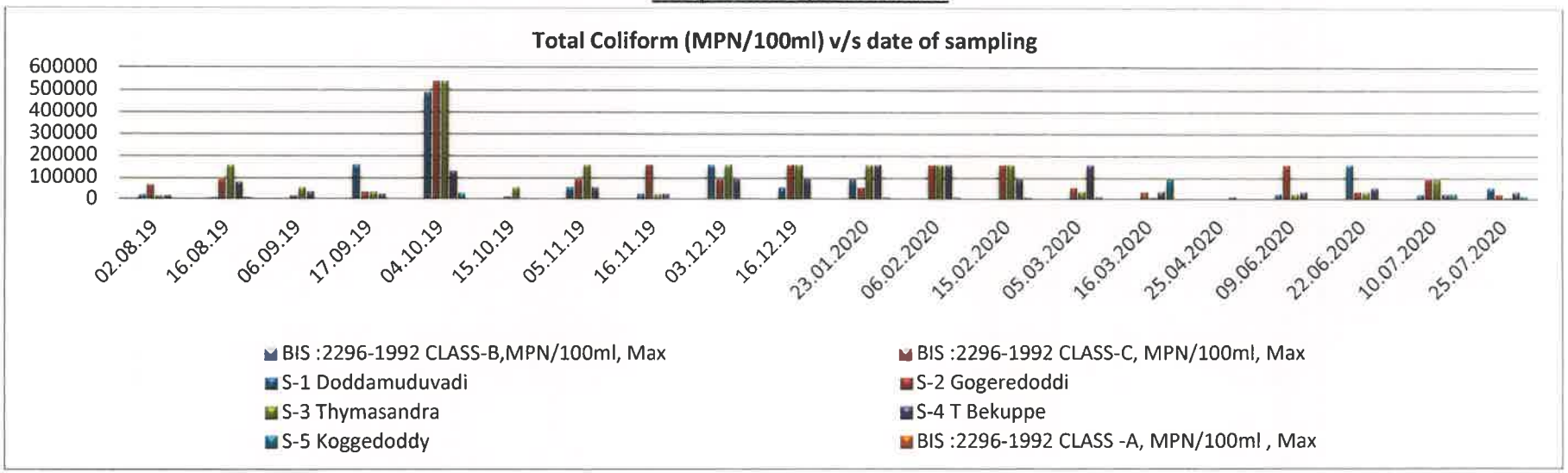
The most common source of dissolved solids in water is from the weathering of sedimentary rocks and the erosion of the earth's surface. Since many minerals are water soluble, high concentrations can accumulate over time through the constantly reoccurring process of precipitation and evaporation. Groundwater usually has higher levels of TDS than surface water. TDS does not directly pose a health risk. Generally, it is aesthetic problems such as taste, odor, and appearance that arise from high concentrations of TDS. From the above graph, it is clear that none of the samples have crossed the limit for class C of BIS 2296-1992 i.e, 1500 mg/L. the maximum TDS observed is 1050 mg/L at Gogeredoddi (S-2) and Thymasandra (S-3) and minimum observed is 462 at Koggedoddi (S-5).

7. Total Coli form(MPN/100ml)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	21000	7900	4600	160000	490000	680	54000	24000	160000	54000	92000	DRY BED					24000	160000	22000	54000
S-2	Gogeredoddi	68000	92000	17000	35000	540000	13000	92000	160000	92000	160000	54000	160000	160000	54000	35000	3300	160000	35000	92000	24000
S-3	Thymasandra	17000	160000	54000	35000	540000	54000	160000	22000	160000	160000	160000	160000	160000	34000	11000	3300	24000	35000	92000	11000
S-4	T Bekuppe	17000	79000	35000	24000	130000	4900	54000	24000	92000	92000	160000	160000	92000	160000	35000	13000	35000	54000	24000	35000
S-5	Koggedoddy	2600	9200	1400	5400	28000	520	1100	3500	5400	3500	9200	9200	9200	13000	92000	3500	5400	5400	28000	16000

Graphical Representation



Discussion

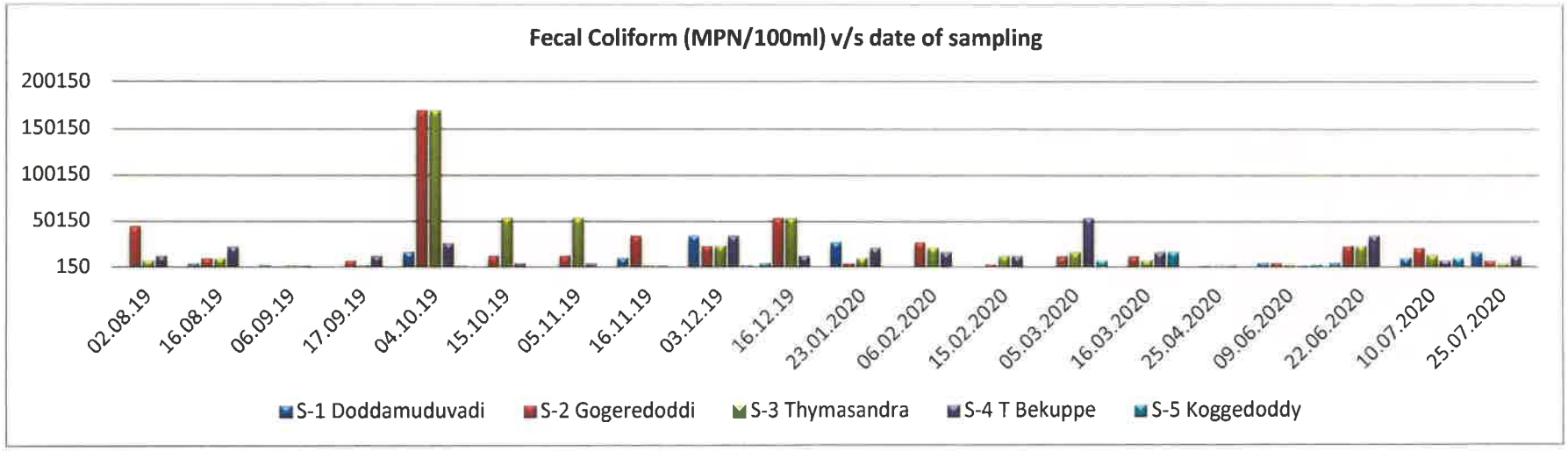
Coli form bacteria have long been used as water quality indicators based on the premise that, because the organism are present in the intestines of warm blooded animals, their presence in water could indicate that recent fecal contamination as occurred. Total coli form bacteria can be killed by disinfection. The maximum total coli form density observed is 540000 (MPN/100mL) at Gogeredoddi (S-2) and Thyamasandra (S-3). The minimum density observed is 520 (MPN/100mL) at Koggedoddi (S-5). BIS 2296-1992 states that limit of total coli form density for class A is 50 MPN/100mL, for class B is 500 MPN/100mL and for class C is 5000 MPN/100mL, Max.

8. Faecal Coli form (MPN/100ml)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	680	4900	3300	1300	17000	680	680	11000	35000	4900	28000	DRY BED					5400	5400	11000	17000
S-2	Gogeredoddi	45000	11000	1700	7900	170000	13000	13000	35000	24000	54000	4900	28000	3500	13000	13000	2300	5400	24000	22000	7900
S-3	Thymasandra	7800	11000	3300	3300	170000	54000	54000	3300	24000	54000	11000	22000	13000	17000	7900	2300	3500	24000	14000	4900
S-4	T Bekuppe	13000	23000	2300	13000	27000	4900	4900	2200	35000	13000	22000	17000	13000	54000	17000	2200	2400	35000	7900	13000
S-5	Koggedoddy	1100	700	680	330	2600	520	490	220	2800	520	170	1300	490	7900	17000	270	3500	490	11000	2200

Graphical Representation



Discussion

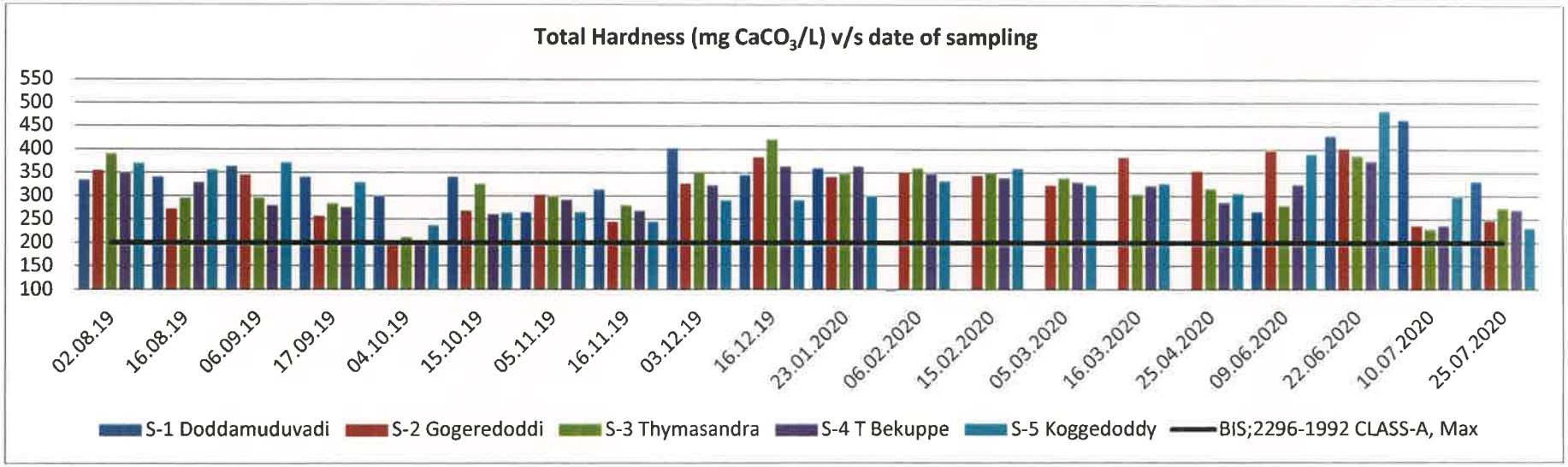
The presence of fecal coli form in the water indicates sewage contamination and the possible presence of pathogenic organisms. This organism can enter rivers through direct discharge of waste from agricultural runoff and from human and animal sewage. The maximum fecal coli form density observed is 170000 (MPN/100mL) at Gogeredoddi (S-2) and Thyamasandra (S-3). The minimum density observed is 170 (MPN/100mL) at Koggedoddi (S-5).

9. Total hardness (mg $CaCO_3$ /L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	336	342	365	342	301	342	267	316	404	346	362	DRY BED					268	431	465	334
S-2	Gogeredoddi	356	273	346	258	202	269	304	246	328	385	343	353	345	325	385	356	400	404	238	249
S-3	Thymasandra	391	296	296	285	213	327	300	281	353	423	350	361	353	340	305	317	280	388	231	276
S-4	T Bekuppe	352	331	281	277	198	262	293	269	324	365	366	349	341	332	324	288	326	377	238	272
S-5	Koggedoddy	371	358	373	331	238	265	267	246	292	292	301	334	361	325	328	307	392	485	300	233

Graphical Representation



Discussion

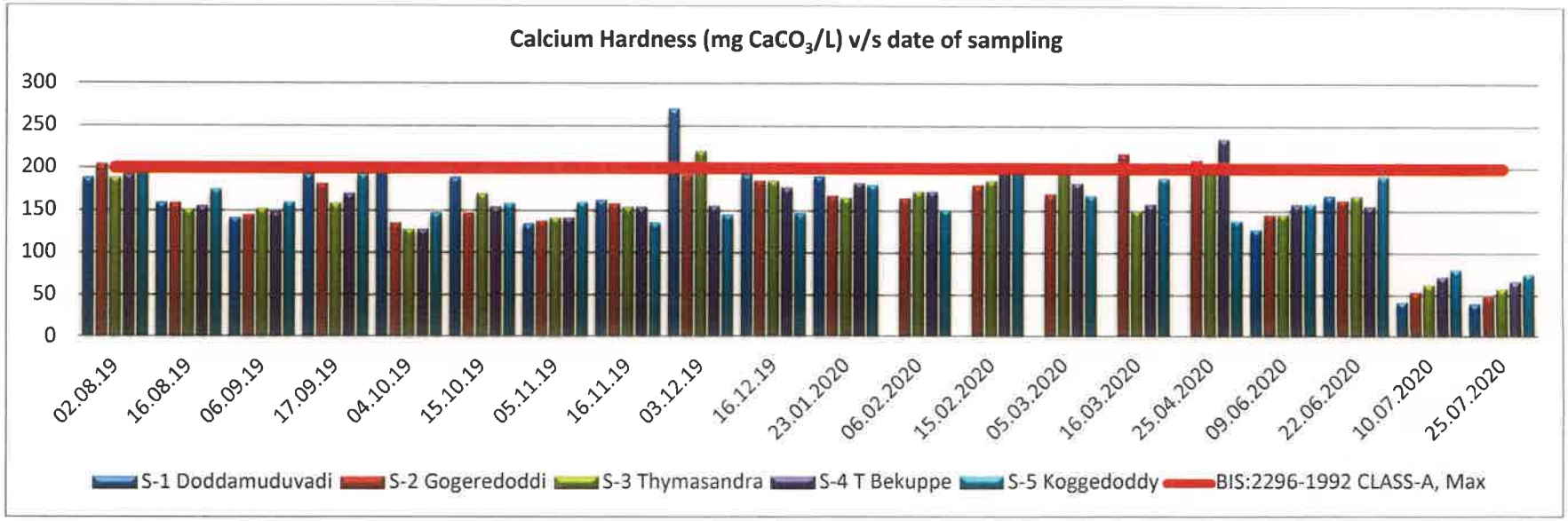
Water's hardness is determined by the concentration of multivalent cations in the water. Multivalent cations are positively charged metal complexes with a charge greater than 1^+. Usually, the cations have the charge of 2^+. Common cations found in hard water include Ca^{2+} and Mg^{2+}. These ions enter a water supply by leaching from minerals within an aquifer. The maximum hardness observed is 485 mg $CaCO_3$/L at Koggedoddi (S-5). The minimum hardness observed is 213 mg $CaCO_3$/L at Thymasandra (S-3). The BIS 2296-1992 states that the total hardness for Class A is 200 mg $CaCO_3$/L, max, and no limit for other classes is mentioned.

10. Calcium hardness (mg CaCO3/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	188	159	141	193	204	189	134	162	271	193	190	dry bed					128	168	42	40
S-2	Gogeredoddi	204	159	144	181	135	146	137	158	191	185	168	165	180	170	218	210	145	163	54	49
S-3	Thymasandra	188	151	152	158	127	170	141	154	220	185	165	173	185	198	150	205	145	168	63	58
S-4	T Bekuppe	192	155	148	170	127	154	141	154	155	177	183	173	198	183	158	235	158	155	72	67
S-5	Koggedoddy	204	174	159	193	146	158	160	135	144	146	180	150	205	168	188	138	158	190	80	75

Graphical Representation



Discussion

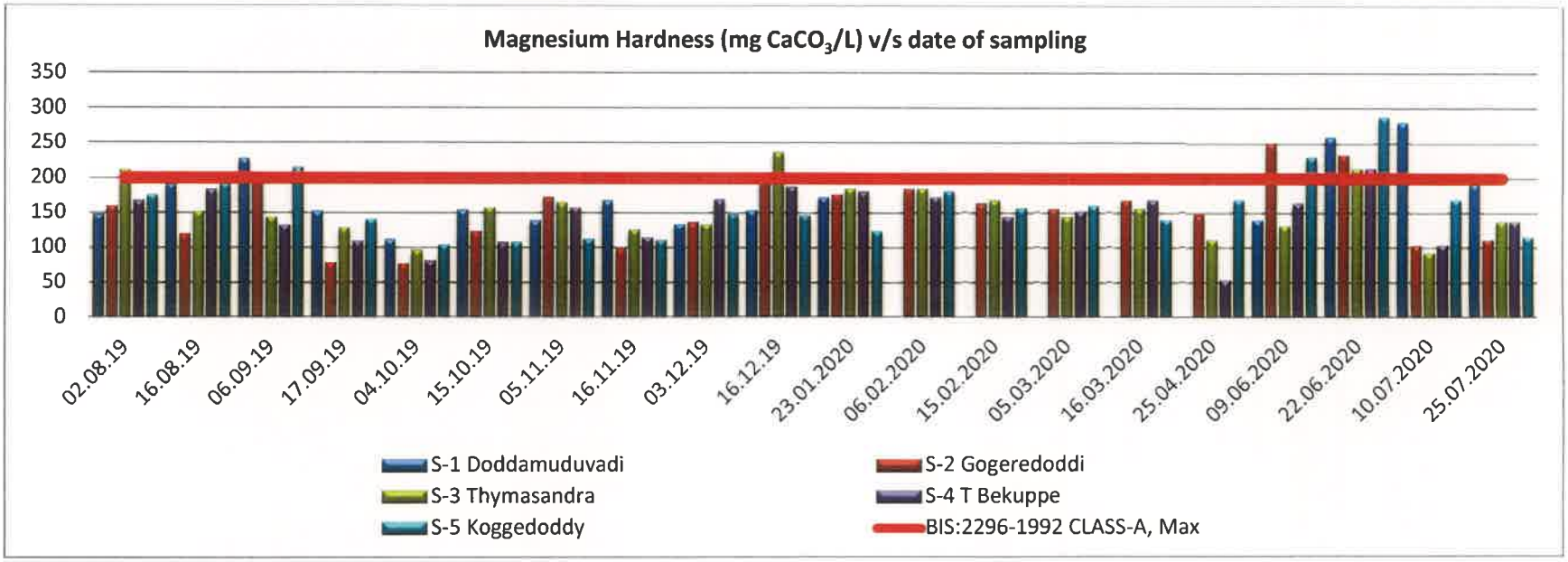
The concentration of calcium in water depends on the residence time of the water in calcium-rich geological formations. Surface water generally contains lower concentrations of calcium than groundwater. The maximum and minimum calcium hardness observed are 271 mg $CaCO_3$/L and 40 mg $CaCO_3$/L respectively at Doddamuduvadi (S-1). BIS 2296-1992 states that the Calcium hardness for Class A is 200 mg $CaCO_3$/L, max, and no limit for other classes is mentioned.

11. Magnesium hardness (mg CaCO3/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	148	192	228	152	112	154	138	168	133	154	173	Dry bed					140	259	280	192
S-2	Gogeredoddi	160	120	204	78	77	123	173	99	137	200	177	185	165	156	169	148	251	235	104	111
S-3	Thymasandra	212	152	144	129	96	158	165	126	133	238	185	185	169	144	156	111	132	214	92	138
S-4	T Bekuppe	168	184	132	109	81	108	158	114	169	188	181	173	144	152	169	53	165	214	104	138
S-5	Koggedoddy	176	192	216	141	104	108	112	111	148	146	123	181	156	160	140	169	230	288	169	115

Graphical Representation



Discussion

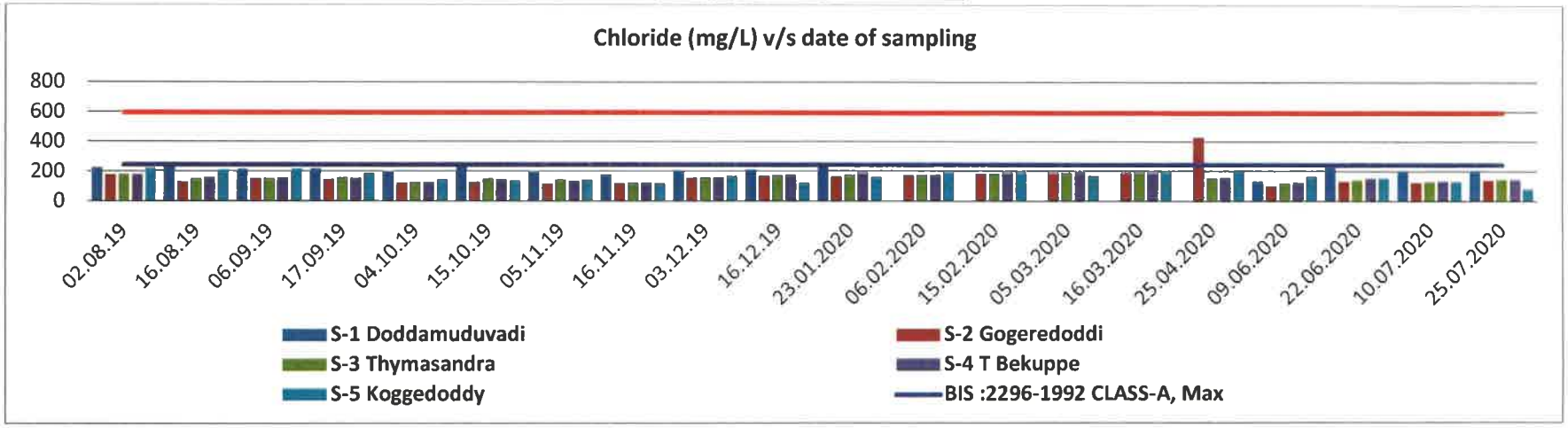
The concentration of magnesium in water depends on the residence time of the water in magnesium-rich geological formations. Surface water generally contains lower concentrations of magnesium than groundwater. The maximum Magnesium hardness observed is 288 mg $CaCO_3$/L, at Koggedoddi (S-5) and the minimum observed is 77 mg $CaCO_3$/L, at Gogeredoddi (S-2). BIS 2296-1992 states that the magnesium hardness for Class A is 200 mg $CaCO_3$/L, max, and no limit for other classes is mentioned.

12. Chloride (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	231	236	223	225	207	233	206	180	213	219	246	Dry bed					138	232	213	214
S-2	Gogeredoddi	183	134	156	150	125	132	120	122	160	174	169	179	186	194	192	439	106	140	130	147
S-3	Thymasandra	185	155	156	162	129	154	147	126	160	177	179	177	186	190	196	156	124	147	136	151
S-4	T Bekuppe	185	164	160	158	129	149	139	126	162	181	196	181	194	202	196	162	128	160	142	153
S-5	Koggedoddy	225	217	223	188	148	139	145	122	172	125	168	198	198	174	202	213	170	160	138	88

Graphical Representation



Discussion

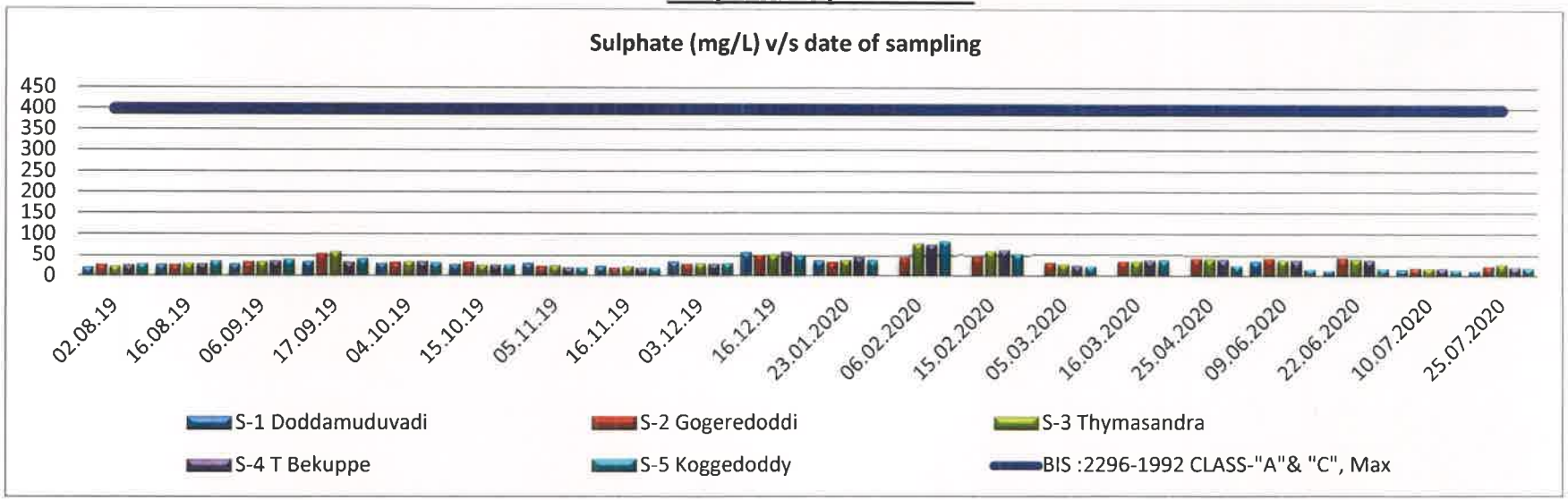
Chloride in the form of chloride ion, is one of the major inorganic anion in water and waste water. The salty taste produced by chloride concentrations is variable and dependent on the chemical composition of water. Some water containing 250mg/L may have detectable salty taste if the cation is sodium. On the other hand, the typical salty taste may be absent in water containing as much as 1000 mg/L when the predominant cations are Calcium and Magnesium. The chloride concentration is higher in waste water than in raw water because NaCl is a common article of diet and passes unchanged through the digestive system. High chloride content may harm metallic pipes and structures, as well as growing plants. In the current study, the maximum chloride concentration observed is 439 mg/L at Gogeredoddi (S-2) and minimum observed is 88 mg/L at Koggedoddi (S-5). BIS 2296-1992 limits for class A and Class C and E are 250 mg/L and 600 mg/L, max respectively.

13. Sulphate (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	21	29	30	36	32	29	31	25	36	58	38	Dry bed					36	14	16	13
S-2	Gogeredoddi	29	29	35	55	34	34	24	21	31	52	35	46	48	34	37	44	43	45	21	25
S-3	Thymasandra	24	32	35	60	36	27	26	23	31	52	40	79	61	30	37	42	40	42	19	30
S-4	T Bekuppe	27	31	37	34	36	27	21	20	30	59	46	77	64	27	40	41	39	40	19	22
S-5	Koggedoddy	31	37	40	42	33	27	21	20	32	50	39	85	54	25	39	26	17	18	15	20

Graphical Representation



Discussion

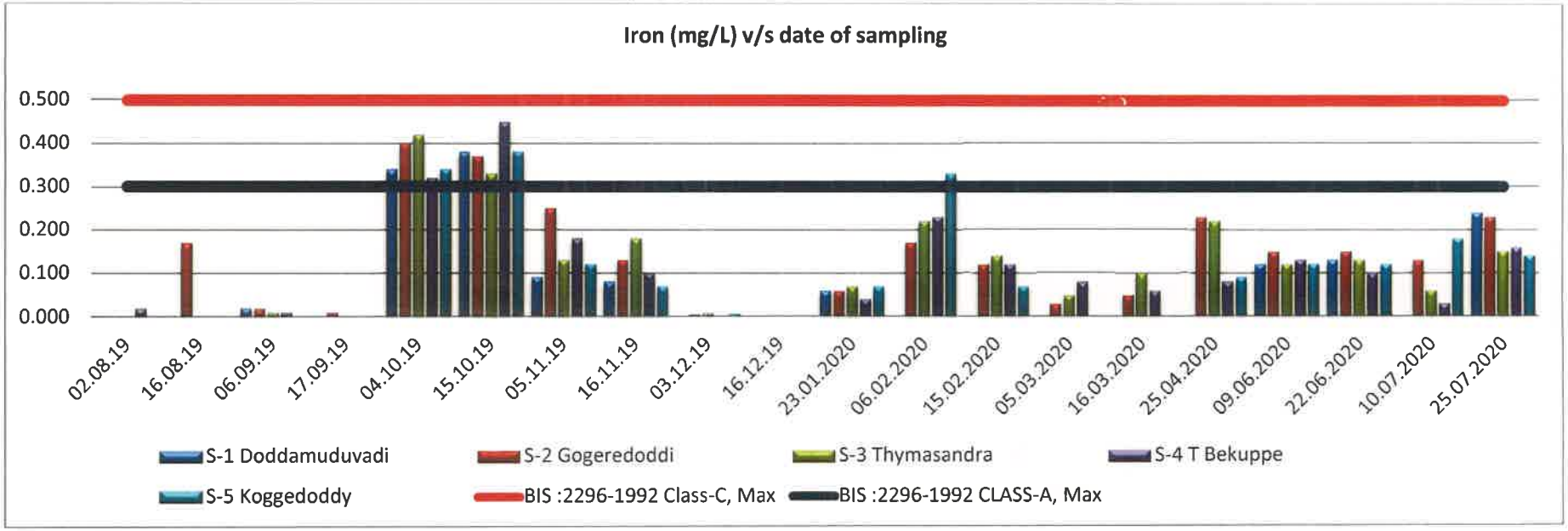
Sulphate is a substance that occurs naturally in drinking water. Health concerns regarding sulphate in drinking water have been raised because of reports that diarrhoea may be associated with ingestion of water containing high levels of sulphate. In the current study, the maximum value of sulphate observed is 85 mg/L at koggedoddi (S-5) and the minimum observed is 13 mg/L at Doddamuduvadi (S-1). The acceptable limit for class A and C for Sulphate in surface water as per BIS 2296-1992 is 400 mg/L, max.

14. Iron (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	0.000	0.000	0.020	0.000	0.340	0.380	0.090	0.080	0.000	0.000	0.060	Dry bed					0.120	0.130	0.000	0.240
S-2	Gogeredoddi	0.000	0.170	0.020	0.010	0.400	0.370	0.250	0.130	0.005	0.000	0.060	0.170	0.120	0.030	0.050	0.230	0.150	0.150	0.130	0.230
S-3	Thymasandra	0.000	0.000	0.010	0.000	0.420	0.330	0.130	0.180	0.009	0.000	0.070	0.220	0.140	0.050	0.100	0.220	0.120	0.130	0.060	0.150
S-4	T Bekuppe	0.020	0.000	0.010	0.000	0.320	0.450	0.180	0.100	0.001	0.000	0.040	0.230	0.120	0.080	0.060	0.080	0.130	0.100	0.030	0.160
S-5	Koggedoddy	0.000	0.000	0.000	0.000	0.340	0.380	0.120	0.070	0.007	0.000	0.070	0.330	0.070	0.000	0.000	0.090	0.120	0.120	0.180	0.140

Graphical Representation



Discussion

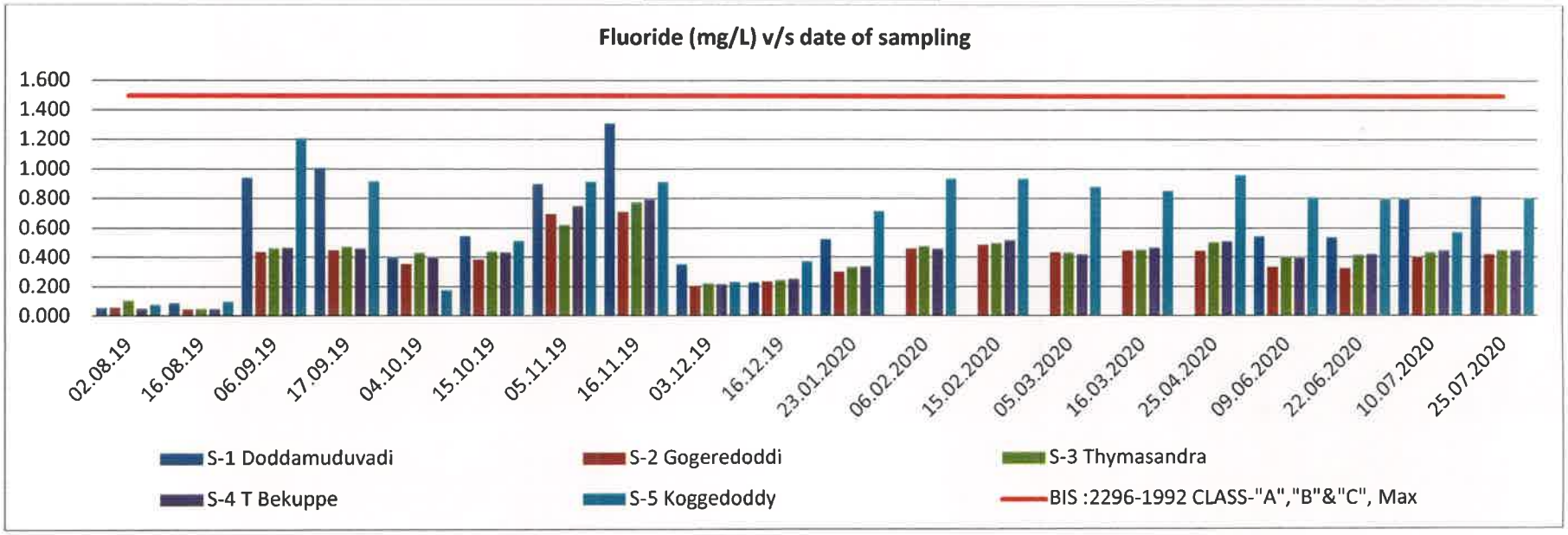
Iron exists naturally in rivers. It may also be released to water from natural deposits, industrial wastes, refining of iron ores, and corrosion of iron containing metals. In this current study, the maximum iron concentration observed is 0.45 mg/L at T Bekuppe (S-4). The acceptable limit for Iron for Class A is 0.3 mg/L and Class C is 0.5 mg/L, max as per BIS 2296-1992.

15. Fluorides (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	0.059	0.092	0.944	1.010	0.400	0.548	0.899	1.310	0.356	0.233	0.527	DRY BED					0.545	0.538	0.800	0.819
S-2	Gogeredoddi	0.062	0.050	0.440	0.451	0.360	0.388	0.700	0.714	0.208	0.239	0.307	0.463	0.488	0.438	0.449	0.448	0.337	0.329	0.407	0.425
S-3	Thymasandra	0.109	0.052	0.464	0.473	0.433	0.443	0.623	0.779	0.225	0.247	0.335	0.478	0.499	0.433	0.454	0.505	0.408	0.418	0.437	0.450
S-4	T Bekuppe	0.054	0.053	0.469	0.462	0.402	0.437	0.752	0.795	0.222	0.256	0.341	0.461	0.520	0.424	0.468	0.512	0.401	0.426	0.450	0.450
S-5	Koggedoddy	0.082	0.102	1.210	0.921	0.179	0.514	0.917	0.917	0.234	0.375	0.720	0.939	0.939	0.883	0.856	0.962	0.812	0.798	0.576	0.808

Graphical Representation



Discussion

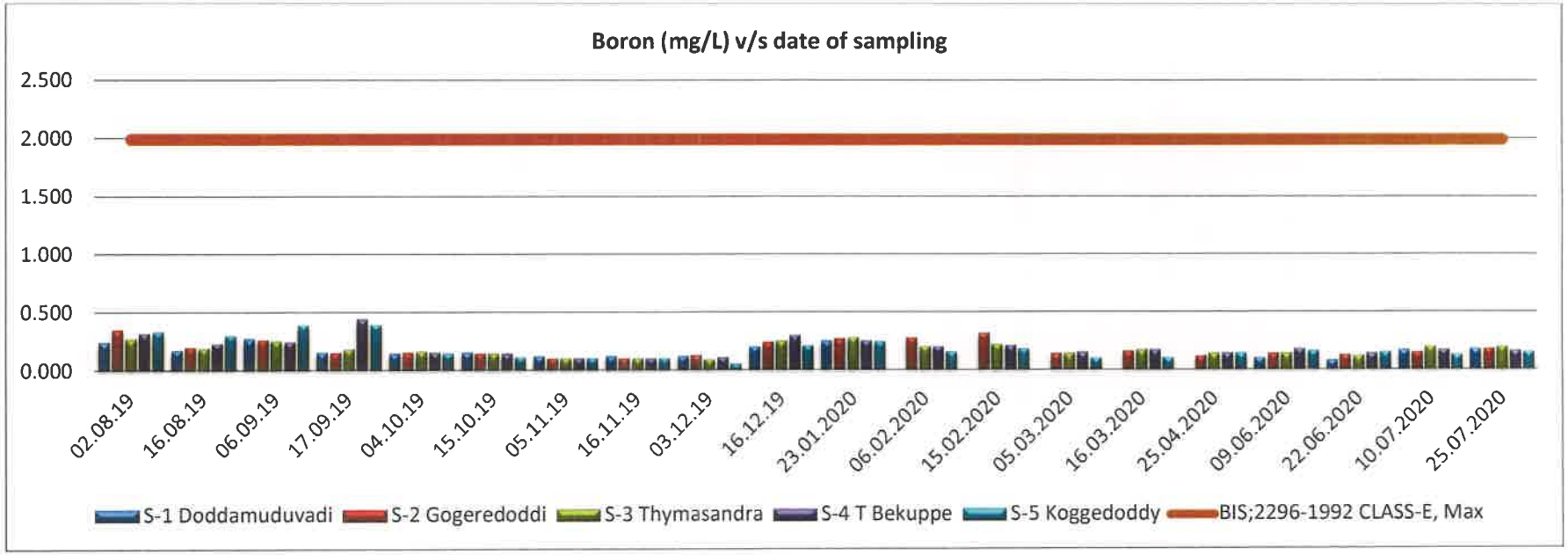
Anthropogenic sources contributing to fluoride are mainly mining activities, phosphate fertilizer effluents. Fluoride in water is mostly due to geogenic in nature. The maximum Fluoride concentration observed is 1.310 mg/L at Doddamuduvadi (S-1) and minimum observed is 0.05 mg/L at Gogeredoddi (S-2). The acceptable limit for fluoride for classes A, B and C is 1.5 mg/L, max.

16. Boron (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	0.250	0.180	0.280	0.160	0.150	0.160	0.130	0.130	0.130	0.210	0.260	Dry bed					0.110	0.090	0.180	0.190
S-2	Gogeredoddi	0.360	0.210	0.270	0.160	0.160	0.150	0.110	0.110	0.140	0.250	0.280	0.290	0.330	0.150	0.170	0.130	0.150	0.140	0.160	0.190
S-3	Thymasandra	0.280	0.200	0.260	0.190	0.170	0.150	0.110	0.110	0.100	0.260	0.290	0.210	0.230	0.150	0.180	0.150	0.150	0.130	0.210	0.210
S-4	T Bekuppe	0.330	0.240	0.250	0.450	0.160	0.150	0.110	0.110	0.120	0.310	0.260	0.210	0.220	0.160	0.180	0.150	0.190	0.150	0.180	0.170
S-5	Koggedoddy	0.340	0.310	0.400	0.400	0.150	0.120	0.110	0.110	0.060	0.220	0.250	0.160	0.190	0.110	0.110	0.150	0.170	0.160	0.140	0.160

Graphical Representation



Discussion

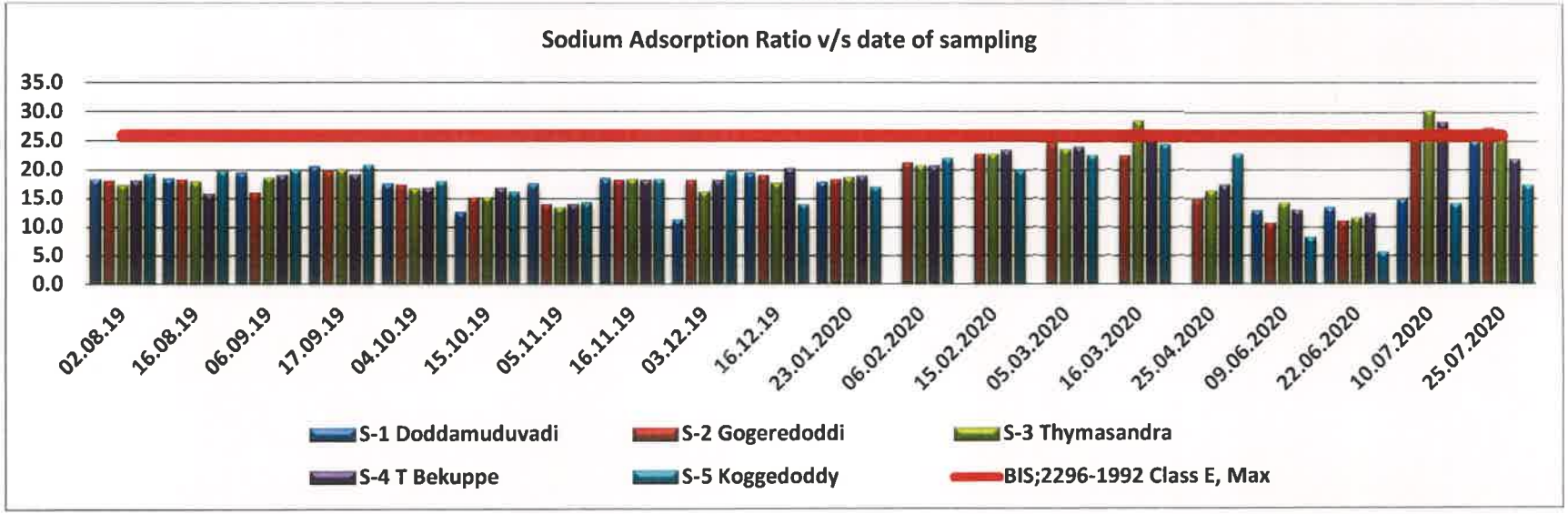
Boron enters the surface water mainly through the weathering of rocks. To a lesser extent, boron is released to the surface water from anthropogenic sources (e.g., via fertilizer and herbicide applications, and industrial and municipal wastes). In the current study, the maximum concentration of Boron observed is 0.36 mg/L at Gogeredoddi (S-2). The minimum observed is 0.06 mg/L at Koggedoddi (S-5). The acceptable limit for boron for class E is 2mg/L, max as per BIS 2296-1992. Limits for no other classes are mentioned.

17. Sodium Adsorption Ratio (SAR)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	18.4	18.5	19.5	20.7	17.6	12.6	17.6	18.5	11.4	19.5	18.0	DRY BED					12.9	13.5	14.9	25.0
S-2	Gogeredoddi	18.1	18.4	16.1	19.8	17.5	15.2	14.0	18.2	18.3	19.1	18.4	21.3	22.8	24.8	22.6	14.8	10.7	11.1	25.8	27.3
S-3	Thymasandra	17.4	18.1	18.7	20.1	16.7	15.2	13.4	18.4	16.2	17.7	18.8	20.8	22.8	23.7	28.6	16.3	14.1	11.6	30.2	25.5
S-4	T Bekuppe	18.1	15.9	19.1	19.2	16.9	16.9	14.0	18.3	18.3	20.3	19.0	20.8	23.5	24.1	26.8	17.4	13.0	12.4	28.4	21.8
S-5	Koggedoddy	19.4	19.8	20.1	20.9	18.1	16.2	14.3	18.4	19.8	14.0	17.0	22.0	19.9	22.6	24.5	22.8	8.2	5.6	14.1	17.3

Graphical Representation



Discussion

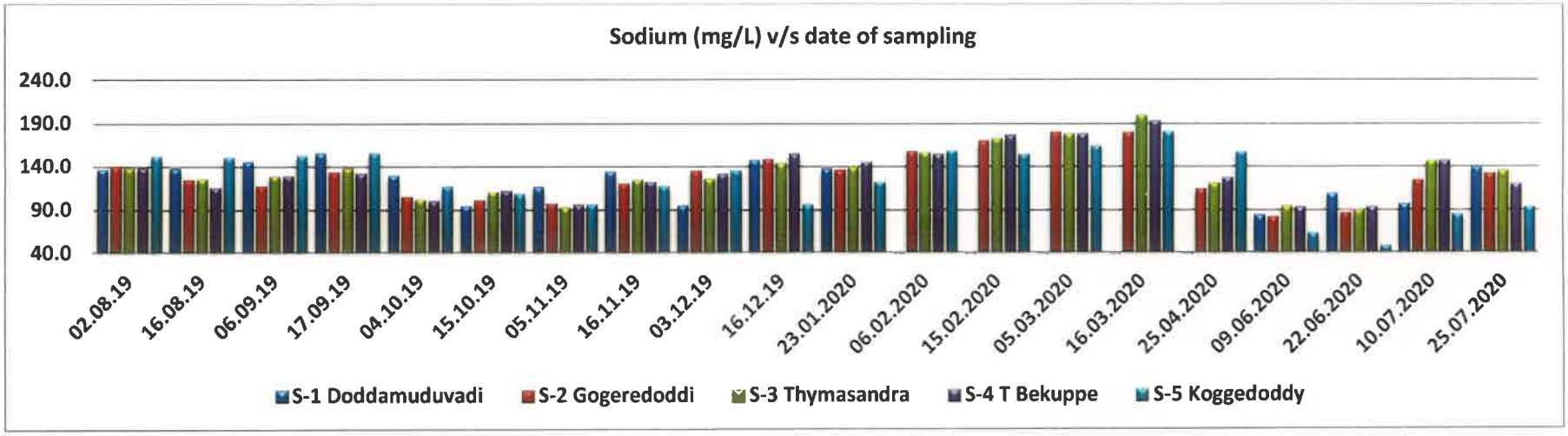
The **Sodium adsorption ratio (SAR)** is an irrigation water quality parameter used in the management of sodium-affected soils. It is an indicator of the suitability of water for use in agricultural irrigation, as determined from the concentrations of the main alkaline and earth alkaline cations present in the water. High sodium ions in water affects the permeability of soil and causes infiltration problems. In this current study, the SAR concentration observed is 30.2 at Thyamasandra (S-3) and the minimum observed is 5.6 at Koggedoddi (S-5). The acceptable limit for SAR for class E is 26, max. Limits for other classes is not mentioned.

18. Sodium (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	137	138	146	156	130	94	116	134	95	148	138	DRY BED					84	109	97	140
S-2	Gogeredoddi	141	125	118	134	105	101	98	120	135	150	136	159	171	181	181	115	83	87	125	132
S-3	Thymasandra	139	126	129	138	102	111	93	125	126	144	140	157	173	179	200	121	95	90	147	136
S-4	T Bekuppe	139	116	129	132	100	112	96	122	131	155	146	155	177	179	194	127	94	94	147	120
S-5	Koggedoddy	153	151	153	156	117	108	96	117	135	96	122	159	155	164	181	158	63	48	85	93

Graphical Representation



Discussion

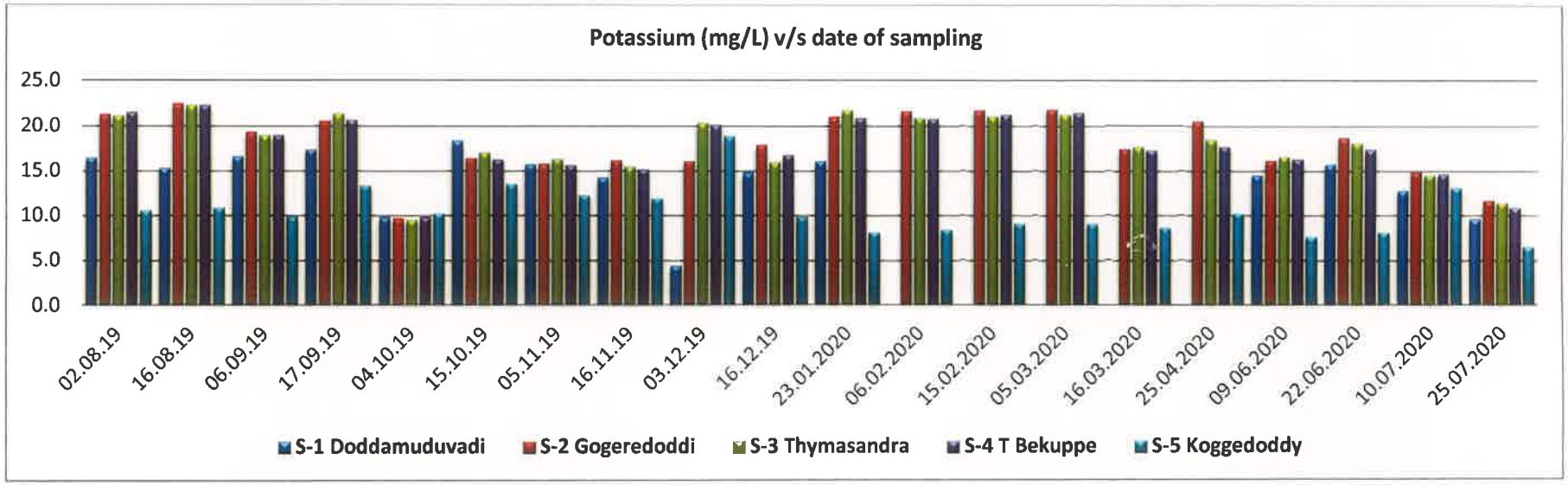
There are a number of anthropogenic sources of sodium that can contribute significant quantities of sodium to surface water, including road salt, water treatment chemicals, domestic water softeners, and sewage effluents. The addition of sodium compounds during water treatment for adjustment of pH and water softening are the uses most likely to increase the sodium content of drinking water. In this current study, the maximum sodium concentration observed is 200 mg/L at Thymasandra (S-3) and the minimum observed is 48 mg/L at Koggedoddi (S-5).There are no limits specified in the BIS 2296:1992 standard.

19. Potassium (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	16.5	15.3	16.6	17.4	9.8	18.4	15.7	14.3	4.4	14.8	16.1	Dry bed					14.5	15.7	12.8	9.6
S-2	Gogeredoddi	21.4	22.6	19.4	20.6	9.7	16.4	15.8	16.2	16.1	17.9	21.1	21.7	21.8	21.9	17.5	20.6	16.2	18.7	14.9	11.7
S-3	Thymasandra	21.2	22.4	19.0	21.4	9.5	17.1	16.3	15.5	20.4	15.9	21.8	20.9	21.1	21.3	17.7	18.5	16.6	18.1	14.5	11.4
S-4	T Bekuppe	21.6	22.4	19.0	20.7	9.8	16.2	15.6	15.2	20.2	16.8	20.9	20.8	21.3	21.5	17.3	17.7	16.3	17.4	14.6	10.8
S-5	Koggedoddy	10.5	10.9	9.9	13.3	10.2	13.5	12.3	11.9	18.8	9.9	8.1	8.4	9.1	9.1	8.6	10.2	7.6	8.1	13.1	6.5

Graphical Representation



Discussion

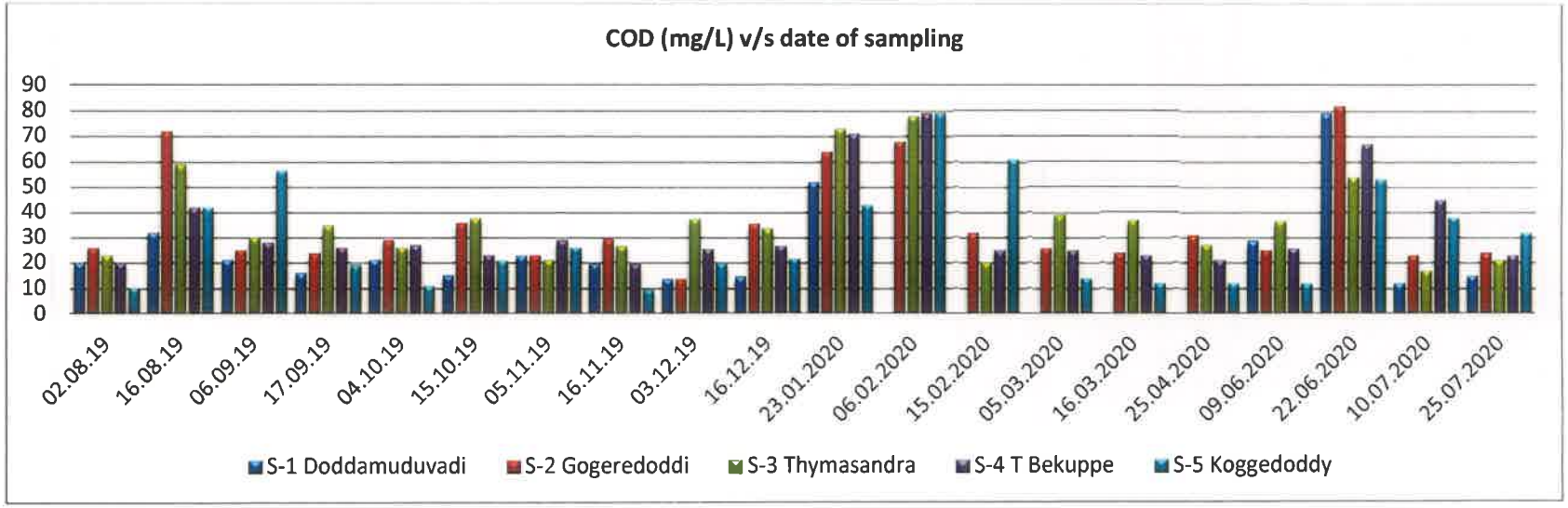
Potassium occurs in various minerals, from which it may be dissolved through weathering processes. A number of potassium compounds, mainly potassium nitrate, are popular synthetic fertilizers.95% of commercially applied potassium is added to synthetic fertilizers. In this current study, the maximum Potassium concentration observed is 22.6 mg/L at Gogeredoddi (S-2) and the minimum observed is 4.4 mg/L at Doddamuduvadi (S-1). There are no limits specified in the BIS 2296:1992 standard

20. Chemical Oxygen demand (COD), mg/L

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	20	32	21	16	21	15	23	20	14	15	52	Dry bed					29	79	12	15
S-2	Gogeredoddi	26	72	25	24	29	36	23	30	14	36	64	68	32	26	24	31.0	26	82	23	24
S-3	Thymasandra	23	59	30	35	26	38	21	27	38	34	73	78	20	39	37	27.0	37	54	17	21
S-4	T Bekuppe	20	42	28	26	27	23	29	20	26	27	71	79	25	25	23	21.0	26	67	45	23
S-5	Koggedoddy	10	42	57	19	11	21	26	10	20	22	43	79	61	14	12	12.0	12	53	38	32

Graphical Representation



Discussion

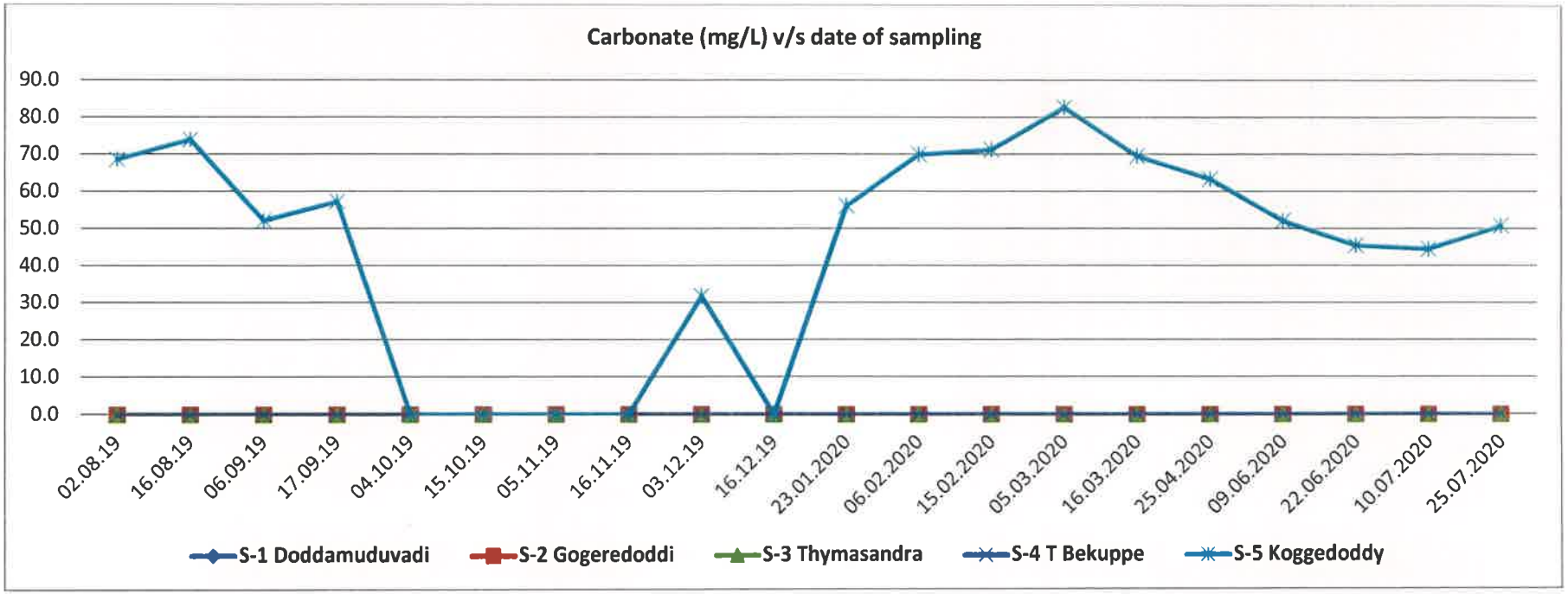
The concentration of Chemical Oxygen demand depends on both organic and oxidisable inorganic matter present in water. High COD level indicates the presence of more such matter in the sample. There is no standard limit for surface water as per BIS 2296:1992. In the current study, the maximum COD value observed is 82 mg/L at Gogeredoddi (S-2) and minimum value is 10 mg/L at Koggedoddi (S-5).

21. Carbonate (mg/L)

Observed Data

Station Code	Station Name/ Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Dry bed					0.0	0.0	0.0	0.0
S-2	Gogeredoddi	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S-3	Thymasandra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S-4	T Bekuppe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S-5	Koggedoddy	68.7	74.0	52.2	57.4	0.0	0.0	0.0	0.0	31.8	0.0	56.3	70.0	71.3	82.7	69.6	63.4	52.2	45.5	44.5	50.9

Graphical Representation



Discussion

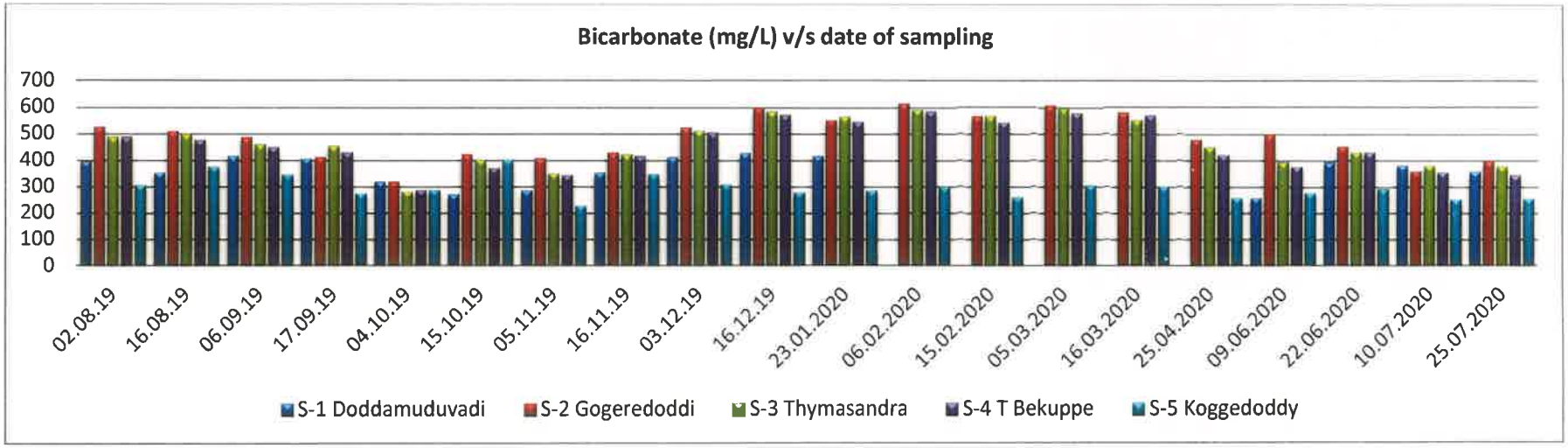
Carbonate will be present in the sample, whose pH is 8.3 and above .In the current study, the carbonate is only seen at Koggedoddy (S-5) station that may be due to rocky bed , which contains Carbonate salts of Calcium and Magnesium after T Bekuppe station (S-4).

22. Bicarbonate (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	398	355	419	408	320	271	286	353	414	429	419	DRY BED					259	395	383	358
S-2	Gogeredoddi	527	511	488	414	320	424	409	430	525	599	553	616	568	610	584	481	501	455	361	399
S-3	Thymasandra	489	500	461	456	282	403	350	424	512	585	566	591	568	597	554	452	395	432	383	381
S-4	T Bekuppe	489	478	451	430	287	371	344	417	505	572	546	585	544	578	572	422	377	432	356	345
S-5	Koggedoddy	306	376	345	276	287	403	227	347	308	279	286	299	260	305	301	258	277	291	253	255

Graphical Representation



Discussion

Anthropogenic sources of bicarbonate include limestone applied to fields to increase soil pH, or to poorly buffered lakes to remediate acidification. The effluent from wastewater treatment plants can also add alkalinity to a stream as the wastewater from industry, and domestic uses, contains bicarbonate from cleaning agents and food residues.

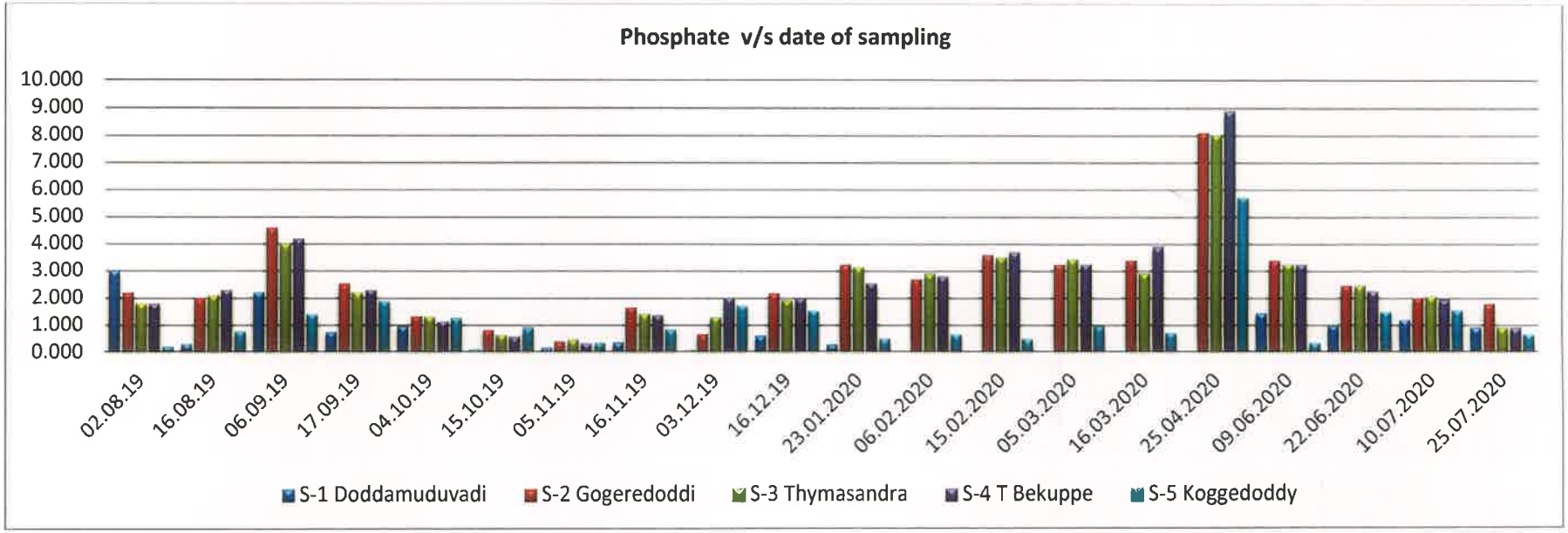
In the current study, from the above graph it clear bicarbonate is the major anion. The maximum concentration of bicarbonate observed is 616 mg/L at Gogeredoddi (S-2) and the minimum observed is 227 mg/L at koggedoddi. There is no standard limit for surface waters as per BIS 2296:1992.

23. Phosphate (mg/L)

Observed Data

Station Code	Station name / Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	3.000	0.300	2.200	0.740	0.960	0.100	0.160	0.360	0.080	0.600	0.280	Dry bed					1.450	1.000	1.200	0.900
S-2	Gogeredoddi	2.200	2.000	4.600	2.540	1.340	0.830	0.400	1.660	0.660	2.180	3.250	2.700	3.600	3.250	3.400	8.100	3.400	2.450	2.000	1.800
S-3	Thymasandra	1.800	2.100	4.000	2.200	1.320	0.630	0.460	1.420	1.300	1.920	3.150	2.900	3.500	3.450	2.900	8.000	3.250	2.450	2.050	0.900
S-4	T Bekuppe	1.800	2.300	4.200	2.300	1.140	0.560	0.320	1.380	2.020	2.000	2.550	2.800	3.700	3.250	3.900	8.900	3.250	2.250	1.950	0.900
S-5	Koggedoddy	0.200	0.760	1.400	1.880	1.270	0.900	0.340	0.820	1.720	1.540	0.480	0.650	0.490	0.960	0.700	5.700	0.340	1.500	1.550	0.650

Graphical Representation



Discussion

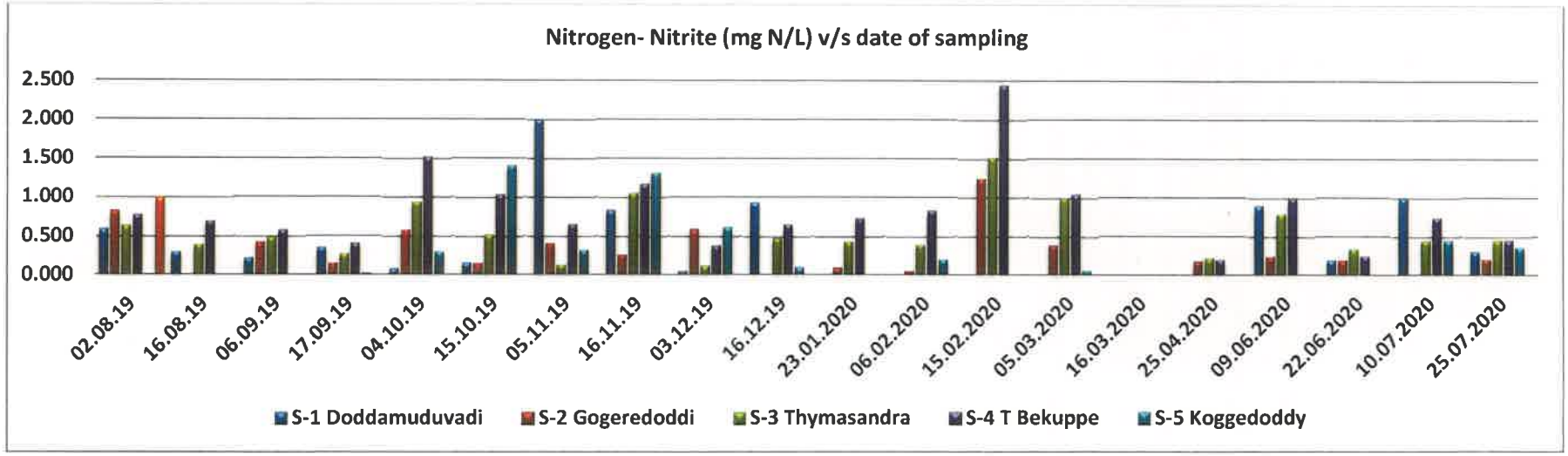
Phosphate is readily taken by phytoplankton and it is necessary for plant and animal growth. Presence of high concentrations of phosphate in water body is due to the entry of agricultural runoff. It may also enter into surface water from man-generated wastes and industrial effluents. In this current study, the maximum phosphate concentration observed is 8.9 mg/L at T Bekuppe (S-4) and the minimum is 0.1 mg/L at Dodamuduvadi (S-1). There is no standard limit for surface waters as per BIS 2296:1992.

24. Nitrogen-Nitrite (mg N/L)

Observed Data

Station Code	Station Name/ Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	0.60	0.30	0.22	0.36	0.08	0.16	2.00	0.84	0.05	0.94	0.02	Dry bed					0.90	0.20	1.00	0.31
S-2	Gogeredoddi	0.83	0.01	0.43	0.16	0.58	0.15	0.41	0.26	0.60	0.02	0.10	0.06	1.25	0.40	0.01	0.19	0.25	0.20	0.01	0.21
S-3	Thymasandra	0.64	0.40	0.49	0.28	0.94	0.52	0.13	1.06	0.12	0.48	0.44	0.40	1.52	1.00	0.01	0.23	0.80	0.35	0.45	0.46
S-4	T Bekuppe	0.78	0.70	0.59	0.42	1.52	1.04	0.66	1.18	0.38	0.66	0.74	0.84	2.45	1.05	0.02	0.21	1.00	0.25	0.75	0.46
S-5	Koggedoddy	0.02	0.01	0.01	0.03	0.30	1.42	0.32	1.32	0.62	0.10	0.01	0.20	0.01	0.06	0.01	0.02	0.02	0.01	0.45	0.36

Graphical Representation



Discussion

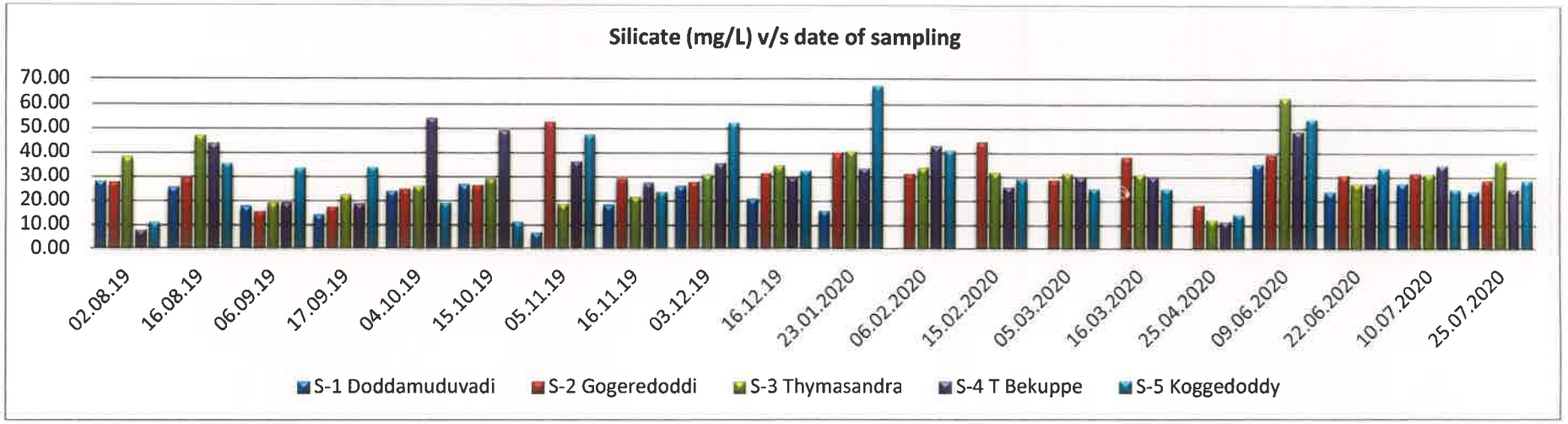
Nitrite generally occurs in trace quantities in surface water but may attain high levels in some ground water. The rich sources of Nitrites are from fertilizers and domestic wastage and industrial effluents of nitrifying biological treatment plants. In this current study, the maximum nitrite concentration observed is 2.45 mg N/L at T Bekuppe (S-4) and the minimum observed is 0.01 mg N/L at Koggedoddi (S-5). There is no standard limit for surface waters as per BIS 2296:1992.

25. Silicate (mg/L)

Observed Data

Station Code	Station Name/ Sampling date	02.08.19	16.08.19	06.09.19	17.09.19	04.10.19	15.10.19	05.11.19	16.11.19	03.12.19	16.12.19	23.01.2020	06.02.2020	15.02.2020	05.03.2020	16.03.2020	25.04.2020	09.06.2020	22.06.2020	10.07.2020	25.07.2020
S-1	Doddamuduvadi	28.20	25.70	17.9	14.2	24.0	26.8	6.90	18.3	26.2	20.9	16.0	Dry bed					35.4	23.8	27.3	23.9
S-2	Gogeredoddi	27.90	29.60	15.6	17.5	24.9	26.4	52.60	29.3	28.0	31.7	40.3	31.5	44.7	28.9	38.5	18.4	39.3	30.8	31.7	28.7
S-3	Thymasandra	38.40	47.10	19.2	22.5	26.0	29.2	18.60	21.6	31.0	35.0	40.9	34.0	31.8	31.5	31.1	12.3	62.8	27.3	31.1	36.8
S-4	T Bekuppe	7.95	43.80	19.2	18.7	54.2	49.0	36.50	27.5	35.9	29.9	33.7	42.9	25.8	30.1	30.1	11.7	48.7	27.2	34.9	24.8
S-5	Koggedoddy	11.15	35.65	33.6	34.1	19.1	11.2	47.40	23.7	52.3	32.8	67.6	41.0	29.1	25.1	24.9	14.5	53.8	33.9	24.9	28.6

Graphical Representation



Discussion

Silicate is common contaminant in most waters because of natural deposits that dissolve in to water over time. Natural, physical and chemical weathering processes also produce many extremely small particles that are colloids of silicate material. In this study, the maximum silicate concentration observed is 67.6 mg/L at Koggedoddi (S-5) and the minimum is 6.9 mg/L at Doddamuduvadi (S-1). There is no standard limit for surface waters as per BIS 2296:1992.

Trace and toxic elements

Sl.No	Station Name / Trace & toxic parameter	August-2019							December-2019						
		As	Cd	Cr	Cu	Pb	Ni	Zn	As	Cd	Cr	Cu	Pb	Ni	Zn
		mg/L							mg/l						
S-1	Doddamuduvadi	0.0012	0.0001	0.0028	0.0005	0.0000	0.0010	0.0157	0.0026	0.0000	0.0062	0.0201	0.0002	0.0059	0.0098
S-2	Gogeredoddi	0.0009	0.0005	0.0028	0.0010	0.0002	0.0016	0.0159	0.0023	0.0000	0.0031	0.0084	0.0000	0.0056	0.0026
S-3	Thymasandra	0.0035	0.0002	0.0033	0.0005	0.0000	0.0105	0.0186	0.0031	0.0000	0.0163	0.0091	0.0001	0.0035	0.0044
S-4	T BeKuppe	0.0008	0.0001	0.0004	0.0036	0.0000	0.0030	0.0137	0.0017	0.0001	0.0031	0.0085	0.0006	0.0092	0.0438
S-5	Koggedoddi	0.0005	0.0000	0.0002	0.0009	0.0001	0.0034	0.0153	0.0026	0.0000	0.0055	0.0043	0.0001	0.0088	0.0460
BIS :2296-1992	**Class A, Max**	**0.05**	**0.01**	**0.05**	**1.5**	**0.1**	-	**15**	**0.05**	**0.01**	**0.05**	**1.5**	**0.1**	-	**15**
	Class B, Max	**0.2**	-	-	-	-	-	-	**0.2**	-	-	-	-	-	-
	Class C, Max	**0.2**	**0.01**	**0.05**	**1.5**	**0.1**	-	**15**	**0.2**	**0.01**	**0.05**	**1.5**	**0.1**	-	**15**

In addition to the major and minor ionic species found in natural waters, a variety of inorganic species, principally heavy metals, of anthropogenic origin may also be found. These constituents are of concern because of their toxicity to microorganisms, plants and animals. Typically, the presence of these constituents is due to improperly processed industrial wastes. UCWQL, being a level II laboratory, have sent the samples to NRWQL, CWC, New Delhi for the analysis of trace and toxic elements in the months of August 2019 and December 2019. The result received from the NRWQL is shown in the above table and it is observed that all the parameters are well within the limit as mentioned in BIS 2296-1992.

PLATE-1

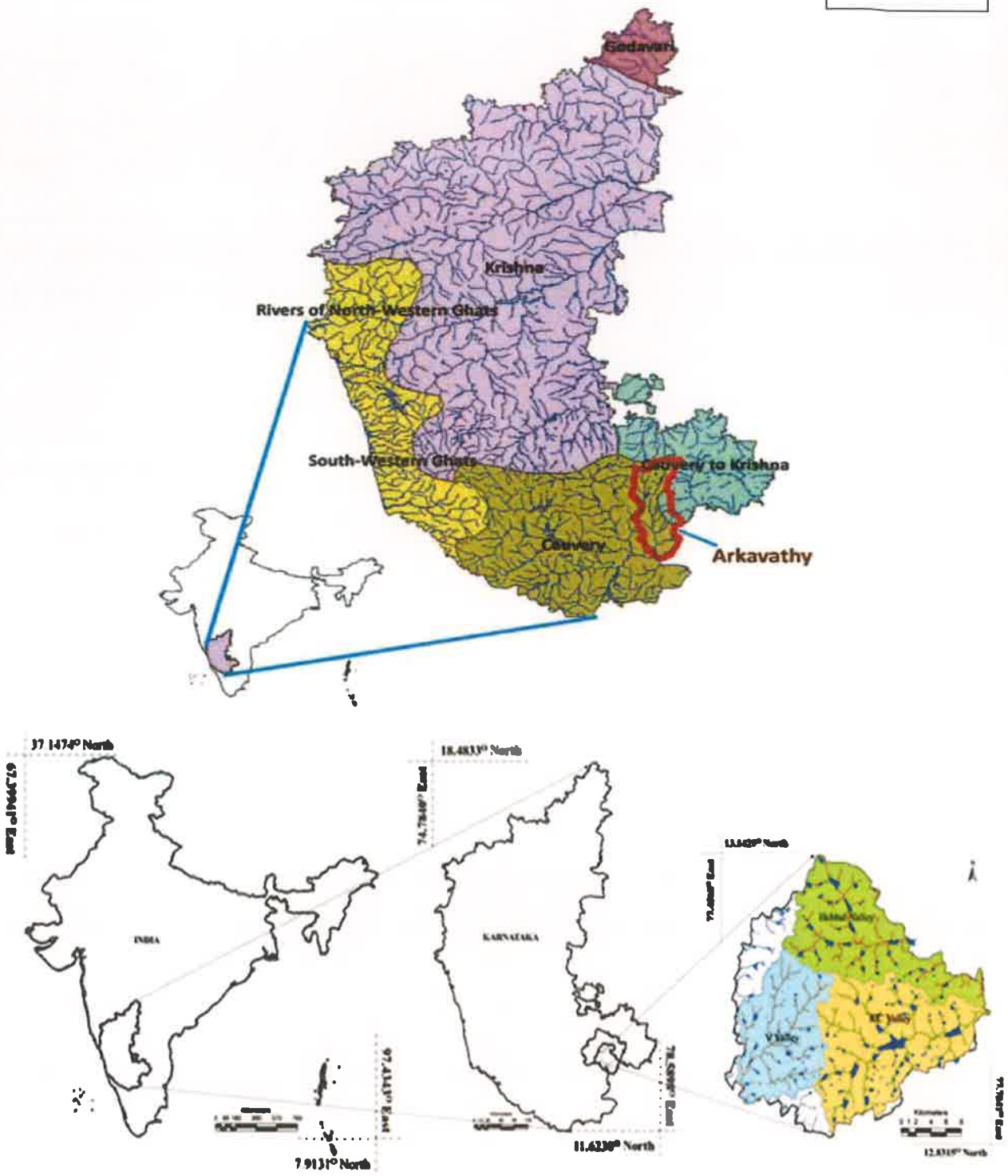
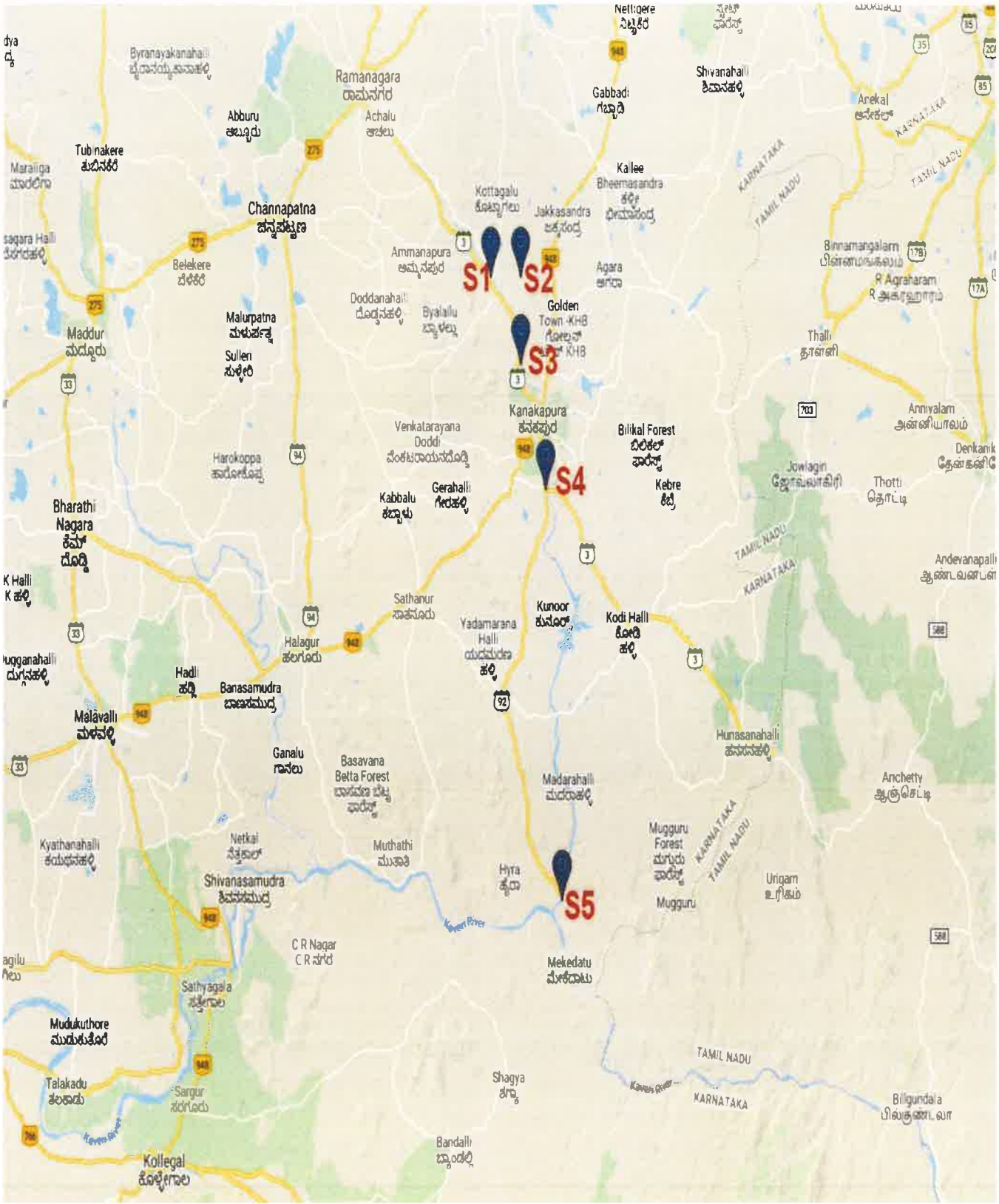


Figure 1.0: Location of Arkavathi sub basin with the River basins of karnataka

PLATE-2



Map showing Sampling location on River Arkavathy and its tributary River Vrushabhavathy.

PLATE-3

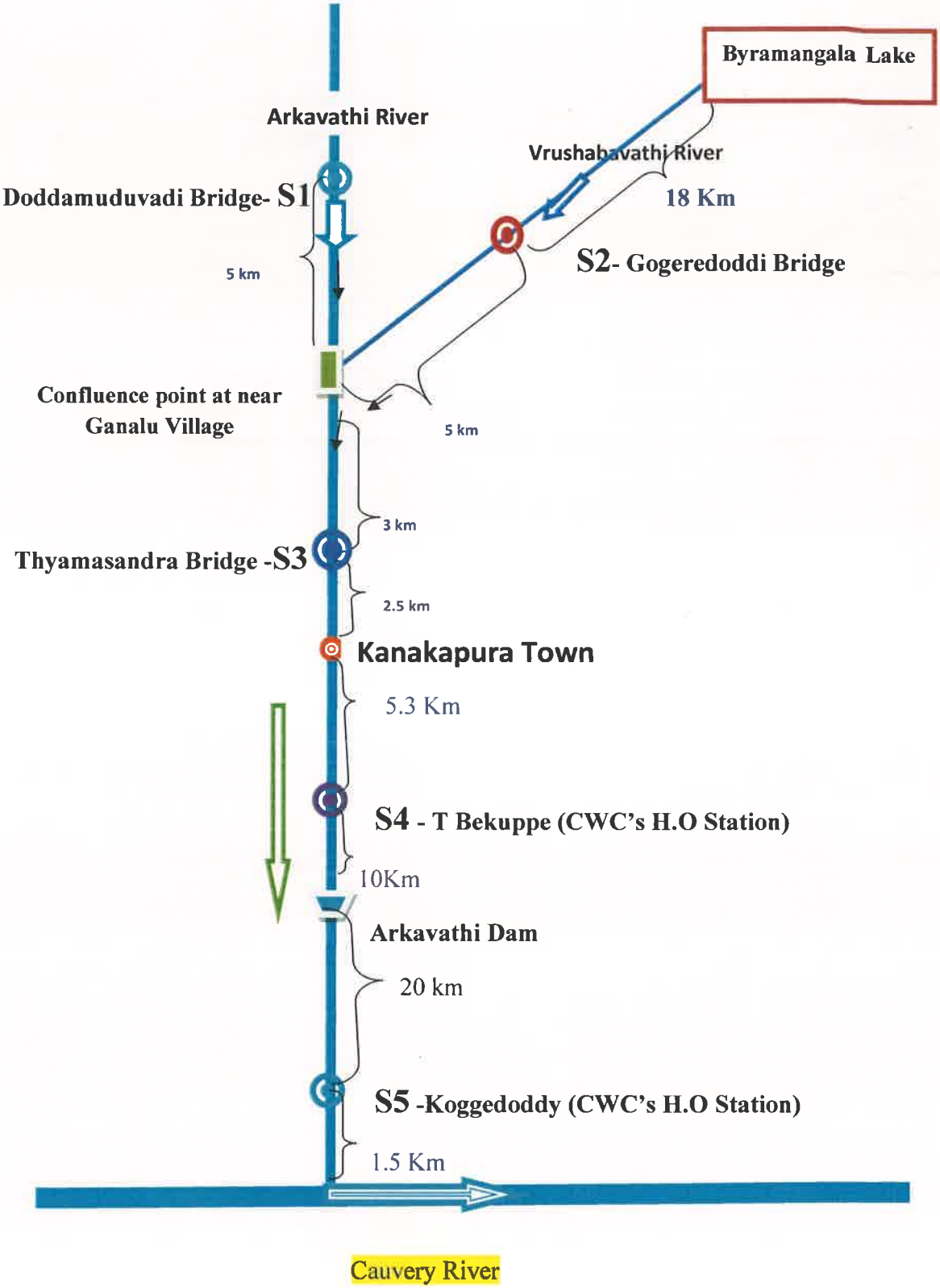


Figure 5.0: Line diagram of River Arkavathy study area

CONCLUSION

Arkavathi river water is generally alkaline in nature and the pH varied from 7.2 (Gogeredoddi –S2) to 8.9 (Koggedoddy-S5). Electrical conductivity values shows a variety of results, the minimum EC observed is 852 µmohs/cm at Koggedoddy (S5) and maximum is 1584 µmohs/cm at Thyamasandra (S3). The in-situ parameter Dissolved Oxygen varies drastically compare to upstream stations and downstream station. The maximum DO observed is 9.4 mg/L at Koggedoddy (S5) and minimum DO observed is 1.0 mg/L at Gogeredoddi.

The major cationic constituents are Sodium, Calcium, Magnesium and Potassium. Among anionic constituents, Bi carbonate is the major anion followed by Chloride, Nitrate and Sulphate. Carbonate is only found at one of the five stations namely Koggedoddy.

Small quantities of Iron, Fluoride, Phosphate, Boron and Silicate are found in water samples of this River. Regarding Oxygen Demand parameters, BOD and COD are analyzed, their maximum values are 38.4 mg/L and 82 mg/L at Gogeredoddi respectively and their minimum values are 0.6 mg/L and 10 mg/L at Koggedoddy respectively.

Throughout the study it is observed that, the river water qualities of Oxygen Demand parameters like DO and BOD, biological parameters like Total coli form and fecal coli form are improved at downstream station Koggedoddy (S5). The possible reason may be presence of Arkavathi reservoir (10 km upstream) and Chunchi falls (6 Km upstream) at higher altitude from Koggedoddy (S5) station. Super saturation caused by rapid aeration is often seen beside dams and large waterfalls. Unlike small rapids and waves, the water flowing over a dam or waterfall traps and carries air with it, which is then plunged into the water. At greater depths and thus greater hydrostatic pressures, this entrained air is forced into solution, potentially raising saturation levels over 100%.And all the sediment and most of the Organic matter get settle down in the reservoir. Therefore parameter BOD also improved a lot compare to upstream stations.

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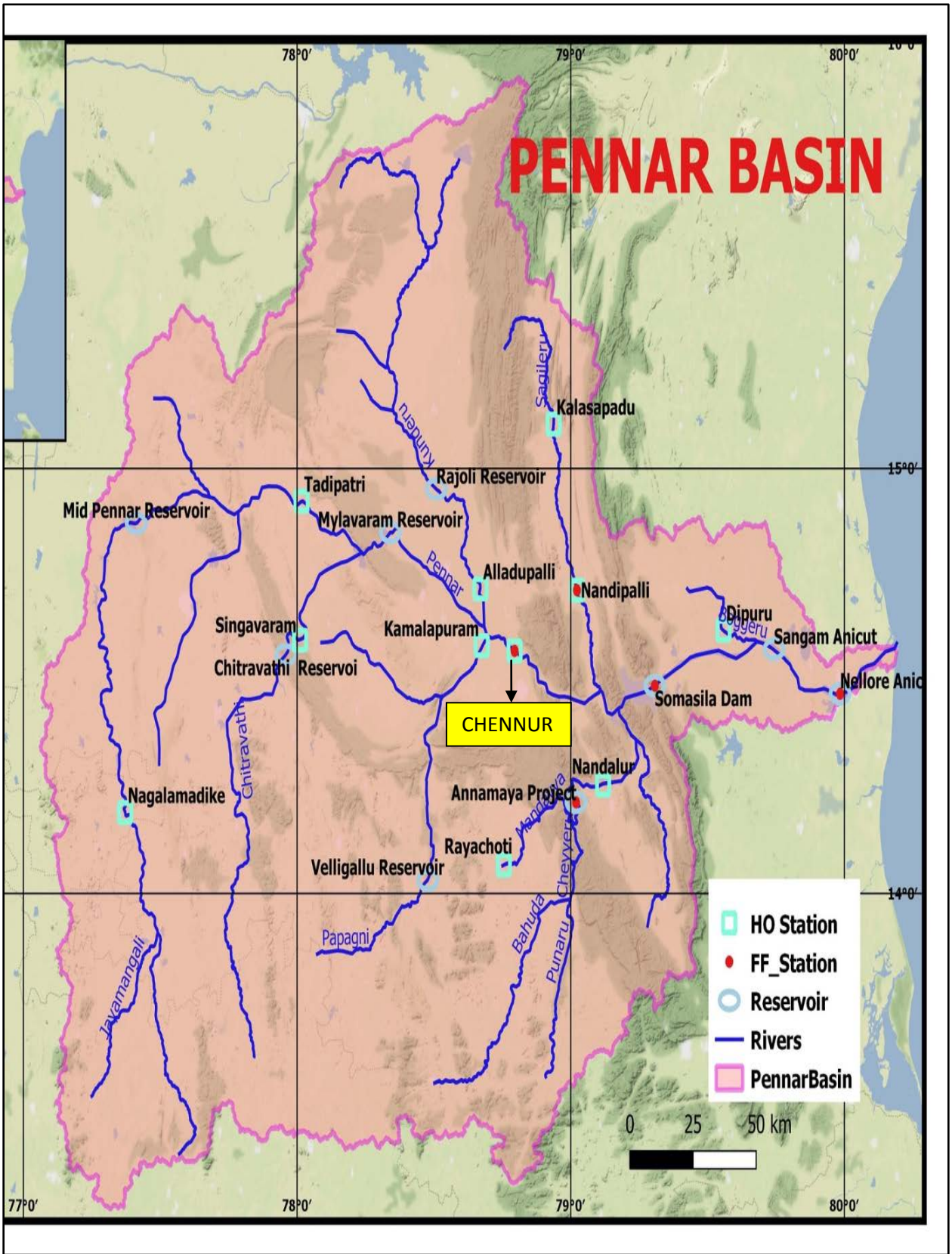
SEASONAL VARIATION IN THE WATER QUALITY IN PENNAR RIVER BASIN

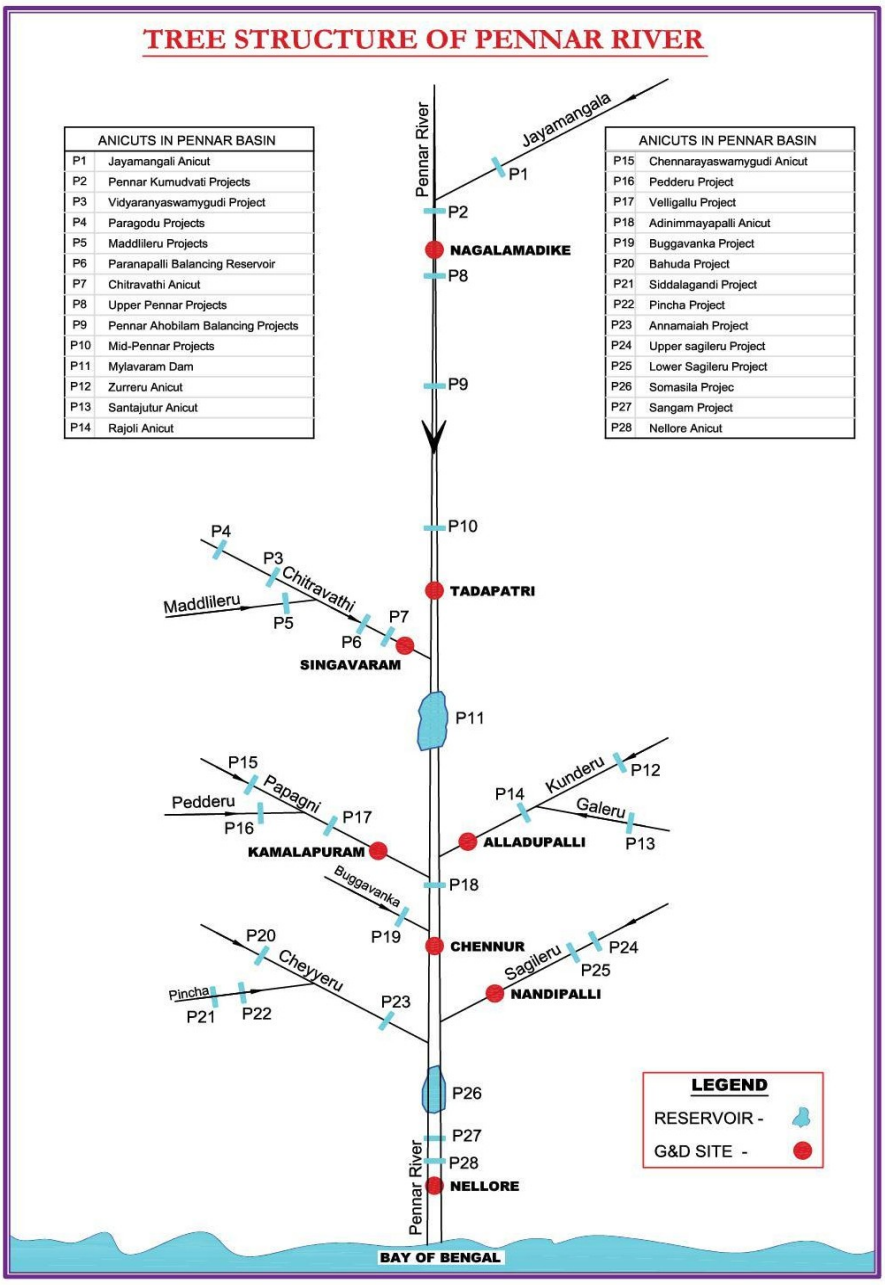
(*Prepared By Shri. J Krishna Pratap V, SRA, with the guidance by Shri. P. Rajan, ARO, Hydrology Division, CWC, Chennai*)

1. Introduction

The river Pennar is one of the major East flowing rivers in Southern India. It originates in the Chennakesava hill of the Nandidurg range in Karnataka. The river drains an area of 55,213 sq.kms through the states of Karnataka and Andhra Pradesh before its convergence into the Bay of Bengal. The total length of the river is 597 Km of which 61 Km flows in Karnataka and the rest in Andhra Pradesh. This river has six tributaries viz., the Jayamangali, Kunderu and Sagileru joining on the left and Chitravathi, Papagni and Cheyyeru joining on the right. There are eight water quality stations in Pennar river Basin i.e. Nagalamadike, Tadipatri, Chennur and Nellore in the main river and the rest are in its tributaries viz., Chitravathi at Singavaram, Kunderu at Alladupalli, Papagni at Kamalapuram and Sagileru at Nandipalli etc. As there is no continuous flow in the river throughout the year, the river can be said as non perennial.


PENNAR BASIN
78°0′
79°0′
80°0′
15°0′
14°0′
77°0′
Kalasapadu
Sagileru
Kunderu
Rajoli Reservoir
Tadipatri
Mid Pennar Reservoir
Mylavaram Reservoir
Pennar
Alladupalli
Nandipalli
Dipuru
Sangam Anicut
Singavaram
Kamalapuram
Chitravathi Reservoi
Somasila Dam
CHENNUR
Chitravathi
Nandalur
Annamaya Project
Nagalamadike
Rayachoti
Velligallu Reservoir
Papagni
Bahuda
Punaru
Javamangali
HO Station
FF_Station
Reservoir
Rivers
PennarBasin
0
25
50 km

TREE STRUCTURE OF PENNAR RIVER



2. Scope of WQ Monitoring and Methodology

The WQ sites at Nagalamadike, Tadipatri and Nellore were completely dry throughout the year 2017-18 and hence water quality analysis at these sites was not done. There was flow throughout the year in the river at site Chennur due to inter basin transfer from river Krishna to Pennar and monthly river water sample collection was carried out at this site during the water year 2017-2018 which were divided as monsoon (Jun. to Oct.), post-monsoon (Nov to Feb.) and pre-monsoon (Mar to May). The sampling locations and their types are presented in Table 1.

Table 1. Location, type & frequency of sampling points

Sl. No.	Site/Station	State	District	Type	Frequency	Latitude	Longitude
1.	Nagalamadike	Andhrapradesh	Tumkur	GDQ	Trend	$14^0$11'20"	$77^0$22'20"
2.	Tadipatri	Andhrapradesh	Anantapur	GDQ	Trend	$14^0$55'19"	$78^0$00'59'
3.	Chennur	Andhrapradesh	Kadapa	GDSQ	Trend	$14^0$34'20"	$78^0$48'00"
4.	Nellore	Andhrapradesh	Nellore	GDSQ	Trend	$14^0$28'13"	79059'20"

Grab sampling procedure has been adopted as per the CWC norms and river water samples were collected on the first working day of every month at the point of maximum flow and depth below 30 cm. from the surface in pre-cleaned, sterilized polyethylene bottles and filled without air bubbles and sent to the Level II lab at HD, Chennai for monthly water quality analysis. Apart from this, water samples were also collected for the analysis of in situ parameters like DO, pH, EC and Temperature etc. on 1^{st}, 11^{th} and 21^{st} date of every month at the site itself.

The physicochemical parameters as mentioned below are estimated by following the standard analytical procedure prescribed by American Public Health Association (APHA23rd Edn.2017).

Table 2. Analytical methods used for determination of physicochemical parameters

Sl.	Parameter	Abbreviations	Unit	Analytical Method
1.	pH	-	-	Electrometric Method
2.	Electrical Conductivity	EC	µS/cm	Laboratory Method
3.	Total Dissolved Solids	TDS	mg/L	Laboratory Method
4.	Calcium	Ca	mg/L	EDTA Titrimetric Method
5.	Magnesium	Mg	mg/L	Calculation Method
6.	Chloride	Cl	mg/L	Argentometric Method
7.	Bicarbonate	HCO_3	mg/L	Titrimetric Method
8.	Fluoride	F	mg/L	ISE Method
9.	Potassium	K	mg/L	Flame Emission Photometric Method
10.	Sodium	Na	mg/L	Flame Emission Photometric Method
11.	Nitrate	NO_3	mg/L	ISE Method
12.	Sulphate	SO_4	mg/L	Turbidimetric Method
13.	Biochemical oxygen demand	BOD	mg/L	IS 3025 (Part 44): 1993 (Reaffirmed 2014)
14.	Dissolved Oxygen	DO	mg/L	Azide Modification Method

3. Results and Discussion

The physicochemical parameters such as pH, Electrical conductivity (EC), Total dissolved solids (TDS), Calcium (Ca), Magnesium (Mg), Chloride (Cl), Bicarbonate (HCO_3), Fluoride (F), Potassium (K), Sodium (Na), Nitrate (NO_3), Sulphate (SO_4), Biochemical oxygen demand (BOD) and Dissolved Oxygen (DO) were analysed for the samples collected at the point of maximum flow and depth from the said sampling station during Monsoon, post-monsoon, and pre-monsoon seasons and their data on minimum, maximum and mean values are presented in Table 3, below.

Table 3

	Monsoon			**Post Monsoon**			**Pre Monsoon**		
Parameters	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**
pH	8.0	7.3	7.7	8.2	7.5	8.0	8.3	8.0	8.2
EC	1615.0	351.0	932.8	1018.0	645.0	833.5	1577.0	1249.0	1383.3
TDS	860.0	188.0	497.2	540.0	342.0	442.0	840.0	662.0	735.7
Ca	65.0	13.0	36.0	43.0	21.0	36.8	77.0	63.0	70.3
Mg	34.4	7.8	20.9	35.0	13.6	22.1	32.1	30.2	31.1
Cl	328.7	64.1	161.8	149.5	86.3	115.8	223.2	176.6	194.1
HCO_3	293.0	77.0	171.8	149.0	128.0	141.5	262.0	223.0	237.7
F	1.0	0.6	0.8	0.7	0.1	0.5	0.9	0.7	0.8
K	8.1	5.8	7.2	5.0	3.8	4.3	6.2	4.9	5.5
Na	246.0	48.0	122.8	114.2	66.0	89.4	172.5	136.2	149.7
NO_3-N	3.7	0.0	0.9	0.2	0.1	0.1	0.4	0.1	0.2
SO_4	162.5	11.1	78.3	125.5	77.8	100.8	220.5	138.7	174.0
BOD	2.3	0.7	1.8	1.9	0.4	1.2	2.2	0.4	1.2
DO	6.5	5.3	6.0	6.2	5.2	5.7	5.1	5.0	5.1

The comparison of the above results is graphically represented under each of the following parameters.

1. **pH**:

pH is a basic indicative parameter to know whether and to what extent the river water is acidic or basic for its suitability for different uses as it affects its chemical characteristics like solubility, metal toxicity etc. pH out of the range between 6.5 to 8.5 affects the ionic concentration of its water quality parameters rendering the water unsuitable for different uses. From the above results (Table 3) the mean values of pH at site Chennur is 7.7, 8.0 and 8.2 for monsoon, post monsoon and pre monsoon respectively. Hence pH of the water in river Pennar is within the tolerance limits of (BIS: 2296-1982) for all the designated uses.

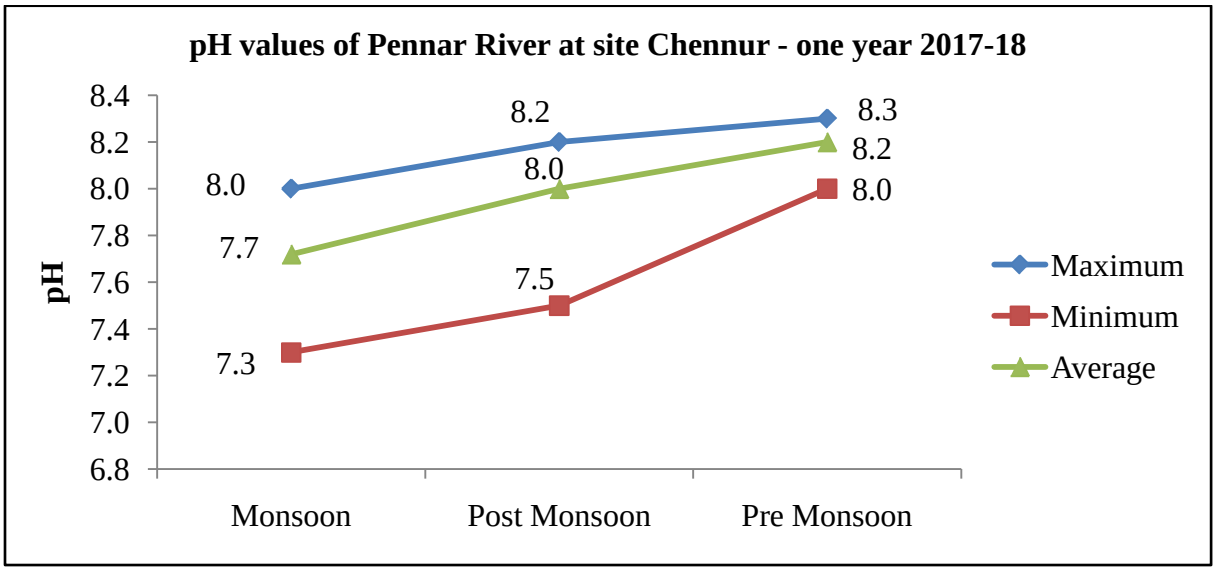


Figure – 1.1

2. **Electrical Conductivity**:

EC is a physical parameter on water quality which determines the salinity of the water and constitutes the total ionic concentration of different chemical parameters present in the water. The results shown in Table 3 indicates the maximum, minimum and the mean values of EC during the monsoon, post monsoon and pre monsoon seasons of 2017-18 as an indicator to assess the purity of water and the mean values of EC at site Chennur during these seasons were 932.8, 833.5 and 1383.3 µS/cm respectively. Hence it can be interpreted that the EC of River Pennar was within the tolerance limits of all classes for all the seasons except during pre monsoon of the year 2017-18 where the EC values were above the tolerance limits for Class D (>1000 µS/cm) i.e not suitable for Propagation of wildlife, fisheries etc.

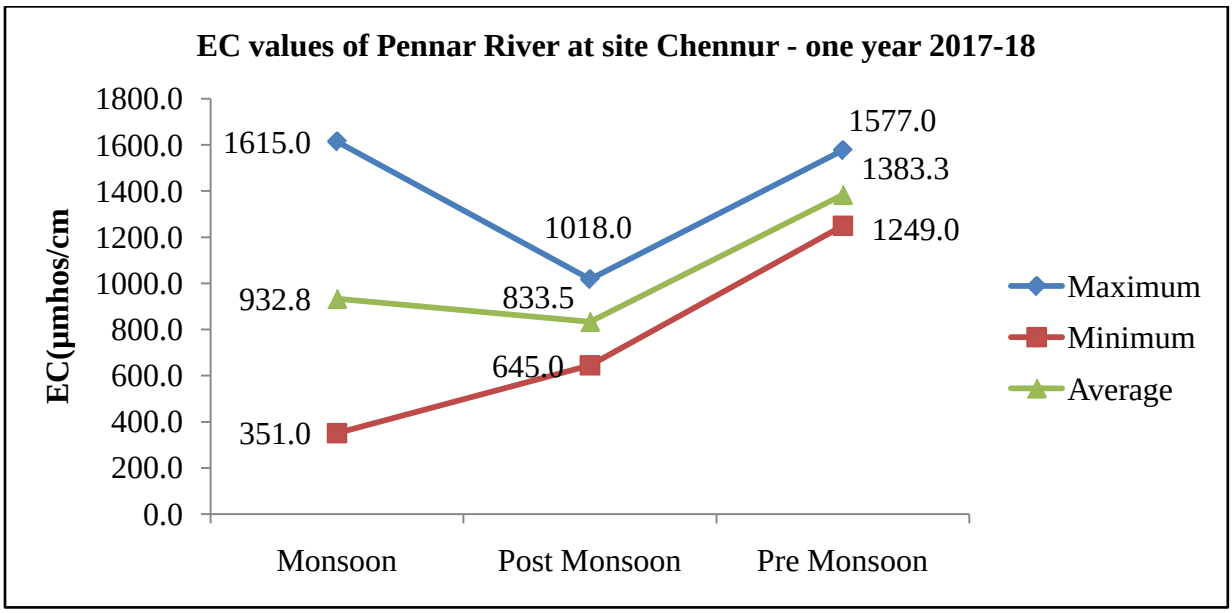


Figure – 1.2

3. TDS:

Total Dissolved Solids (TDS) is a physical parameter correlated to Electrical Conductivity (EC). Hence like EC, water with a high TDS indicates higher ionic concentration and is of poor palatability. The mean concentration of total dissolved solids (TDS) (Fig. 1.3) during monsoon, post monsoon and pre monsoon season were 497.2, 442.0 and 735.7 mg/l respectively. Hence it can be interpreted that the TDS of River Pennar was within the tolerance limits of all classes for all the seasons except during pre monsoon of the year 2017-18 where the TDS values were above the tolerance limits for Class A (>500 mg/L) i.e not suitable for Drinking purpose without conventional treatment but after disinfections.

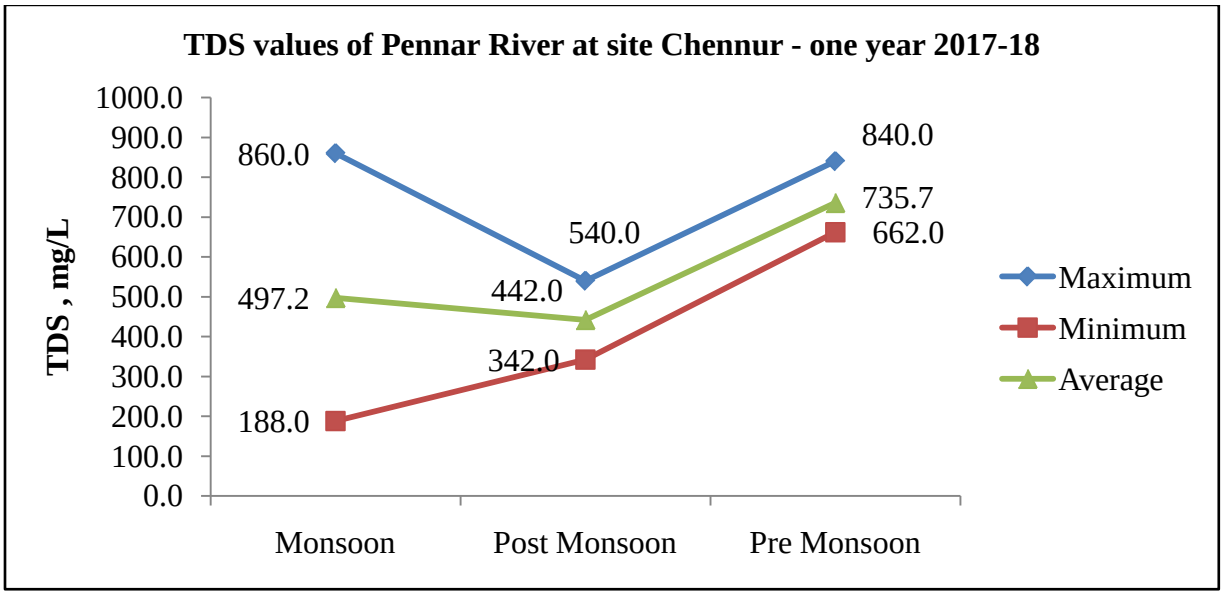


Figure – 1.3

4. Major Cations:

During the monsoon season, the mean concentration of cations such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} ions were 36.0, 20.9, 122.8 and 7.2 mg/l, respectively (Table 3). However, during post monsoon season, the mean values of cations were 36.8, 22.1, 89.4 and 4.3 mg/l respectively (Table 3). Similarly, during the pre-monsoon season, the mean values were 70.3, 31.1, 149.7 and 5.5 mg/l respectively (Table 3). Even though the concentration of cations during monsoon, post-monsoon and pre-monsoon seasons were different from each other, it was found that the order of abundance was similar throughout the year i.e. Na+> Ca2+> Mg2+>K+.

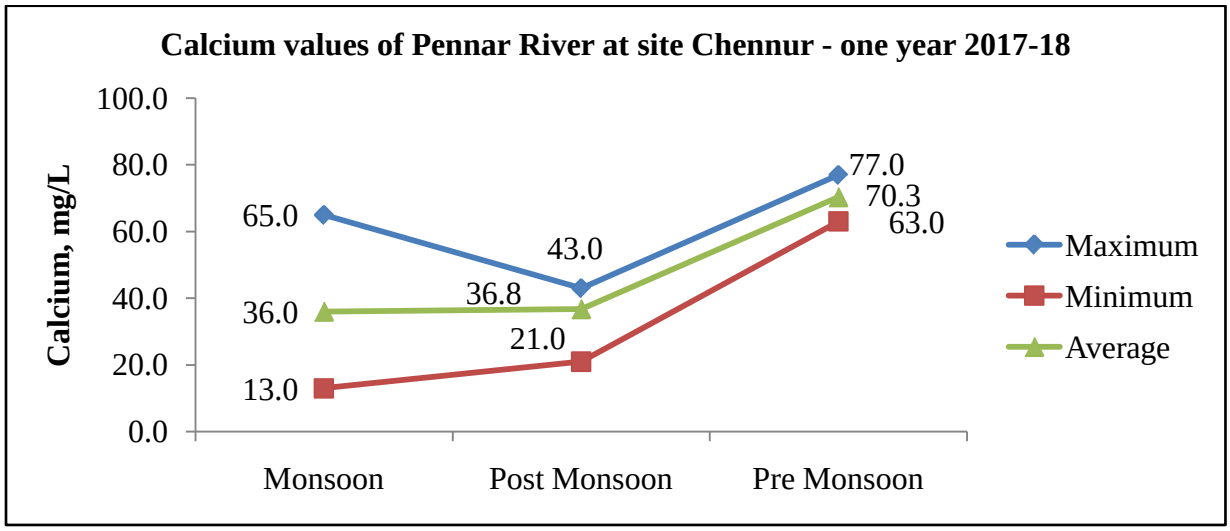
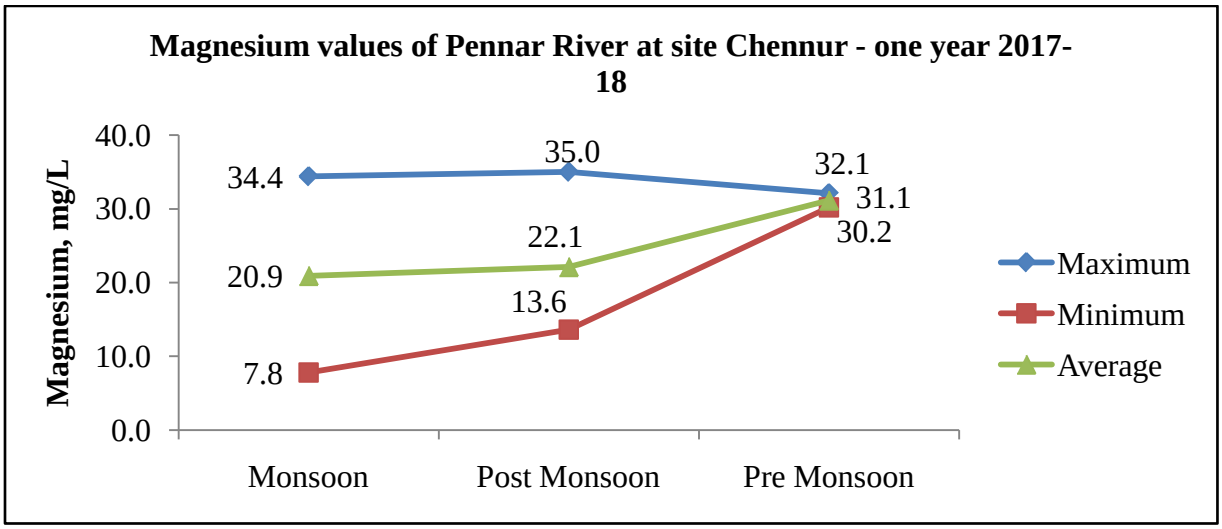


Figure – 1.4



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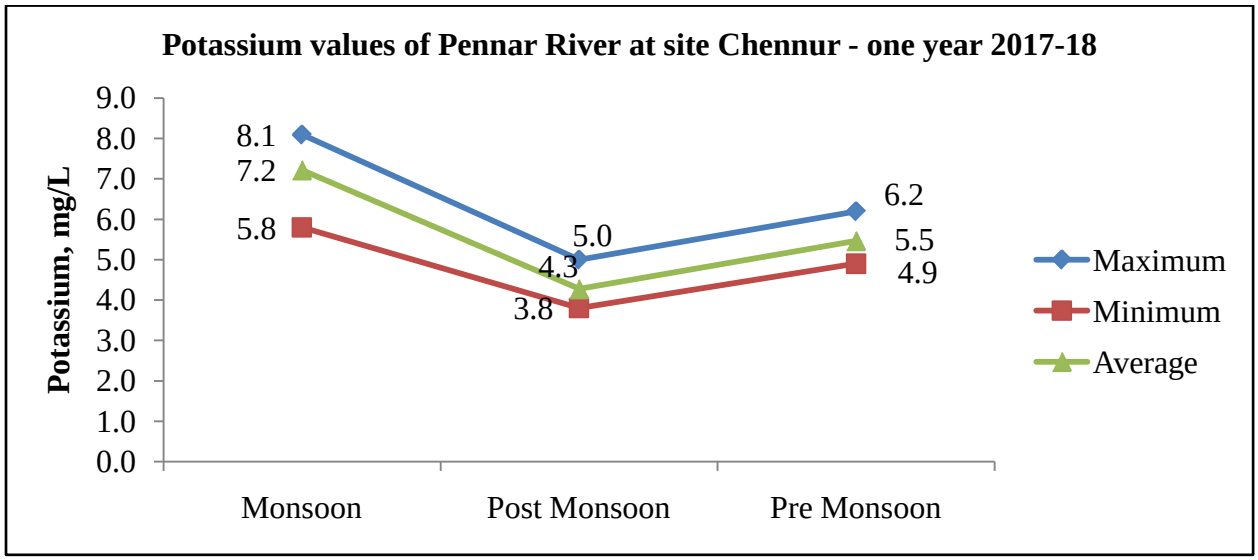

Figure – 1.6

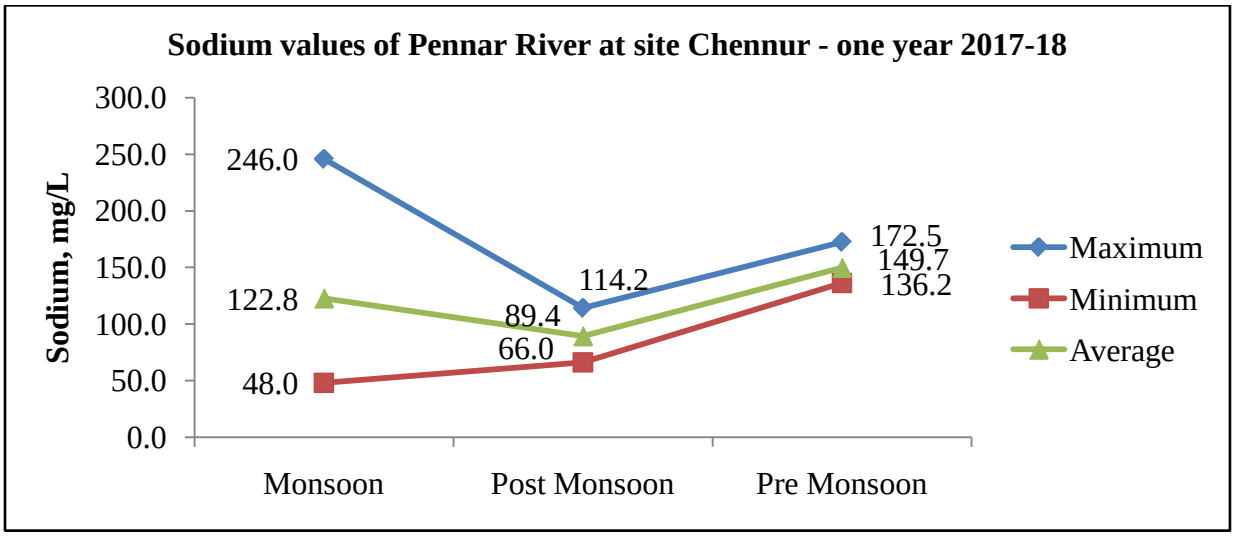

Figure – 1.7

5. Major Anions:

The ionic concentrations of anions such as HCO_3^-, SO_4^{2-}, Cl^- were calculated and the results are presented in Table 3. During monsoon season the mean concentration of anions were 171.8, 78.3 and 161.8 mg/l respectively (Table 3). Similarly the mean anionic concentration for post-monsoon were 141.5, 100.8 and 115.8 mg/l respectively (Table 3) and during pre-monsoon season, the mean concentration were 237.7, 174.0 and 194.1 mg/l respectively (Table 3). Even though the concentration of anions during monsoon, post-monsoon and pre-monsoon seasons were different from each other, the order of abundance was found to be similar throughout the year i.e. $HCO3^->Cl^->SO_4^{2}$-.

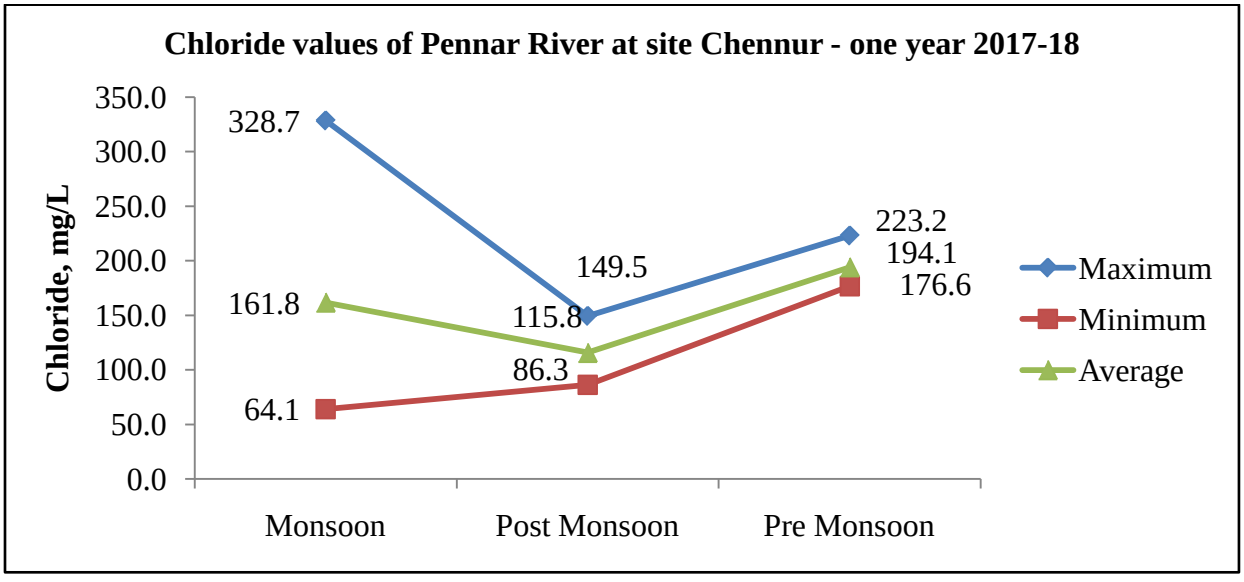

Figure – 1.8

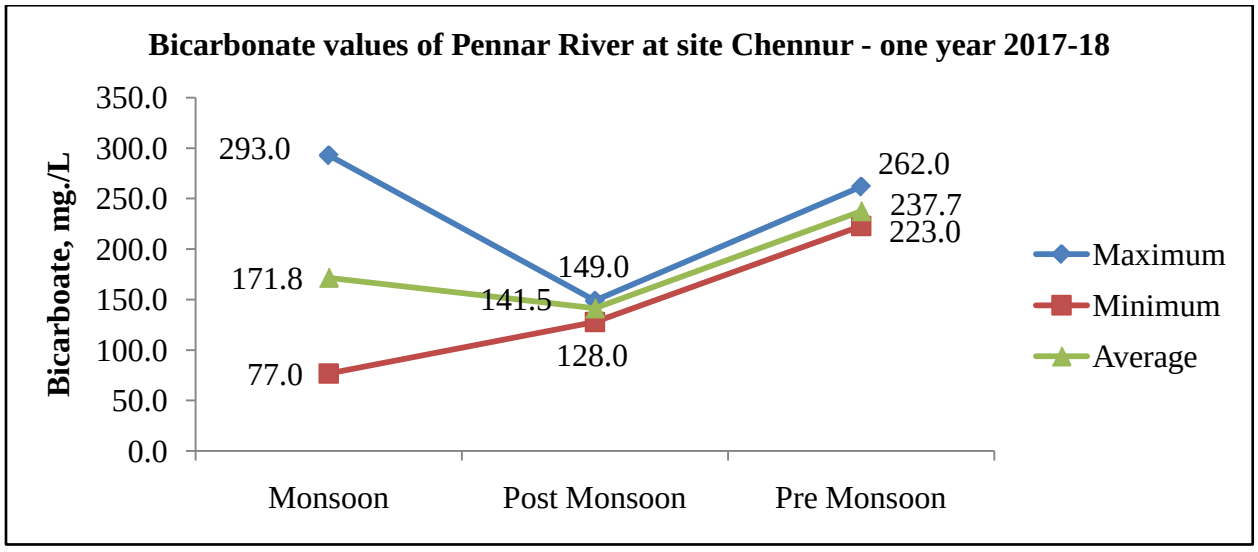

Figure – 1.9

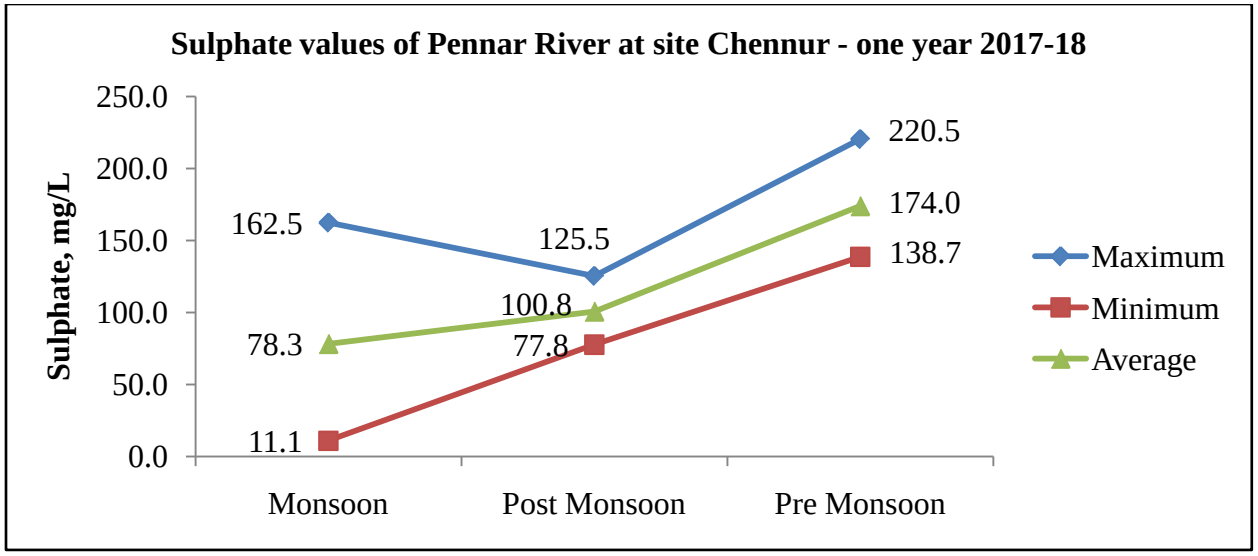

Figure – 2.0

6. Fluoride:

Fluoride is fairly distributed in river and ground water and its presence beyond certain limit for drinking purpose causes flurosis, a health hazard. Fluoride concentration in the river at site Chennur during monsoon was in the range of 0.6 to 1.0 mg/l with mean of 0.8 mg/l. Similarly, during post monsoon season Fluoride value varied from 0.1 to 0.7 mg/l with mean of 0.5 mg/l. However, during pre monsoon, the Fluoride value was within the range of 0.7 to 0.9 mg/l with a mean of 0.8 mg/l. This shows that the values of Fluoride at Pennar river is well within the tolerance limits as per BIS: 2296-1982 standards i.e suitable for all the designated uses.

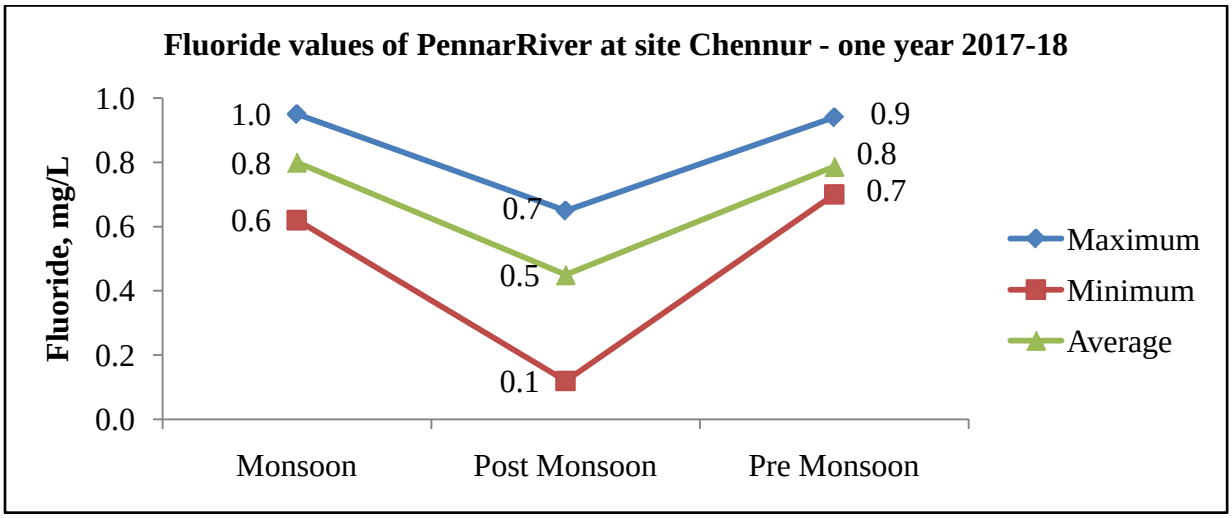

Figure – 2.1

7. Nitrate:

Nitrate is nutrient parameter essential for agricultural purposes but in excess caused by the discharge of sewage, industrial wastes and run off from agricultural fields etc, it causes pollution. The Nitrate in the river at site Chennur during monsoon was in the ranges from 0.0 to 3.7 mg/l with mean of 0.9 mg/l. Similarly, during post monsoon season Nitrate value ranges from 0.1 to 0.2 mg/l with mean of 0.1 mg/l. However during pre monsoon, the Nitrate value ranging from 0.1 to 0.4 mg/l with a mean of 0.2 mg/l. This shows that the values of Nitrate in Pennar river is well within the tolerance limits for all the designated uses throughout the year as per (BIS: 2296-1982) standards.

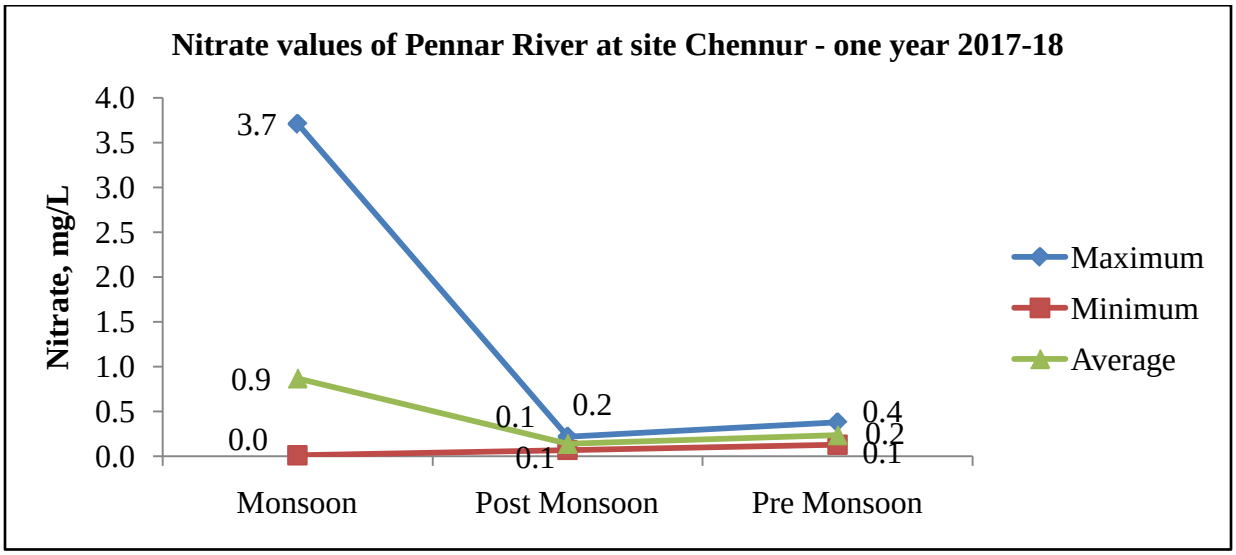

Figure – 2.2

8. Biochemical Oxygen Demand:

The biochemical oxygen demand (BOD) is a test that measures the amount of oxygen consumed by the living organisms present in the water body. The standard test by Winkler's method is carried out under controlled laboratory conditions i.e at 27°C Temperature for 3 days. Since all organic matters are not biodegradable, the test measures the oxygen equivalent of the degradable organic matters only. The Biochemical oxygen demand in the river at site Chennur during monsoon was in the ranges from 0.7 to 2.3 mg/l with mean of 1.8 mg/l. Similarly, during post monsoon season BOD value ranges from 0.4 to 1.9 mg/l with mean of 1.2 mg/l. However, during pre monsoon, the BOD value ranges from 0.4 -2.2 mg/l with a mean of 1.2 mg/l. This shows that the Pennar river is mostly within the tolerance limits of Class A i.e Drinking purposes as per (BIS: 2296-1982) standards.

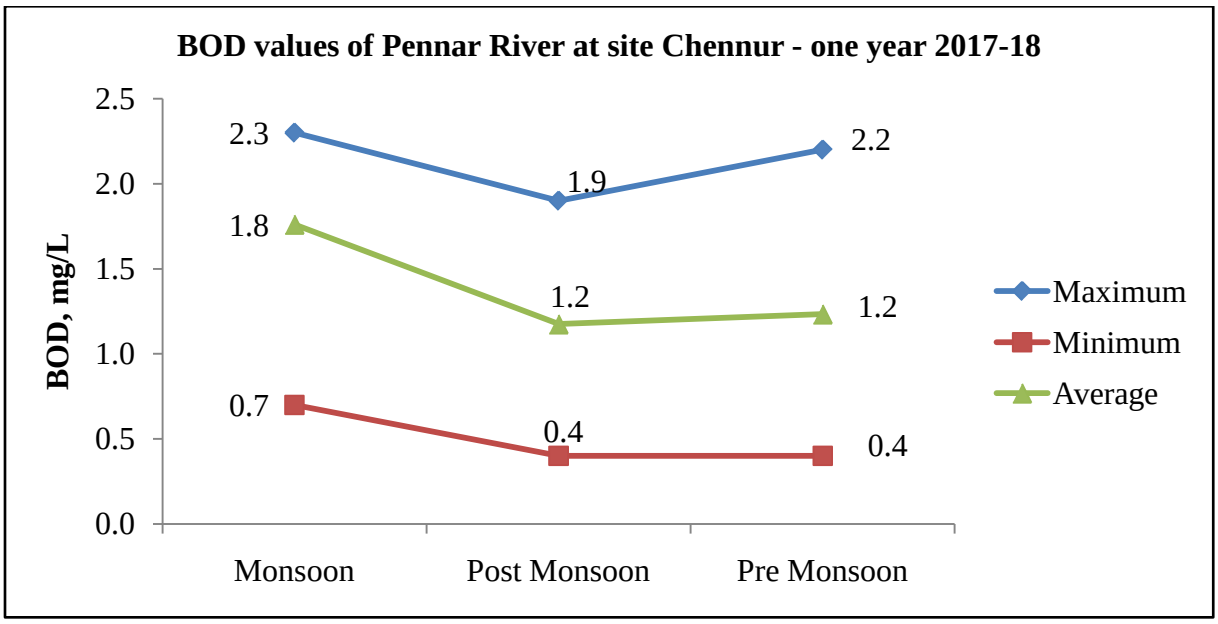

Figure – 2.3

9. Dissolved Oxygen:

Dissolved Oxygen is another biological parameter in the water quality monitoring. Its presence is essential for the survival of aquatic life in the fresh water body. DO level as low as below 4.0 mg/l can harm its aquatic life and water quality. The mean values of dissolved oxygen in the river at Site Chennur during monsoon, post monsoon and pre monsoon were in the range of 6.0, 5.7 and 5.7 mg/l respectively. The said values show that the river water of Pennar throughout the year is fairly within the tolerance limits of (BIS: 2296-1982).

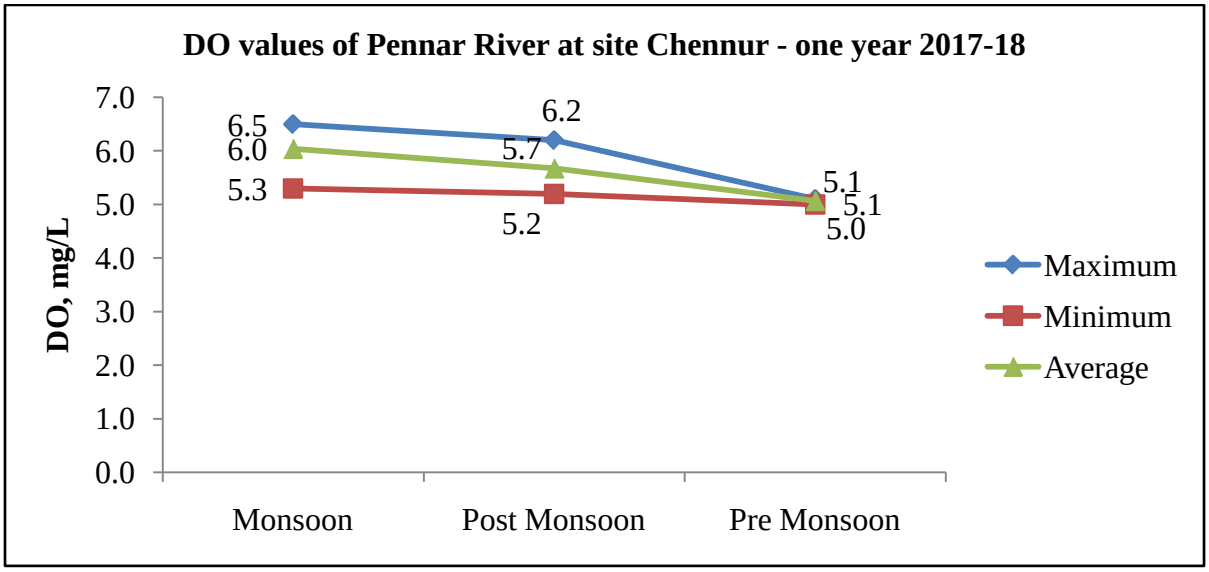

Figure – 2.4

4. Conclusions:

From the above discussion on seasonal variation of the physicochemical parameters of river Pennar at site Chennur for the year 2017-18, it is concluded that the river is free from any industrial pollution. It is also noted that the concentration of parameters are related to the river discharge i.e higher the discharge, lower the concentration and vice versa. The water of Pennar Basin is generally alkaline in nature but within the tolerance limits of BIS (2296-1982) and Fluoride, BOD, DO values etc. are well within the tolerance limits of BIS (2296-1982). However, during pre-monsoon season the EC was very high which is possibly due to lean flow. Human activities like fertilization, bathing, washing, discharge of sewage waste and religious activities along the stretch are the possible causes of pollution if any. The WQ scenario in this basin is found to be free from any serious pollution issue.

Note : As per the CWC Water year, the monsoon period is from June to October, whereas in the Southern India, monsoon for the East Flowing Rivers starts from August and ends in the middle of December.

5.0 References:

1. Water Quality Year Books for the years from 2017 to 2018 published by C&SRO, CWC, Coimbatore.
2. Water Quality Manual of Hydrology project.
3. Tolerance limit relating to selected pollution parameters for inland surface waters required for different uses as prescribed by the Bureau of Indian Standards (BIS: 2296-1982).

Annexure-1

Table-5: Tolerance limit relating to selected pollution parameters for inland surface waters required for different uses as prescribed by the Bureau of Indian Standards (BIS: 2296-1982)

Sl. No	Constituents	Unit	Designated use class of inland surface water				
			A	B	C	D	E
1	pH		6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.0-8.5
2	EC at 25°C	µS/cm,Max	-	-	-	1000	2250
3	DO	mg/L, Min	6	5	4	4	-
4	BOD	mg/L, Max	2	3	3	-	-
5	Total coliform organism	MPN/100 ml, Max	50*	500*	5000*	-	-
6	Colour,	Hazen units, Max	10	300	300	-	-
7	Odour		Un-objectiona	-	-	-	-
8	Taste		Tasteless	-	-	-	-
9	Total dissolved solids	mg/L, Max	500	-	1500	-	2100
10	Total Hardness	as $CaCO_3$, mg/L, Max	300	-	-	-	-
11	Calcium hardness	as $CaCO_3$, mg/L, Max	200	-	-		-
12	Magnesium	as $CaCO_3$, mg/L, Max	100	-	-	-	-
13	Iron	as Fe, mg/L, Max	0.3	-	50	-	-
14	Chloride	as Cl, mg/L, Max	250	-	600	-	600
15	Fluoride	as F, mg/L, Max	1.5	1.5	1.5	-	-
16	Sulphate	as SO_4,mg/L, Max	400	-	400	-	1000
17	Nitrate	as NO_3, mg/L, Max	20	-	50	-	-
18	Free Ammonia	as N, mg/L, Max	-	-	-	1.2	-
19	Arsenic	as As, mg/L, Max	0.05	0.2	0.2	-	-
20	Boron	as B, mg/L, Max	-	-	-	-	2
21	Cadmium	as Cd, mg/L, Max	0.01	-	0.01	-	-
22	Chromium	as Cr^{6+}, mg/L, Max	0.05	0.05	0.05	-	-
23	Copper	as Cu, mg/L, Max	1.5	-	1.50	-	-
24	Cyanide	as CN, mg/L, Max	0.05	0.05	0.05	-	-
25	Lead	as Pb, mg/L, Max	0.1	-	0.10	-	-
26	Manganese	as Mn, mg/L, Max	0.5	-	-	-	-
27	Mercury	as Hg mg/L, Max	0.001	-	-	-	-
28	Zinc	as Zn, mg/L, Max	15	-	15	-	-
29	Pesticides		Absent	-	Absent	-	-
30	Free carbon dioxide	as CO_2, mg/L, Max	-	-	-	6	-
31	Phenolic compound	asC_6H_5OH,mg/L,Max	0.002	0.005	0.005	-	-
32	Sodium percent,	Max	-	-	-	-	60
33	SAR	Max	-	-	-	-	26

A Drinking water source without conventional treatment but after disinfections
B Outdoor bathing-organised
C Drinking water source with conventional treatment followed by disinfections
D Propagation of wildlife, fisheries
E Irrigation, industrial cooling and controlled waste disposal

*** If the coliform count is more than the prescribed tolerance limit, the criteria for coliform shall be satisfied if not more than 20% of samples show more than the tolerance limit specified and not more than 5% of samples show more than 4 times the tolerance limit. Further, the faecal coliform should not be more than 40% of the total coliform.**

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केन्द्रीय जल आयोग
जल विज्ञान मंडल

सत्यमेव जयते

GOVERNMENT OF INDIA
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Department of Water Resources,
River Development & Ganga Rejuvenation
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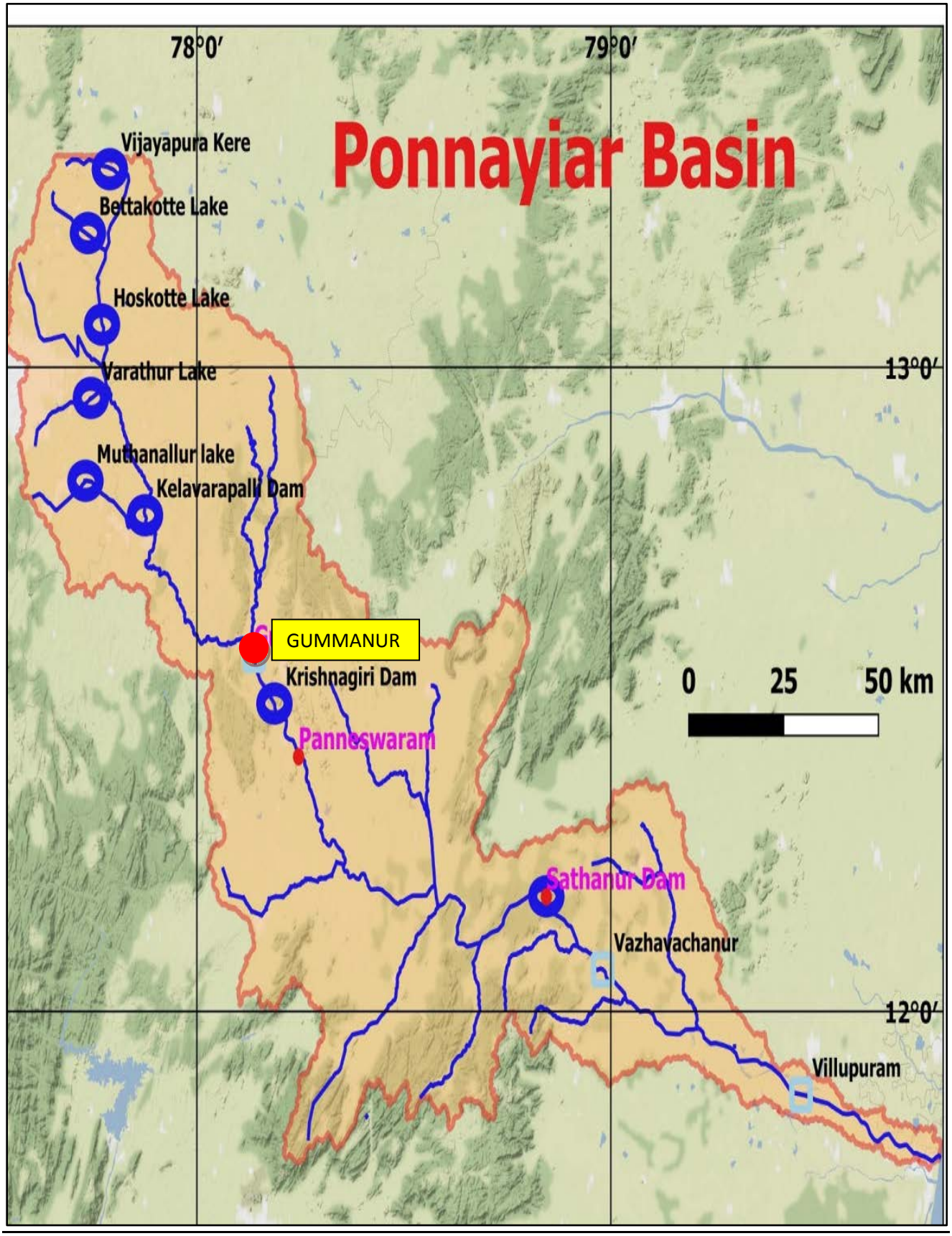
SEASONAL VARIATION IN THE WATER QUALITY PARAMETERS IN PONNAIYAR RIVER BASIN

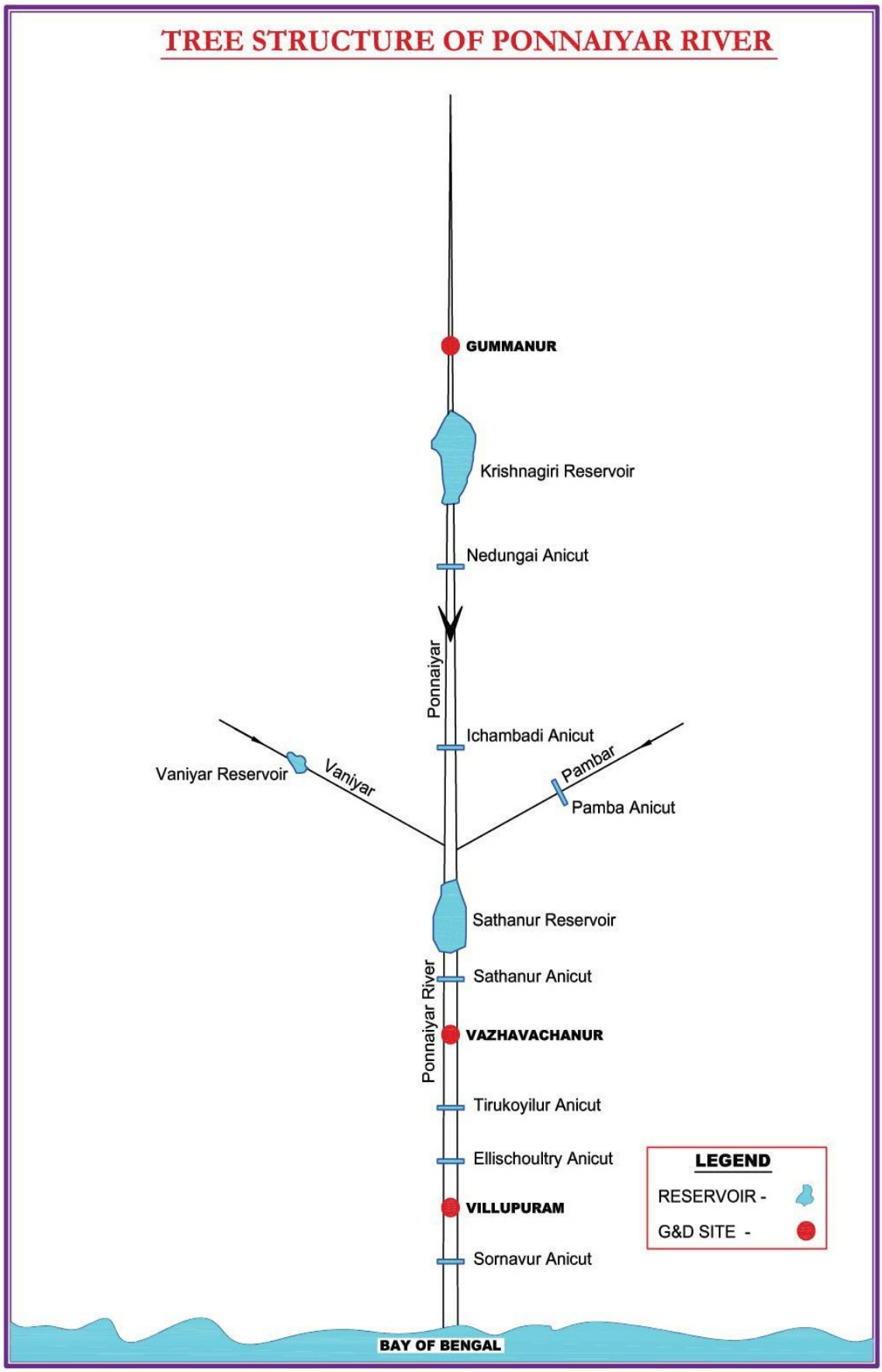
(*Prepared By Shri. CH. AJAY KUMAR, SRA, with the guidance by Shri. P. Rajan, ARO, Hydrology Division, CWC, Chennai*)

1. Introduction

The river Ponnaiyar is one of the major East flowing rivers in Southern India. The Ponnaiyar or the Dakshina Pinakini rises near Hongashenhalli village in Kolar district of Karnataka at an elevation of about 900 m above m.s.l. From its origin, the river Ponnaiyar flows in the southern direction for a length of 79 Km, through Kolar and Bangalore districts of Karnataka before entering into Krishnagiri district of Tamil Nadu. The total length of the river is 396 km. The Ponnaiyar drains an area of 16,019 Sq. Kms. There are three water quality stations on this river i.e. Gummanur, Vazhavachanur and Villupuram. The Ponnaiyar is a nonperennial and rain fed river as there is continuous flow in the river upto Penneshwaramadam throughout the year due to south-western and North-eastern monsoons. And afterwards there is flow in the lower reach of the river mainly due to North-eastern monsoon.


Ponnayiar Basin
78°0′
79°0′
13°0′
12°0′
Vijayapura Kere
Bettakotte Lake
Hoskotte Lake
Varathur Lake
Muthanallur lake
Kelavarapalli Dam
GUMMANUR
Krishnagiri Dam
Panneswaram
Sathanur Dam
Vazhavachanur
Villupuram
0
25
50 km

TREE STRUCTURE OF PONNAIYAR RIVER



2. Scope of WQ Monitoring and Methodology

There was continuous flow in the river at site Gummanur during the water year 2017-2018 which is divided as monsoon (June. to Oct.), post-monsoon (Nov. to Feb.) and pre-monsoon (Mar. to May). There was no flow in the river at site Vazhavachanur during pre-monsoon season from (June to August) and hence the WQ analysis at this site was not done. The site at Villupuram is a trend station and was completely dry throughout the year except for the months of October and December. Hence Vazhavachanur and Villupuram stations are not considered for seasonal variation. The location and type of above water quality stations are presented in Table 1.

Table 1. Location, type & frequency of sampling points:

Sl.	Site/Station	State	District	Type	Frequency	Latitude	Longitude
1.	Gummanur	Tamilnadu	Dharmapuri	GDSQ	Flux	12□33'18"	78□08'18"
2.	Vazhavachanur	Tamilnadu	Thiruvannamalai	GDSQ	Trend	$12^0$03'57"	$78^0$58'41"
3.	Villupuram	Tamilnadu	Villupuram	GDQ	Trend	$11^0$52'14"	$79^0$27'34"

Grab sampling procedure has been adopted as per the CWC norms and river water samples were collected at the point of maximum flow and depth below 30 cm. from the surface in pre-cleaned, sterilized polyethylene bottles and filled without air bubbles and sent to the respective Divisional lab for monthly water quality analysis. Apart from this, water samples were also collected for the analysis of in situ parameters like DO, pH, EC and Temperature etc on 1^{st}, 11^{th} and 21st date of every month at the site itself. The physicochemical parameters as mentioned below are estimated by following the standard analytical procedure prescribed by American Public Health Association (APHA23rd Edn.2017).

Table 2. Analytical methods used for determination of physicochemical parameters

Sl.	Parameter	Abbreviations	Unit	Analytical Method
1.	pH	-	-	Electrometric Method
2.	Electrical Conductivity	EC	µS/cm	Laboratory Method
3.	Total Dissolved Solids	TDS	mg/L	Laboratory Method
4.	Calcium	Ca	mg/L	EDTA Titrimetric Method
5.	Magnesium	Mg	mg/L	Calculation Method
6.	Chloride	Cl	mg/L	Argentometric Method
7.	Bicarbonate	HCO_3	mg/L	Titrimetric Method
8.	Fluoride	F	mg/L	ISE Method
9.	Potassium	K	mg/L	Flame Emission Photometric Method
10.	Sodium	Na	mg/L	Flame Emission Photometric Method
11.	Nitrate	NO_3	mg/L	ISE Method
12.	Sulphate	SO_4	mg/L	Turbidimetric Method
13.	Biochemical oxygen demand	BOD	mg/L	IS 3025 (Part 44): 1993(Reaffirmed 2014)
14.	Dissolved Oxygen	DO	mg/L	Azide Modification Method

3. Results and Discussion

The physicochemical characteristics such as pH, Electrical conductivity (EC), Total dissolved solids (TDS), Dissolved Oxygen (DO), Biochemical oxygen demand (BOD), Calcium (Ca), Magnesium (Mg), Chlorides (Cl), Bicarbonate (HCO_3), Potassium (K), Sodium (Na), Nitrate (NO_3), Sulphate (SO_4), Fluoride (F) and Nitrate (NO_3) were analyzed for the samples collected at the point of maximum flow and depth from the said sampling station during Monsoon, post-monsoon, and pre-monsoon and their data on minimum, maximum and mean values are presented in table-3 below.

Table-3.Physicochemical parameters of surface water in Ponnaiyar River

	Monsoon			Post Monsoon			Pre Monsoon		
Parameters	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**Min**	**Mean**
pH	8.1	7.1	7.7	8.3	7.4	7.8	8.8	7.3	8.2
EC	1260.0	225.0	844.9	1388.0	959.0	1244.3	1376.0	1110.0	1243.0
TDS	688.0	127.0	475.6	808.0	547.0	711.8	787.0	633.0	710.8
DO	8.5	2.8	5.3	5.8	4.0	4.7	5.6	4.6	5.0
BOD	15.3	2.3	5.8	16.5	2.2	6.8	13.7	5.9	10.5
Ca	81.0	20.0	57.8	115.0	71.0	84.3	103.0	53.0	76.3
Mg	33.2	6.5	20.6	41.0	14.6	30.0	51.5	13.6	32.3
Na	138.5	18.5	90.0	156.0	100.0	135.9	166.0	131.5	151.1
K	22.5	3.2	15.3	22.1	4.7	18.3	21.0	18.1	19.8
HCO_3	293.0	87.0	215.2	355.0	274.0	317.7	360.0	205.0	289.1
SO_4	30.9	10.5	24.3	42.4	24.6	32.0	37.3	29.9	33.0
Cl	203.7	25.9	128.9	209.4	138.3	184.4	231.4	183.2	204.8
NO_3-N	27.7	0.2	13.1	35.6	7.6	22.2	18.9	12.9	16.0
F	0.5	0.2	0.4	0.8	0.3	0.6	0.9	0.4	0.6

1. **pH**:

pH is a basic indicative parameter to know whether and to what extent the river water is acidic or basic for its suitability for different uses as it affects its chemical characteristics like solubility, metal toxicity etc. pH out of the range between 6.5 to 8.5 affects the ionic concentration of its water quality parameters rendering the water unsuitable for different uses. It can be noted that the pH value of samples at Gummanur site during Monsoon are in the range of 7.1 to 8.1. Similarly, during Post-monsoon season the pH value ranging from 7.4 to 8.3. This is slightly higher than monsoon season. However, during pre monsoon, the pH was found out to be slightly alkaline ranging from 7.3 to 8.8. The mean values of pH at site Gummanur is 7.7, 7.8 and 8.2 for monsoon, post monsoon and pre monsoon respectively. Hence it is noted that pH values were found to be within the tolerance limits of BIS: 2296-1982 standards for all the designated uses.

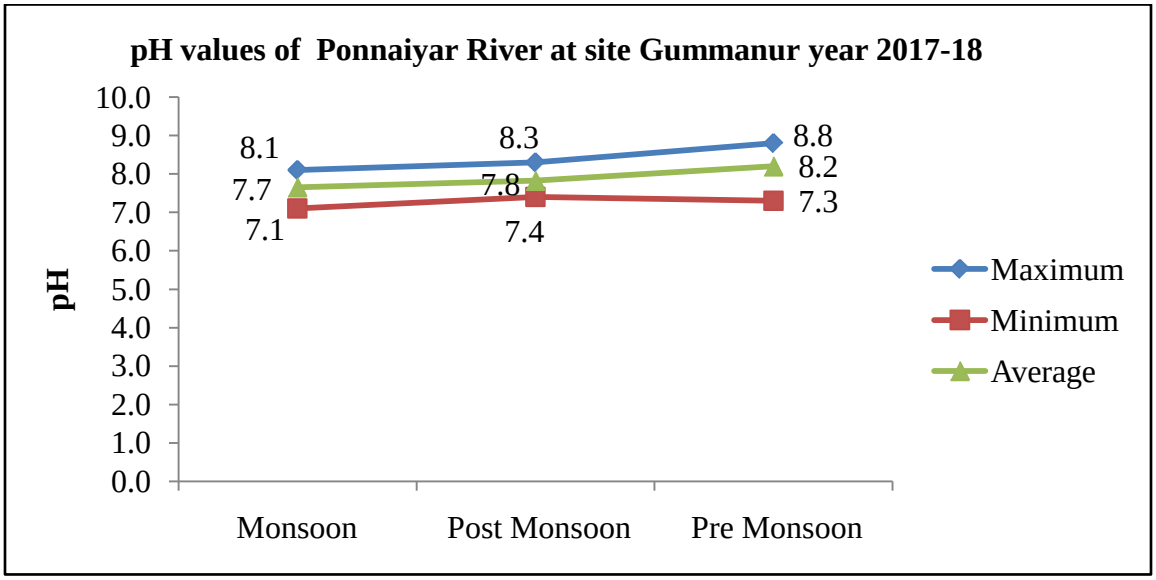


Figure-1.1

2. **Electrical Conductivity**:

EC is a physical parameter on water quality which determines the salinity of the water and constitutes the total ionic concentration of different chemical parameters present in the water. The results shown in Table 3 indicates the maximum, minimum and the mean values of EC during the monsoon, post monsoon and pre monsoon seasons of 2017-18 as an indicator to assess the purity of water. Electrical conductivity during monsoon ranges from 225 to 1260 µS/cm, during the post monsoon season it ranges from 959 to 1388 µS/cm. During pre-monsoon season the EC was very high in the range of 1110 to 1376 µS/cm. The Mean values of EC at site Gummanur during these seasons were 844.9, 1244.3 and 1243.0 µS/cm respectively. Hence the mean values during post monsoon, pre monsoon are above the tolerance limit of Class D, i.e. not suitable for Propagation of wildlife, fisheries.

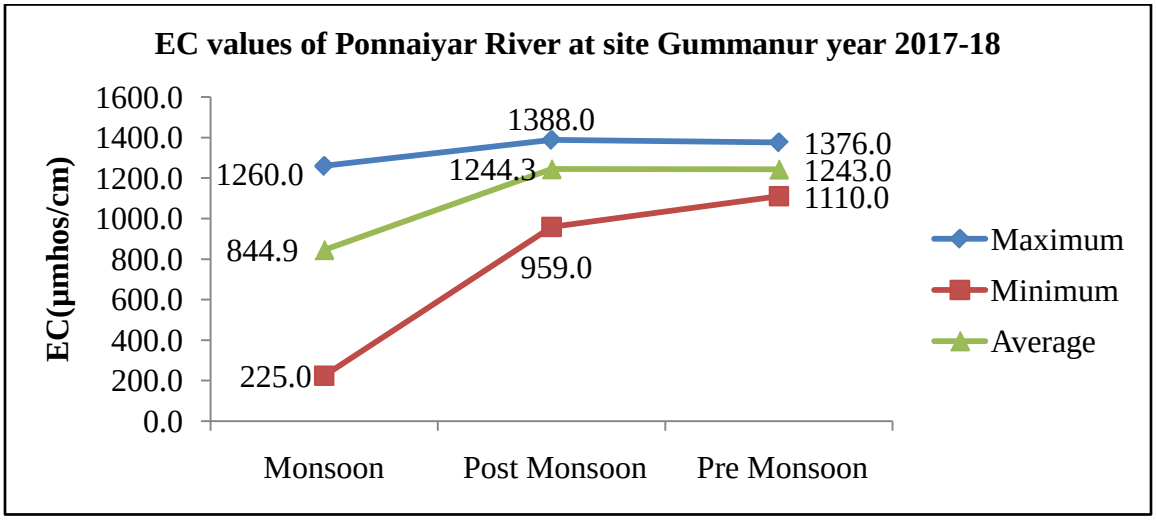


Figure-1.2

3. TDS:

Total Dissolved Solids (TDS) is a physical parameter correlated to Electrical Conductivity (EC). Hence like EC, water with a high TDS indicates higher ionic concentration and is of poor palatability. The concentrations of total dissolved solids (TDS) during monsoon season are in the range of 127 to 688 mg/l. During post monsoon season it ranges from 547 to 808 mg/l. Further, it can be noted that during pre monsoon season values ranges from 633 to 787 mg/l. The mean concentration of total dissolved solids (TDS) (Fig. 1.3) during monsoon, post monsoon and pre monsoon season were 475.6, 711.8 and 710.8 mg/l respectively. Hence the mean values during post monsoon, pre monsoon were above the tolerance limits for Class A (>500 mg/L) i.e not suitable for Drinking purpose without conventional treatment but after disinfections.

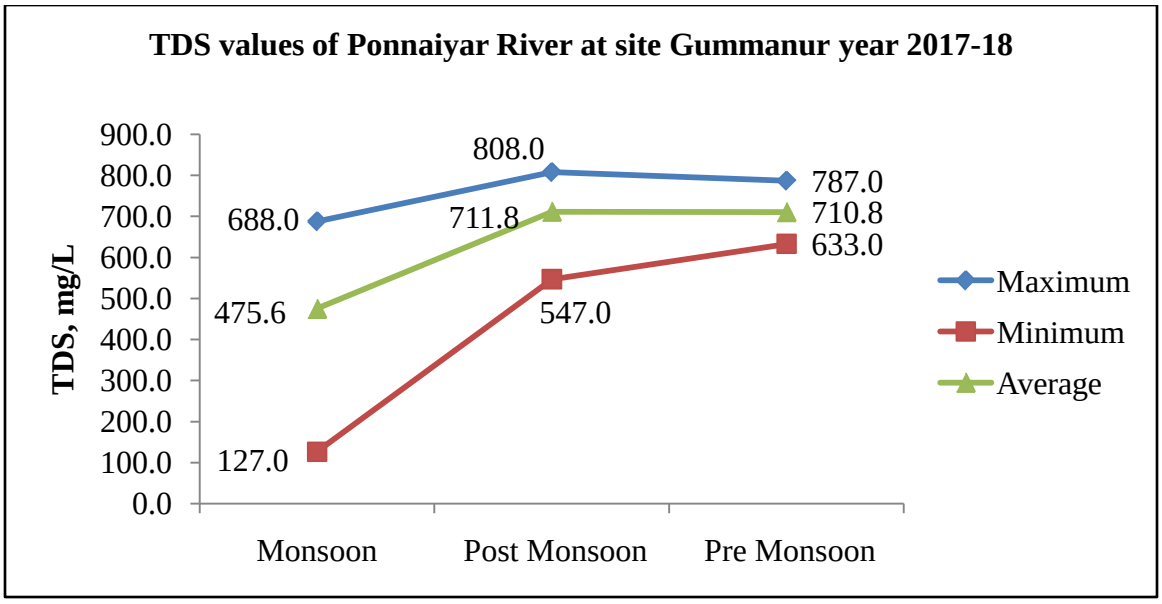


Figure-1.3

4. Dissolved Oxygen:

Dissolved Oxygen is another biological parameter in the water quality monitoring. Its presence is essential for the presence of aquatic life in the fresh water body. DO level as low as below 4.0 mg/l can harm its aquatic life and water quality. The dissolved oxygen concentration in the river at site Gummanur during monsoon season was in the range of 2.8 to 8.5 mg/l. Similarly, during post monsoon season DO values range from 4.0 to 5.8 mg/l. During pre monsoon the DO values are ranging from 4.6 to 5.6 mg/l. The mean values of dissolved oxygen in the river at Site Gummanur during monsoon, post monsoon and pre monsoon were in the range of 5.3, 4.7 and 5.0 mg/l respectively. Hence the mean values show that the river water of Ponnaiyar at Gummanur throughout the year mostly within the tolerance limits of BIS: 2296-1982 standards.

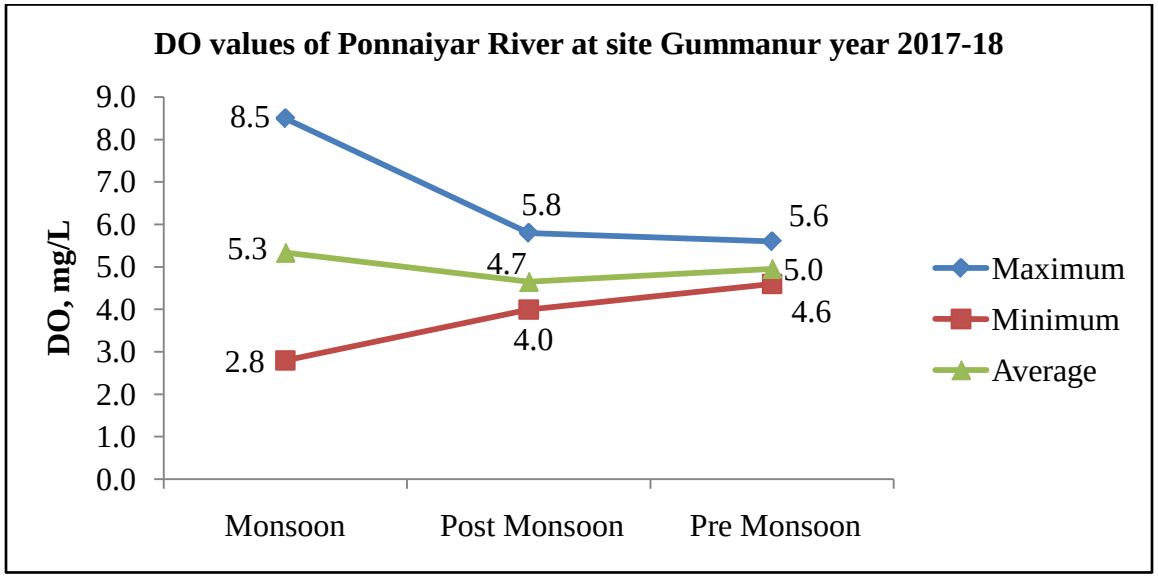


Figure-1.4

5. Biological Oxygen Demand:

The biochemical oxygen demand (BOD) is a test that measures the amount of oxygen consumed by the living organisms present in the water body. The standard test by Winkler's method is carried out under controlled laboratory conditions i.e. at 27°C Temperature for 3 days. Since all organic matters are not biodegradable, the test measures the oxygen equivalent of the degradable organic matters only. The Biochemical oxygen demand in the river at site Gummanur during monsoon was in the range of 2.3 to 15.3mg/l with mean of 5.8 mg/l. During post monsoon season BOD values at Gummanur ranges from 2.2 to 16.5 with mean of 6.8 mg/l. However, during pre monsoon, the BOD value ranges from 5.9 to 13.7 mg/l with a mean of 10.5 mg/l. This shows that BOD values are very high as per tolerance limits of BIS: 2296-1982 standards for all the designated uses.

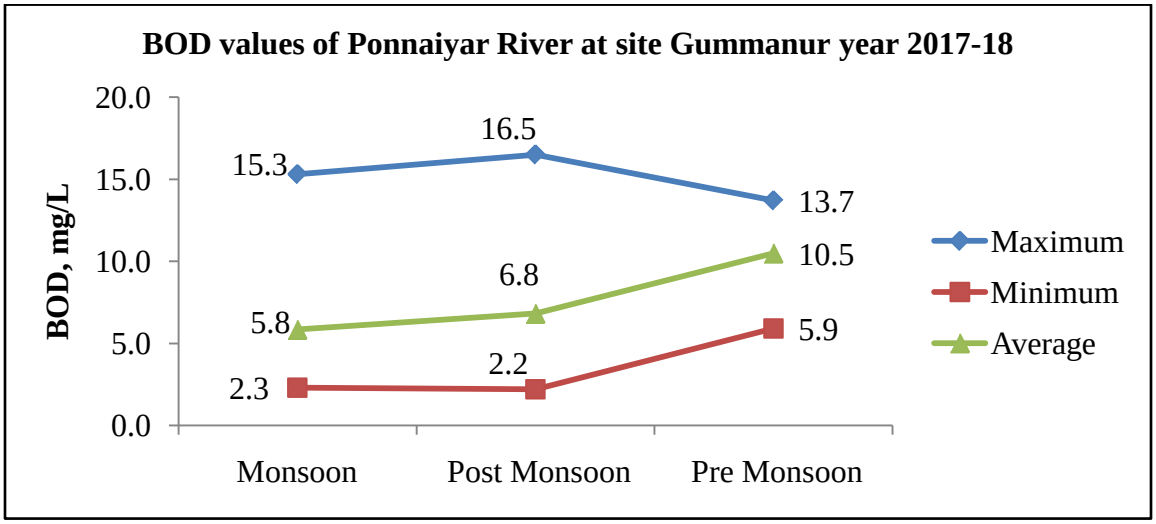


Figure-1.5

6. Major Cations:

During the monsoon season, at site Gummanur the concentration of cations such as Ca^{2}+, Mg^{2}+, Na^{+}, K^{+} ions ranges from 20 to 81 mg/l, 6.5 to 33.2 mg/l, 18.5 to 138.5 mg/l and 3.2 to 22.5 mg/l with mean value of 57.8, 20.6, 90.0 and 15.3 mg/l. The order of abundance was found to be Na+> Ca2+> Mg2+>K+. Similarly, during post monsoon season, at site Gummanur the cations were in the range of 71 to 115 mg/l, 14.6 to 41 mg/l, 100 to 156 mg/l and 4.7 to 22.1 mg/l with mean of 84.3, 30.0, 135.9 and 18.3 mg/l. Similarly, during the pre-monsoon season, the value ranges from 53 to 103 mg/l, 13.6 to 51.5 mg/l, 131.5 to 166.0 mg/l and 18.1 to 21.0 mg/l with mean of 76.3, 32.3, 151.1 and 19.8 mg/l. The order of abundance was Na2+> Ca2+> Mg2+>K+. Despite, the concentration of ions in the monsoon, post-monsoon and pre-monsoon were different from each other, it can be noted that the order of abundance was similar for monsoon, post-monsoon and pre-monsoon.

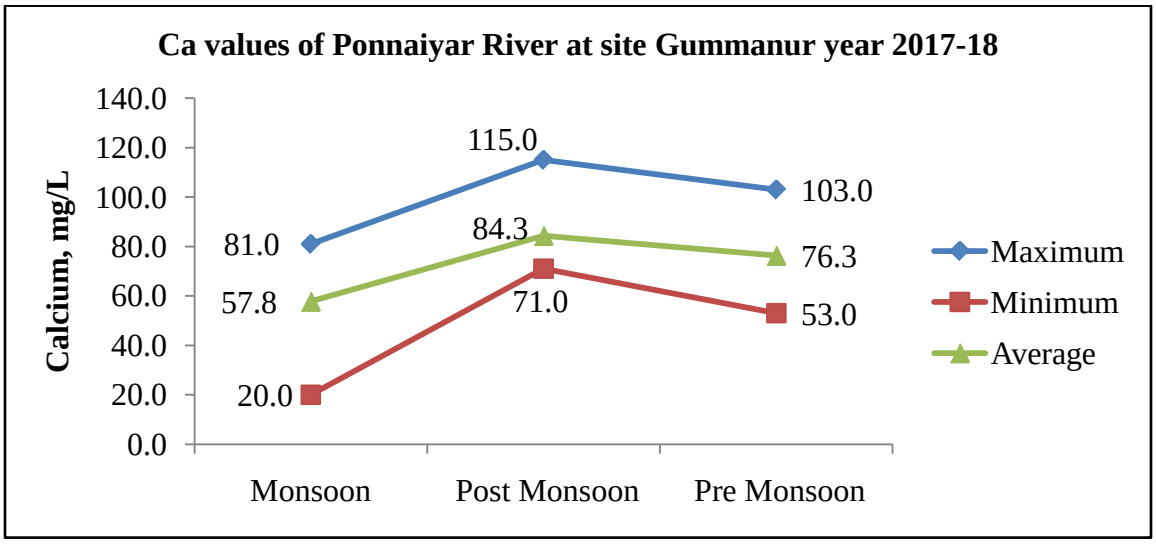


Figure-1.6

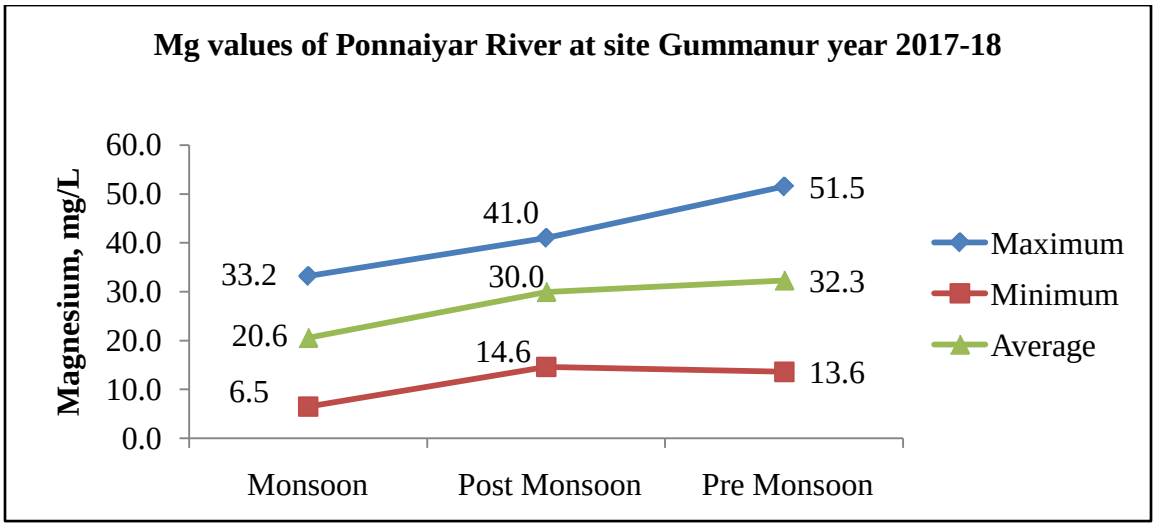


Figure-1.7

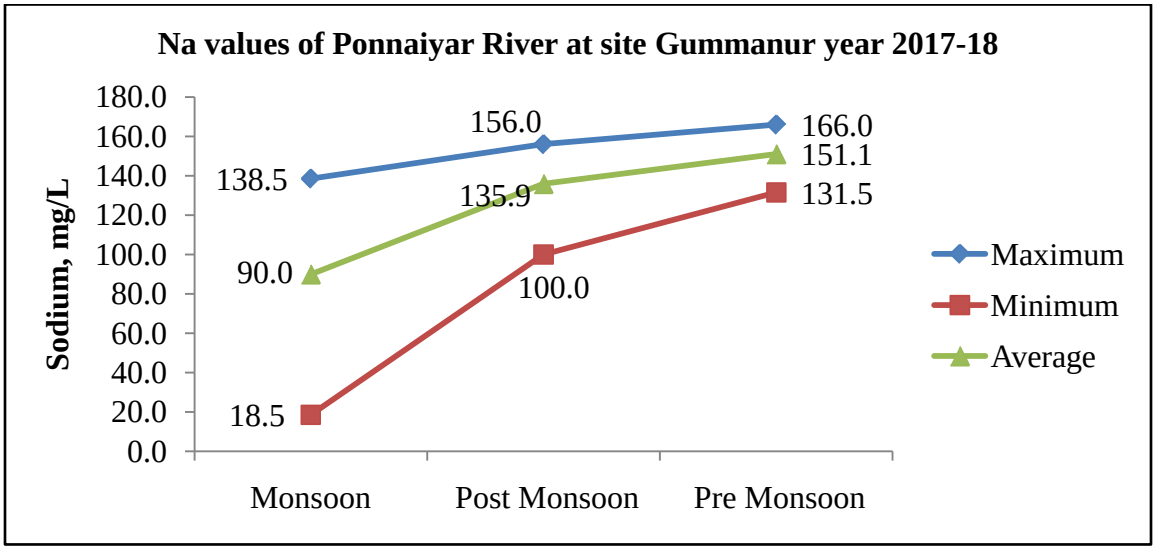


Figure-1.8

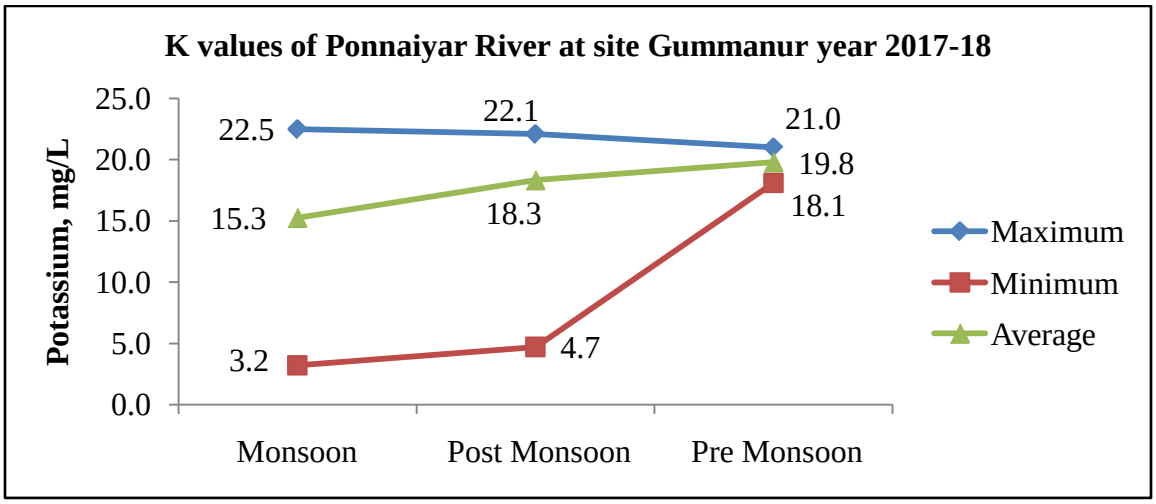


Figure-1.9

7. Major Anions:

The anionic concentrations such as HCO_3^-, SO_4^{2-}, Cl^- were quantified and the results are presented in the following table. During monsoon season the concentration of anions ranges from 87 to 293 mg/l, 10.5 to 30.9 mg/l and 25.9 to 203.7 mg/l with mean of 215.2, 24.3 and 128.9 mg/l. During post-monsoon at Gummanur site anionic concentration ranges from 274 to 355 mg/l, 24.6 to 42.4 mg/l and 138.3 to 209.4 mg/l with mean of 317.7, 32.0 and 184.4 mg/l. Likewise, during pre-monsoon season at site Gummanur the concentration ranges from 205 to 360 mg/l, 29.9 to 37.3 mg/l and 183.2 to 231.4 mg/l with mean of 289.1, 33.0 and 204.8 mg/l. It can be noted that concentration was different but the order of abundance was similar with values exhibiting $HCO3^-$>Cl^-> SO_4^{2-}.

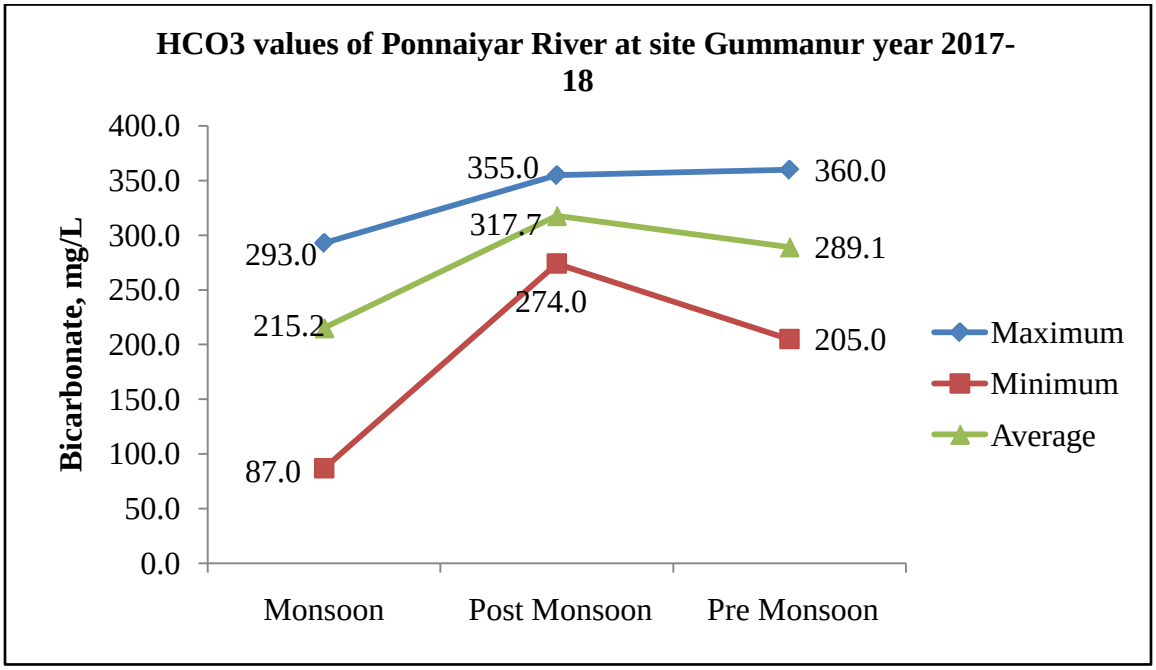


Figure-2.0

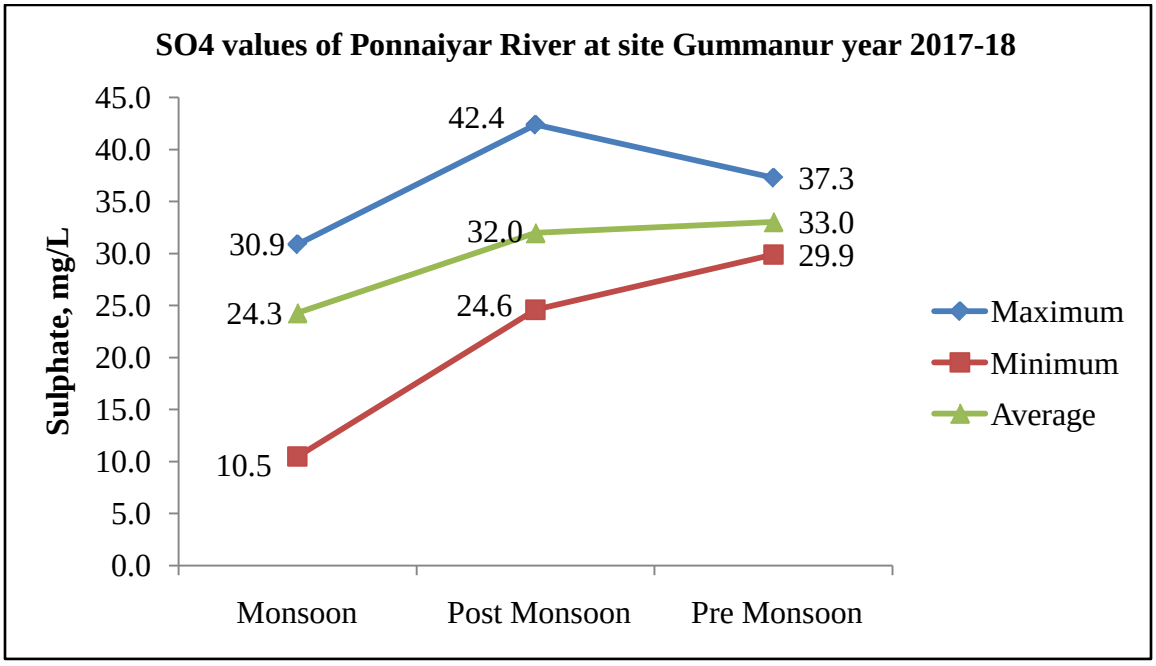


Figure-2.1

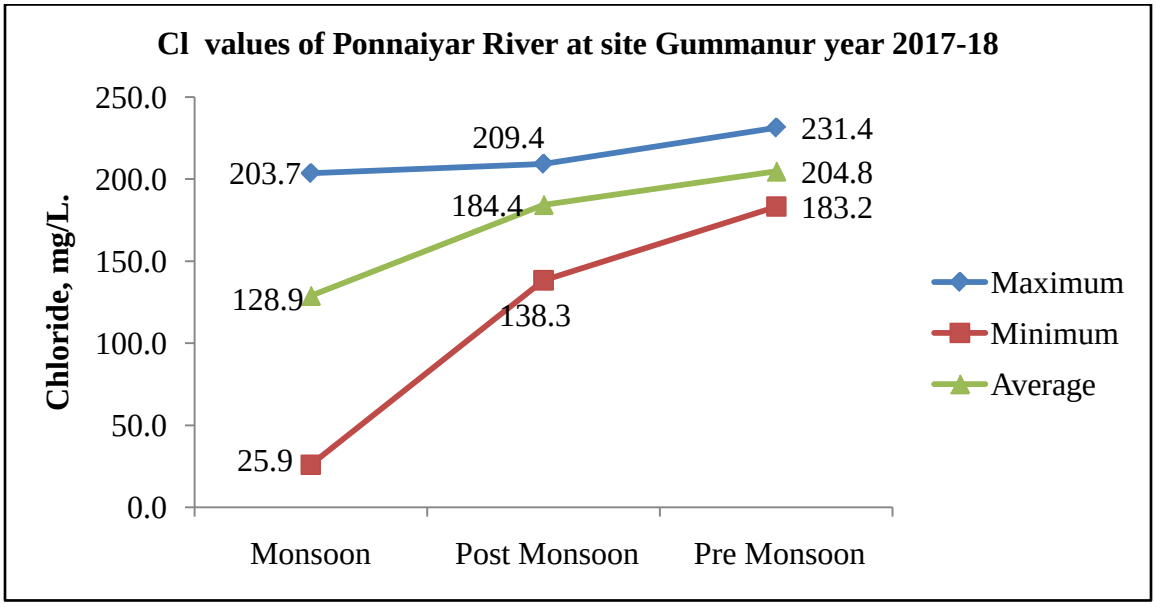


Figure-2.2

8. Nitrate:

Nitrate is nutrient parameter essential for agricultural purposes but in excess caused by the discharge of sewage, industrial wastes and run off from agricultural fields it causes pollution. The Nitrate in the river at site Gummanur during monsoon was in the range from 0.2 to 27.7 mg/l with mean of 13.1 mg/l. During post monsoon season at Gummanur Nitrate value ranges from 7.6 to 35.6 mg/l with mean of 22.2 mg/l. However during pre monsoon, the Nitrate values at site Gummanur are ranging from 12.9 to 18.9 mg/l with a mean of 16.0 mg/l. This shows that the Nitrate mean values at Gummanur during post monsoon are slightly more than class-A limits but within the tolerance limits for other classes as per (BIS: 2296-1982) standards.

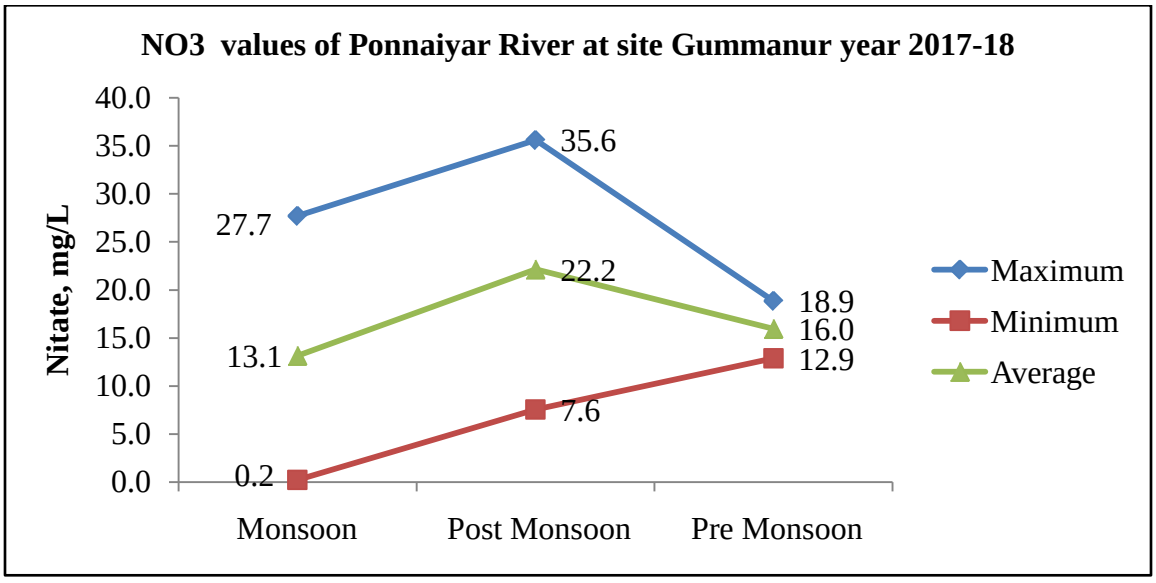


Figure-2.3

9. Fluoride:

Fluoride is fairly distributed in river and ground water and its presence beyond certain limit for drinking purpose causes fluorosis, a health hazard. The Fluoride in the river at site Gummanur during monsoon ranges from 0.2 to 0.5mg/l with mean of 0.4 mg/l. Similarly, during post monsoon season Fluoride value ranges from 0.3 to 0.8 mg/l with mean of 0.6 mg/l. However, during pre monsoon, the Fluoride value at Gummanur ranging from 0.4 to 0.9 mg/l with a mean of 0.6 mg/l. This shows that fluoride mean values in the Ponnaiyar River are within the tolerance limits of BIS: 2296-1982 standards i.e. suitable for all the classes.

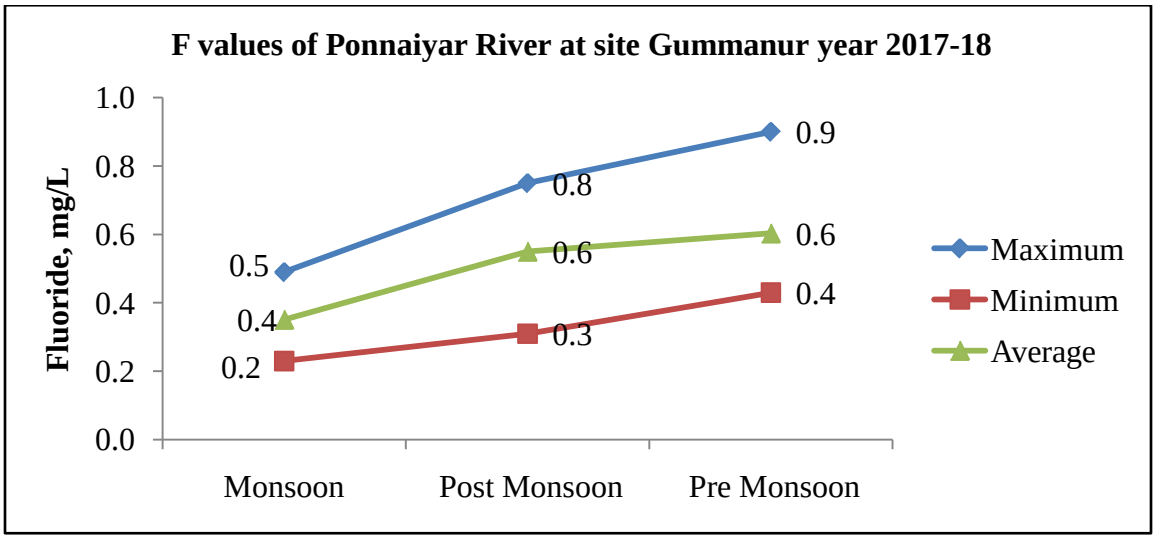


Figure-2.4

Conclusions:

From the discussion on the above details of seasonal variation of the physicochemical parameters of surface water samples collected at site Gummanur on Ponnaiyar River for the year 2017-18, it was found that the river in the upper reach i.e.at Gummanur is slightly polluted. It is also noted that the concentration of parameters are related to the river discharge i.e. higher the discharge, lower the concentration and vice versa. Even though the water in upper reach of Ponnaiyar Basin at Gummanur is slightly polluted with higher BOD values, other WQ parameters of the river in general is normal as pH, Fluoride, and DO values etc, within the tolerance limits of BIS. However, during pre-monsoon season the EC was very high which may be due to lean flow. Human activities like bathing, washing, discharging of sewage waste and religious activities along the stretch are the possible causes of pollution if any. Hence it is concluded that except BOD in the upper reach of the river, WQ scenario in this basin is found to be free from any serious pollution issue.

Note: As per the CWC Water year, the monsoon period is from June to October, whereas in the Southern India, monsoon for the East Flowing Rivers starts from August ends in middle of December.

5.0 References:

1. Water Quality Year Books for the years from 2017 to 2018 published by C&SRO, CWC, Coimbatore.
2. Water Quality Manual of Hydrology project.
3. Tolerance limit relating to selected pollution parameters for inland surface waters required for different uses as prescribed by the Bureau of Indian Standards (BIS: 2296-1982).

Annexure-1

Table-4: Tolerance limit relating to selected pollution parameters for inland surface waters required for different uses as prescribed by the Bureau of Indian Standards (BIS: 2296-1982)

Sl. No	Constituents	Unit	Designated use class of inland surface water				
			A	B	C	D	E
1	pH		6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.0-8.5
2	EC at 25°C	µS/cm,Max	-	-	-	1000	2250
3	DO	mg/L, Min	6	5	4	4	-
4	BOD	mg/L, Max	2	3	3	-	-
5	Total coliform organism	MPN/100 ml, Max	50*	500*	5000*	-	-
6	Colour,	Hazen units, Max	10	300	300	-	-
7	Odour		Un-objectional	-	-	-	-
8	Taste		Tasteless	-	-	-	-
9	Total dissolved solids	mg/L, Max	500	-	1500	-	2100
10	Total Hardness	as $CaCO_3$, mg/L, Max	300	-	-	-	-
11	Calcium hardness	as $CaCO_3$, mg/L, Max	200	-	-		-
12	Magnesium	as $CaCO_3$, mg/L, Max	100	-	-	-	-
13	Iron	as Fe, mg/L, Max	0.3	-	50	-	-
14	Chloride	as Cl, mg/L, Max	250	-	600	-	600
15	Fluoride	as F, mg/L, Max	1.5	1.5	1.5	-	-
16	Sulphate	as SO_4,mg/L, Max	400	-	400	-	1000
17	Nitrate	as NO_3, mg/L, Max	20	-	50	-	-
18	Free Ammonia	as N, mg/L, Max	-	-	-	1.2	-
19	Arsenic	as As, mg/L, Max	0.05	0.2	0.2	-	-
20	Boron	as B, mg/L, Max	-	-	-	-	2
21	Cadmium	as Cd, mg/L, Max	0.01	-	0.01	-	-
22	Chromium	as Cr^{6+}, mg/L, Max	0.05	0.05	0.05	-	-
23	Copper	as Cu, mg/L, Max	1.5	-	1.50	-	-
24	Cyanide	as CN, mg/L, Max	0.05	0.05	0.05	-	-
25	Lead	as Pb, mg/L, Max	0.1	-	0.10	-	-
26	Manganese	as Mn, mg/L, Max	0.5	-	-	-	-
27	Mercury	as Hg mg/L, Max	0.001	-	-	-	-
28	Zinc	as Zn, mg/L, Max	15	-	15	-	-
29	Pesticides		Absent	-	Absent	-	-
30	Free carbon dioxide	as CO_2, mg/L, Max	-	-	-	6	-
31	Phenolic compound	asC_6H_5OH,mg/L,Max	0.002	0.005	0.005	-	-
32	Sodium percent,	Max	-	-	-	-	60
33	SAR	Max	-	-	-	-	26

A Drinking water source without conventional treatment but after disinfections

B Outdoor bathing-organised

C Drinking water source with conventional treatment followed by disinfections

D Propagation of wildlife, fisheries

E Irrigation, industrial cooling and controlled waste disposal

*** If the coliform count is more than the prescribed tolerance limit, the criteria for coliform shall be satisfied if not more than 20% of samples show more than the tolerance limit specified and not more than 5% of samples show more than 4 times the tolerance limit. Further, the faecal coliform should not be more than 40% of the total coliform.**

STUDY OF WATER QUALITY PARAMETERS OF GODAVABARI RIVER AT BHADRACHALAM

GODAVARI RIVER ORIGIN AT TRIYAMBKESHWAR, NASIK

GODAVABARI RIVER AT BHADRACHALAM

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Upper Godavari Division, Central Water Commission
Hyderabad

Table of Contents

1. INTRODUCTION

1.1 Godavari River System

The river Godavari, the largest of the peninsular rivers, and third largest in India, drains about 10% of India's total geographical area. The catchment area of the river is 3, 12,812 sq.km. and is spread in the states of Maharashtra (48.8%), Andhra Pradesh (3.7%), Telangana (20%), Madhya Pradesh (7.9%), Chhattisgarh (12.4%), Orissa (5.7%) and Karnataka (1.5%). The basin lies in the Deccan plateau and is situated between latitude 16^0 16' 00" North and 22^0 36' 00" North and longitude 73^0 26' 00" East and 83^0 07' 00" East.

The river Godavari rises at an elevation of 1,067 m in the Western Ghats near Triyambak Hills in the Nasik district of Maharashtra. After flowing for about 1,465 km., in a generally south-east direction, it falls into the Bay of Bengal.

About 64 km. from its source, the Godavari receives the waters from Dharna, on its right bank and a short distance downstream the Kadana joins it from the left. The combined waters of the Pravara and Mula which rise in the hills of Akola join the river from left about 217 km. from its source. About 338 km. from its source, the river receives the combined waters from the Purna and Dudhna rivers and after a further 138 km. at the border of Maharashtra and Telangana, the waters of the Manjira river joins it from the South. At this point, Godavari flows at an elevation of about 329 m.

The river Pranhita, conveying the combined waters of Penganga, the Wardha and Wainganga, which drain Nagpur and southern slopes of the Satpura ranges, falls into Godavari about 306 km below its confluence with the Manjira. The waters of the Indravathi join the river Godavari 48 km downstream. The last major tributary is the Sabari from Orissa, which joins the Godavari, 100 km. up-stream of Rajahmundry.

The largest tributary of the Godavari is the Pranhita with about 34.87% coverage of drainage area. The Pravara, Manjira and Maner are right bank tributaries covering about 16.14%, the Purna, Pranhita, Indravathi and Sabari are important left bank tributaries, covering nearly 59.7% of the total catchment area of the basin. The Godavari in the upper, middle, and lower reaches make up for the balance 24.16%. The particulars of the catchment area, length, elevation of the source points of the river and its tributaries in the order of their occurrence along the length of the main river were indicated in the Table-1.

Table - 1 Important Tributaries of Godavari River

S. No.	Name of the River	Elevation of Source	Length of Tributary (km)	Catchment area (sq.km.)	Average annual rainfall (mm)
1	Upper Godavari (source to Manjira confluence)	1,067	675	33502	770
2	Pravara	1,050	208	6537	606
3	Purna	838	373	15579	797
4	Manjira	823	724	30844	846
5	Middle Godavari (between confluence points Manjira and Pranhita)	323	328	17205	955
6	Maner	533	225	13106	932
7	Penganga	686	676	23898	960
8	Wardha	777	483	24087	1055
9	Pranhita	640	721	61093	1363
10	Lower Godavari (Pranhita confluence to sea)	107	462	24869	1208
11	Indravathi	914	535	41665	1588
12	Sabari	1,372	418	20427	1433
			Total	312812	

2. Study Areas:

Water Quality Site description and sample collection:

Central water Commission was monitoring water quality at site Bhadrachalam Godavari River under Bhadrachalam sub-division control of Lower Godavari Division, Hyderabad. Surface water samples were collected from river Godavari at site Bhadrachalam which lies at latitude 17°39'57" and longitude 80°53'02". This site is designated as Trend station due to influence of human activity. So water quality is monitored twelve times in a year. Water samples from the site were collected in one plastic bottle for analysis of physicochemical parameters and in sterile glass bottles for DO & BOD analysis and transported to the laboratory in ice-boxes, processed within 1-4 hrs. and stored at 4-5°C for further analysis.

Following Physicochemical properties were studied pH, Electrical Conductivity, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand and Fluoride of water samples data is considered for study the water Quality seasonal Average from period 2014-15 to 2018-2019 annually. Water quality year commences from 1st June of the calendar year and extends to 31st May of the next calendar and covers one complete hydrological cycle. Every water quality year is split in to three seasons as Flood, Winter and Summer of which average values are extracted to predict the water quality. Flood season covers from June to October, Winter seasons covers from November to February and Summer season covers from March to May of one cycle/year.

3. Water Quality Standards:

The Physico-chemical parameters like pH, Electrical Conductance, Dissolved Oxygen and Bio-chemical Oxygen Demand, Chemical Oxygen Demand and Fluoride are main constituents defining the quality of river water in surface water. Presence of these parameters in river water beyond the permissible limit is considered as polluted river water quality. CPCB has identified water quality requirements in terms of a few chemical characteristics, known as primary water quality criteria (Table 2).

Further, Bureau of Indian Standards (BIS) known as Indian Standard Institute (ISI) vide its document BIS 10500:2012 has recommended water quality standards for drinking water (Table 3).

Table 2: Designated Best Uses of Water by CPCB

Designated Best Use	Class	Criteria
Drinking Water Source without conventional treatment but after disinfection	**A**	1. Total Coliforms Organism MPN/100 ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6 mg/L or more 4. Biochemical Oxygen Demand 5 days 20 °C, 2 mg/L or less
Outdoor bathing (Organized)	**B**	1. Total Coliforms Organism MPN/100 ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5 mg/L or more 4. Biochemical Oxygen Demand 5 days 20 °C, 3 mg/L or less
Drinking water source after conventional treatment and disinfection	**C**	1. Total Coliforms Organism MPN/100 ml shall be 5000 or less 2. pH between 6 and 9 3. Dissolved Oxygen 4 mg/L or more 4. Biochemical Oxygen Demand 5 days 20 °C, 3 mg/L or less
Propagation of Wild life and Fisheries	**D**	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4 mg/L or more 3. Free Ammonia (as N) 1.2 mg/L or less
Irrigation, Industrial Cooling, Controlled Waste disposal	**E**	1. pH between 6.0 and 8.5 2. Electrical Conductivity at 25 °C micro mhos/cm, maximum 2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2 mg/L
	Below-E	Not meeting any of the A, B, C, D & E criteria

Table 3: Drinking Water Quality Standards, BIS: 10500, 2012*

S. No.	Characteristic	Requirement (Acceptable Limit)	Permissible limit in the absence of Alternate source
Essential Characteristics			
1	Color, Hazen units, Max	5	15
2	Odor	Agreeable	Agreeable
3	Taste	Agreeable	Agreeable
4	Turbidity NTU, Max	1	5
5	pH Value	6.5 -8.5	No relaxation
6	Total Hardness (as $CaCO_3$) mg/L, Max.	200	600
7	Iron (as Fe), mg/L, Max	0.3	No relaxation
8	Chlorides (as Cl), mg/L, Max	250	1000
9	Residual free chlorine, mg/L, Minimum	0.2	1.0
Desirable Characteristics			
10	Total Dissolved solids, mg/L, Max	500	2000
11	Calcium (as Ca) mg/L, Max.	75	200
12	Magnesium (as Mg) mg/L, Max	30	100
13	Copper (as Cu), mg/L, Max	0.05	1.5
14	Manganese (as Mn) mg/L, Max	0.1	0.3
15	Sulphates (as SO_4), mg/L, Max	200	400
16	Nitrate (as NO_3) mg/L, Max.	45	No relaxation
17	Fluorides (as F), mg/L, Max	1	1.5
18	Ammonia (as total ammonia-N) mg/L	0.5	No relaxation
19	Mercury (as Hg), mg/L, Max	0.001	No relaxation
20	Cadmium (as Cd), mg/L, Max	0.003	No relaxation
21	Selenium (as Se), mg/L, Max	0.01	No relaxation
22	Total Arsenic (as As), mg/L, Max	0.01	No relaxation
23	Cyanides (as CN), mg/L, Max	0.05	No relaxation
24	Lead (as Pb), mg/L, Max	0.01	No relaxation
25	Zinc (as Zn), mg/L, Max	5	15
26	Total Chromium (as Cr), mg/L, Max	0.05	No relaxation
27	Total Alkalinity mg/L, Max	200	600
28	Aluminum (as Al) mg/L, Max	0.03	0.2
29	Boron mg/L, Max	0.5	1.0
30	Mineral oil, mg/L, Max	0.5	
31	Poly Nuclear Aromatic Hydrocarbons, PAH's, mg/L, Max	0.0001	No relaxation
32	Anionic detergents (as MBAS), mg/L, Max	0.2	1
33	Total Coliform	Shall not be detected in any 100 of sample	
36	Phenolic Compounds, mg/L, Max	0.001	0.002

**** Limits have been given for specific parameters only as per Drinking Water Quality Standards, BIS: 10500, 2012.***

4. Results and Discussions:

The water samples were analyzed for physicochemical characteristics. The physicochemical parameters were analyzed namely, pH, EC, DO, BOD, COD and Fluoride are presented.

Table 4: List of physicochemical parameters and their test methods

S. No.	Parameters	Unit	Method used
1.	pH		pH meter
2	Electrical Conductivity	µs/cm	Conductivity meter
3.	Dissolved Oxygen (DO)	mg/l	Winkler method
4.	Biochemical Oxygen Demand (BOD)	mg/l	5 days incubation at 20° C and titration of initial and final DO
5.	Chemical Oxygen Demand	mg/l	Open Reflux Method
6.	Fluoride	mg/l	Ion Selective Method

Table 5: Seasonal average values of physicochemical parameters studied at site BHADRACHALAM River Godavari

SEASON	PARAMETER	2014-15	2015-16	2016-17	2017-18	2018-19
Flood	pH	7.8	7.7	8.3	7.8	8.2
	EC (µS/cm)	753	210	218	191	237
	DO (mg/l)	6.1	-	5.9	6.5	6.5
	BOD (mg/l)	0.9	1.0	0.9	0.8	1.6
	COD (mg/l)	8.7	10.1	8.9	17.8	9.0
	F (mg/l)	0.42	0.22	0.16	0.19	0.23
WINTER	pH	8.1	8.4	8.5	8.1	8.1
	EC (µS/cm)	253	548	269	250	356
	DO (mg/l)	7.7	7.1	-	8.3	7.4
	BOD (mg/l)	0.8	0.7	1.6	1.6	1.1
	COD (mg/l)	5.0	3.9	6.1	7.2	6.3
	F (mg/l)	0.28	0.20	0.36	0.22	0.30
SUMMER	pH	8.2	8.5	8.4	8.3	8.1
	EC (µS/cm)	357	494	306	315	325
	DO (mg/l)	5.8	6.4	-	6.5	7.7
	BOD (mg/l)	0.7	1.5	1.1	1.7	1.0
	COD (mg/l)	4.1	2.3	7.0	17.8	6.3
	F (mg/l)	0.39	0.29	0.40	0.50	0.28

(1) pH: The pH values of the samples ranged from 7.7-8.5, where most of the water samples of all seasons tested in the study were found to be in the permissible range of pH value recommended by several health and pollution control organizations e.g. WHO, CPCB, BIS i.e. 6.5-8.5. The pH of Godavari River was showing alkaline character throughout the study period (2014-2019) in all seasons (Figure 1).

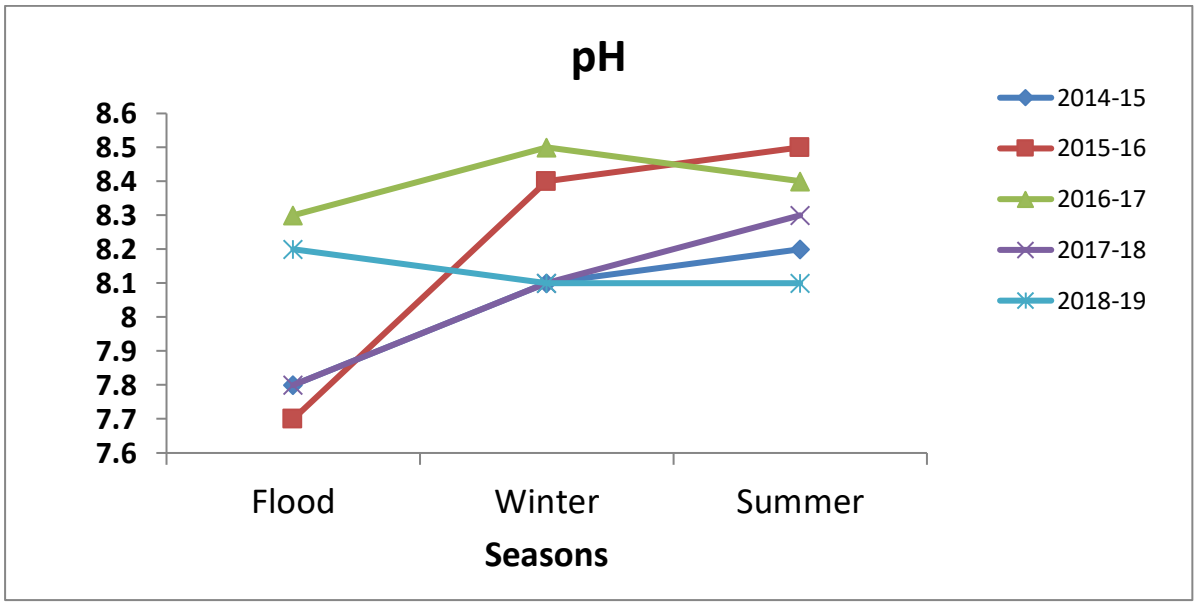

Figure 1: Seasonal Variation of pH values for the period 2014-15 to 2018-2019 at site BHADRACHALAM

(2) **Electrical conductivity:** Electrical conductivity usually used for indicating the total concentration of ionized constituents of water. Electric conductivity is varying much having highest Average value 753 µS/cm in winter season of water Quality year 2014-15 was recorded (Figure 2).

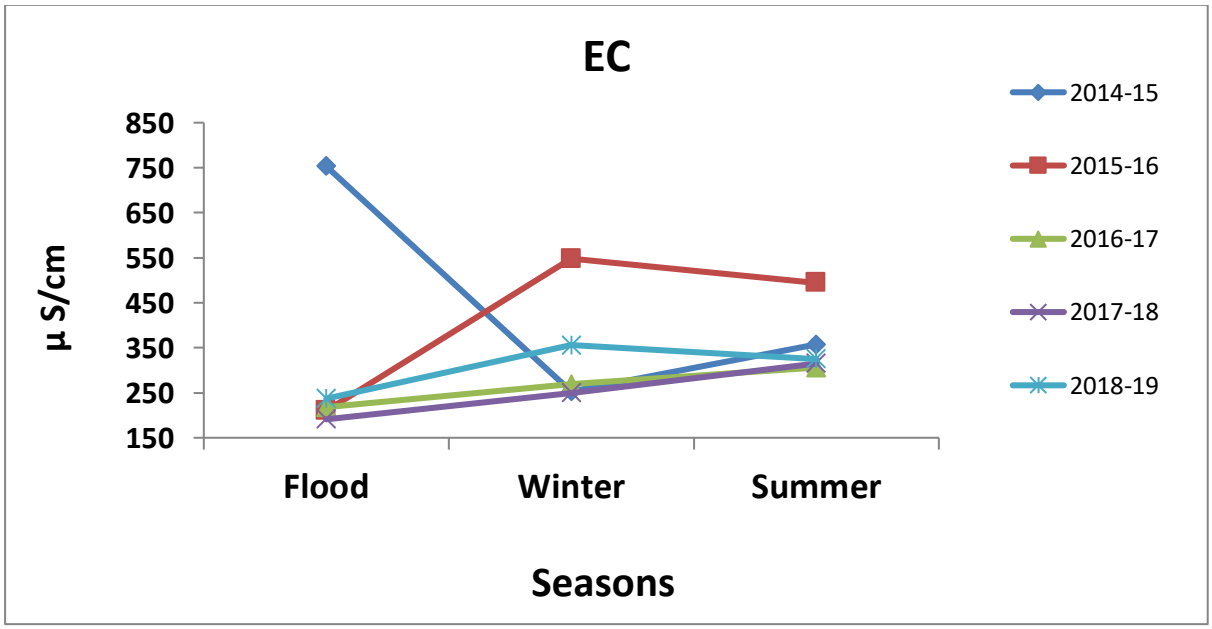

Figure 2: Seasonal Variation of E C values for the period 2014-15 to 2018-2019 at site BHADRACHALAM

(3.) Dissolved oxygen (DO):

The dissolved oxygen content is one of the most important factors in stream health. Its deficiency directly affects the ecosystem of a river due to bioaccumulation and biomagnifications. The oxygen content in water samples depends on a number of physical, chemical, biological and microbiological processes. DO values also show lateral, spatial and seasonal changes depending on industrial, human and thermal activity in the present study, the value of DO ranged from 5.9 – 8.3 mg/l respectively. As the DO values at all seasons are in desirable limit and can use for drinking water source after disinfection as it meets the **class A** designated use of water by CPCB.

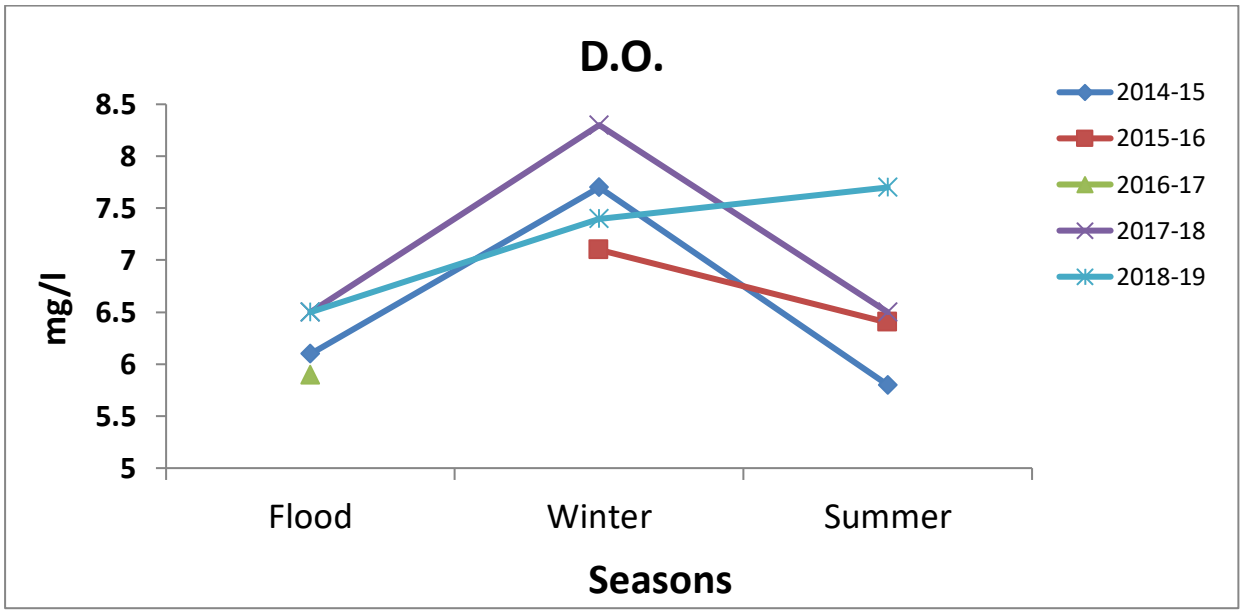

Figure 3: Seasonal Variation of D.O. values for the period 2014-15 to 2018-2019 at site BHADRACHALAM

(4) Biochemical Oxygen Demand (BOD):

BOD is a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in the water and increases the biochemical oxygen demand. The Average value for BOD was found to be maximum 8.3 mg/l in Flood season of water quality year 2017-18 shown in Figure 4.

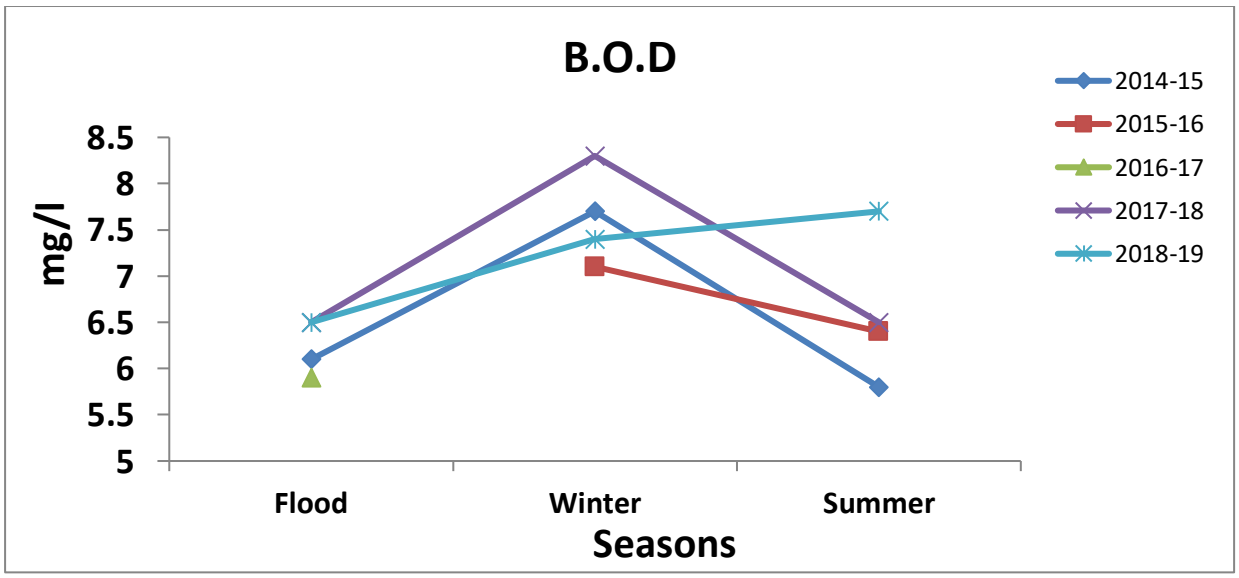

Figure 4: Seasonal Variation of B. O. D. values for the period 2014-15 to 2018-2019 at site BHADRACHALAM

(5) Chemical Oxygen Demand (COD):

BOD is a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in the water and increases the biochemical oxygen demand. The Average value for BOD was found to be maximum 17.8 mg/l in Flood season of water quality year 2017-18 shown in Figure 5.

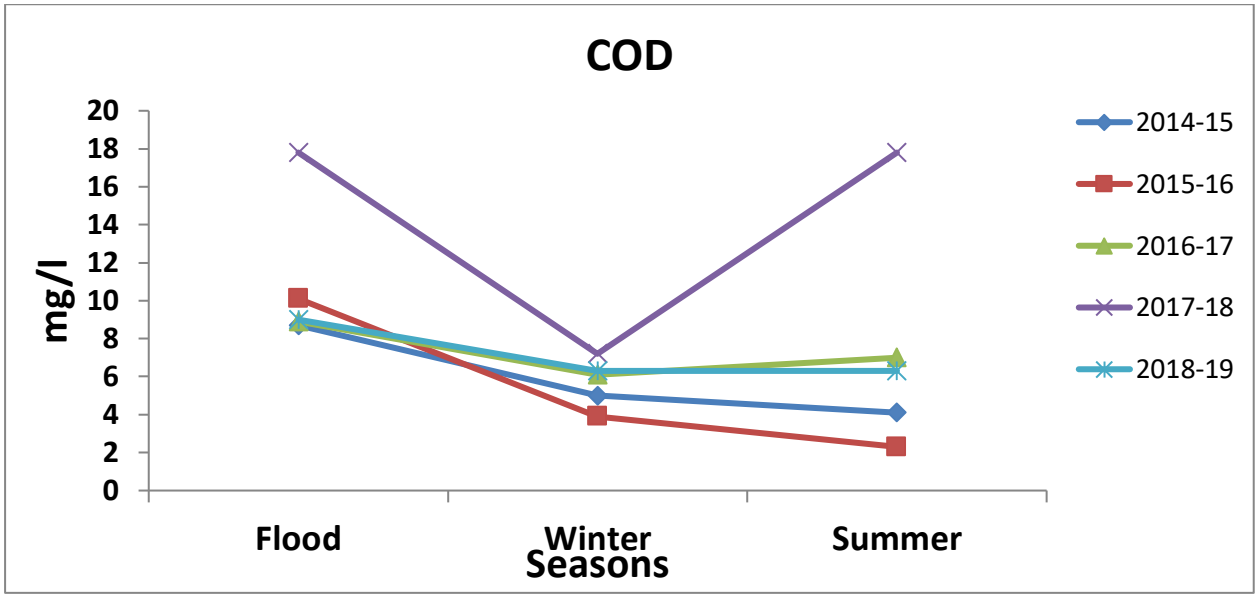

Figure 5: Seasonal Variation of C. O. D. values for the period 2014-15 to 2018-2019 at site BHADRACHALAM

(6) Fluoride: Fluoride originates from the weathering of fluoride-containing minerals and enters surface waters with run-off waste from certain industrial processes (such as metal-and chemical-based manufacturing). The Fluoride levels recorded during the study are presented in Table: 5 and its monthly variations are shown in Fig: 6. Measurement of fluoride content is especially important when a water body is used for drinking water supply. At high concentrations fluoride is toxic to humans and animals and can cause bone diseases. The maximum tolerance limits of Fluoride as per IS 2296-1982 for class A waters is 1.5 mg/L. The average seasonal variation in Fluoride concentration represents no significant change in Godavari River at BHADRACHALAM site and falls in **Class A**.

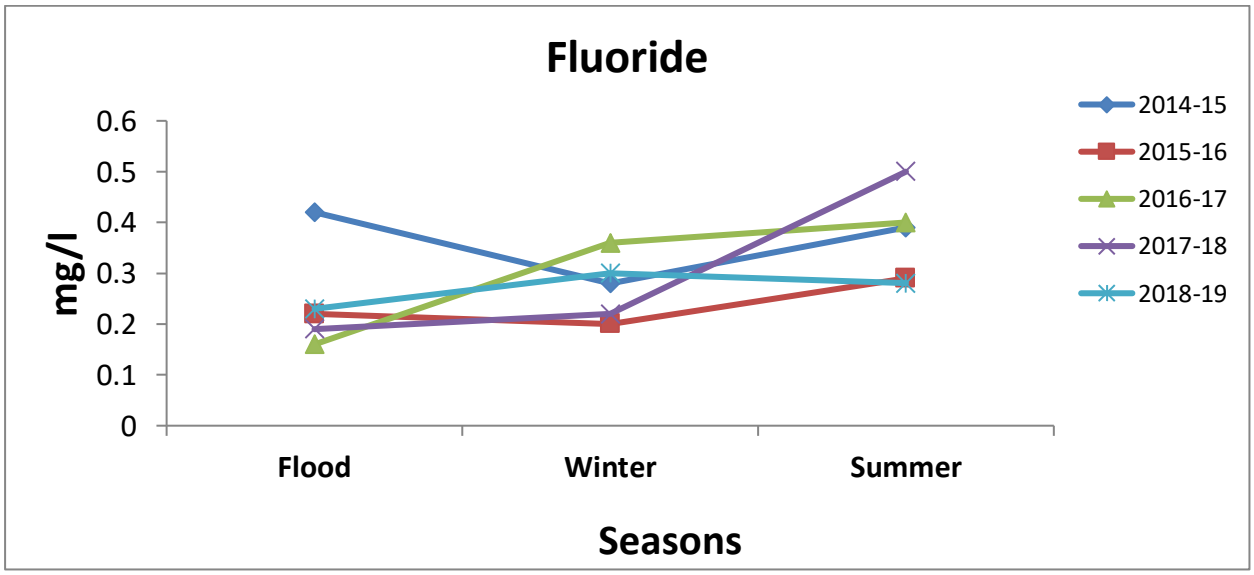

Figure 6: Seasonal Variation of FLUORIDE values for the period 2014-15 to 2018-2019 at site BHADRACHALAM

5. Conclusion:

- The seasonal average values indicate that during flood season, river water is more affected than during winter & summer. This could be due to the fact that the microbial activity gets increased thereby keeping DO level at a very satisfactory range during entire flood season.
- The seasonal average values show that the Godavari River waters are bacteriologically safe and suitable for growth of any type of crops in general.
- The water quality of Godavari River indicates that pH and conductivity are meeting the desired water quality criteria.
- Water quality seasonal average results clearly showed that above water quality parameters studied are within the permissible limit in all seasons since 5 years.
- To sustaining the desired level of water quality of Godavari River and stretches the municipalities and industries need to treat their wastewater and effluent before discharging.

MINISTRY OF JAL SHAKTI
GOVERNMENT OF INDIA

KRISHNA & GODAVARI BASIN ORGANISATION

CENTRAL WATER COMMISSION

HYDERABAD

STUDY OF WATER QUALITY PARAMETERS ON INDRAVATHI RIVER

By

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Upper Godavari Division
KGRWQL

Indravati River

The Indravati River is a stream of the river Godavari. Its starting point, found to be the Ghats of Dandakaranya, range from a hilltop village Mardiguda of Thuamula Rampur Block in the Kalahandi district of the state of Odisha. Due to the amalgamation of three streams, The River follows a westerly path and enters Jagadalpur in the state of Chhattisgarh. The river moves from here in a southern route, before eventually uniting with the Godavari at the borders of three states. They are the state of Chhattisgarh, Maharashtra and Telangana. The river at a variety of stages of its course forms the boundary between Chhattisgarh and Maharashtra. The river Indravati is also known as the oxygen of the Bastar district of state of Chhattisgarh. This district is one of the greenest and eco-friendly districts, found in the whole of India.

Water Quality Monitoring Network at present:

At present, Central Water Commission providing analytical facilities for the analysis of river water samples collected from 3 water quality monitoring stations belonging to Indravathi River.

CLASSIFICATION OF WATER QUALITY MONITORING STATIONS:

The three tier laboratory system consists of:

In accordance with the definition given in the "Uniform Protocol on Water Quality Monitoring Notification" 2005, subsequently updated during 2017, available at CPCB website (http://cpcb.nic.in/wqm/Guidelines_Water_Quality_Monitoring_2017.pdf) water quality monitoring stations are classified as follows:

1. Baseline stations: Baseline stations mean the monitoring location where there is no influence of human activities on water quality.

2. Trend stations: "Trend station" means the monitoring location designed to show how a particular point on a watercourse varies over time due, normally, to the influence of man's activities.

3. Flux stations or Impact stations: "Flux stations or Impact stations" means the location for measuring the mass of particular pollutant on Main River stem for measuring the extent of pollution due to human interference or geological feature at any point of time and are necessary for measuring impact of pollution control measures adopted.

As per above protocol 'Indravathi river falls under Baseline stations, since there is no influence of human activities on water quality'.

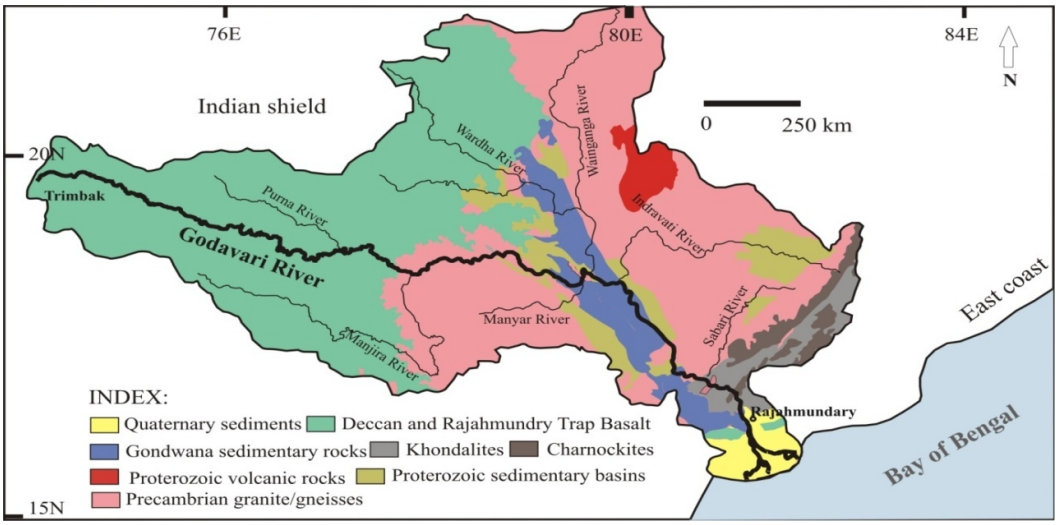


Figure : River stretch of Godavari Basin

Site description and sample collection:

Central water Commission was monitoring water quality at sites on Indravathi river since 1964 under ISD Jagdalpur sub-division control of Lower Godavari Division Hyderabad. Surface water samples were collected from river Indravathi at site Jagdalpur, Nowragpur & Pathagudem. This site is designated as Trend station due to influence of human activity. So water quality is monitored twelve times in a year. Water samples from the site were collected in one plastic bottle for analysis of physicochemical parameters and in sterile glass bottles for DO & BOD analysis and transported to the laboratory in ice-boxes, processed within 1-4 hrs and stored at 4-5°C for further analysis.

Present study focused on:

Following Physicochemical properties were studied pH, Electrical Conductivity, Dissolved Oxygen, Biochemical Oxygen Demand & TDS of water samples data is considered for study the water Quality seasonal Average from 2010-2020 period annually. Water quality year commences from 1st June of the calendar year and extends to 31st may of the next calendar and covers one complete hydrological cycle. Every water quality year is split in to three seasons as Flood, winter and summer of which average values are extracted to predict the water quality. Flood seasons covers from June to October, winter seasons covers from November to February and summer season covers from March to May of one cycle/year.

Results and Discussions:

The water samples were analyzed for physicochemical characteristics. The physicochemical parameters were analyzed namely, pH, EC, DO, BOD5& TDS are presented.

The instrumental methods, the relevant parameters analyzed and instruments used are given here under.

S. No.	Method	Parameter analyzed	Instrument used
1	Conductometric method	Electrical Conductance	Digital Conductivity meter
2	Potentiometric method	pH	Digital pH meter
3	Gravimetric method	Total dissolved solids	Hot Air oven for total dryness at 180ºC
4	Winkler Method (Titrimetric)	Dissolved Oxygen	Digital Burette
5		Biological Oxygen Demand	Digital Burette

Seasonal Variation of Electrical Conductivity on Indravathi River:

Conductivity or electrical conductivity (EC) of natural water is due to the presence of salts, which dissociate into cations and anions. It is the ability of a solution to conduct current. The units of EC are µmhos/cm or µS/cm and is expressed at 25°C. Even in cases where the chemical composition of water is represented almost exclusively by inorganic ions, the correlation between their content and EC may change considerably since different ions conduct electricity to different extents.

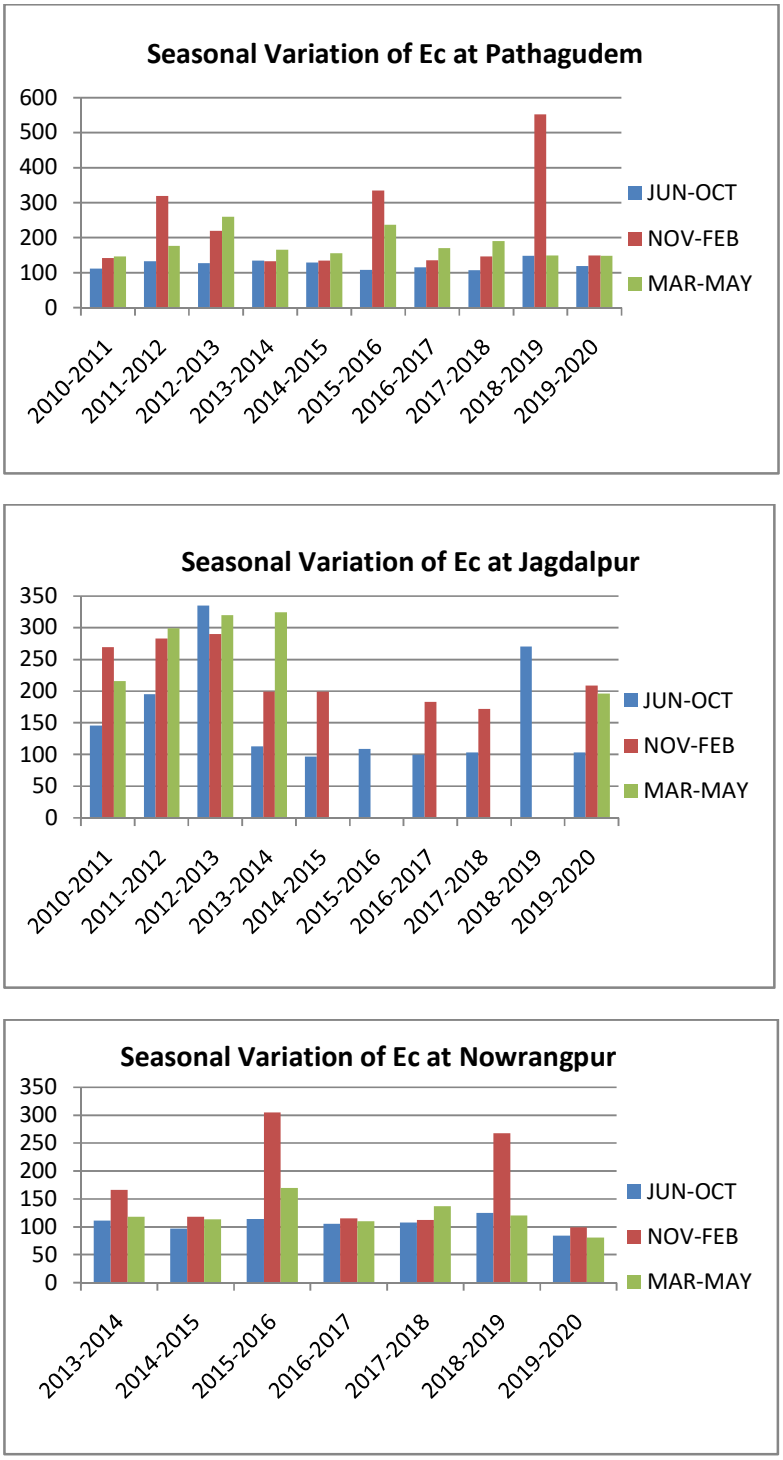


Figure 1: Average Seasonal Variation of Ec values for the sites present on river Indravathi

Seasonal Variation of pH on Indravathi River:

The hydrogen ion concentration in water is expressed in terms of pH. The pH value of natural waters mostly depends on free carbon dioxide, bicarbonates and carbonate ions. The pH value is also affected by the presence of naturally present humic substances and various acids and alkalis, which may be discharged into the body of water through wastes. Alkalinity and acidity are related parameters, which reflect the capacity of a water sample to neutralise acid or alkalinity, respectively.

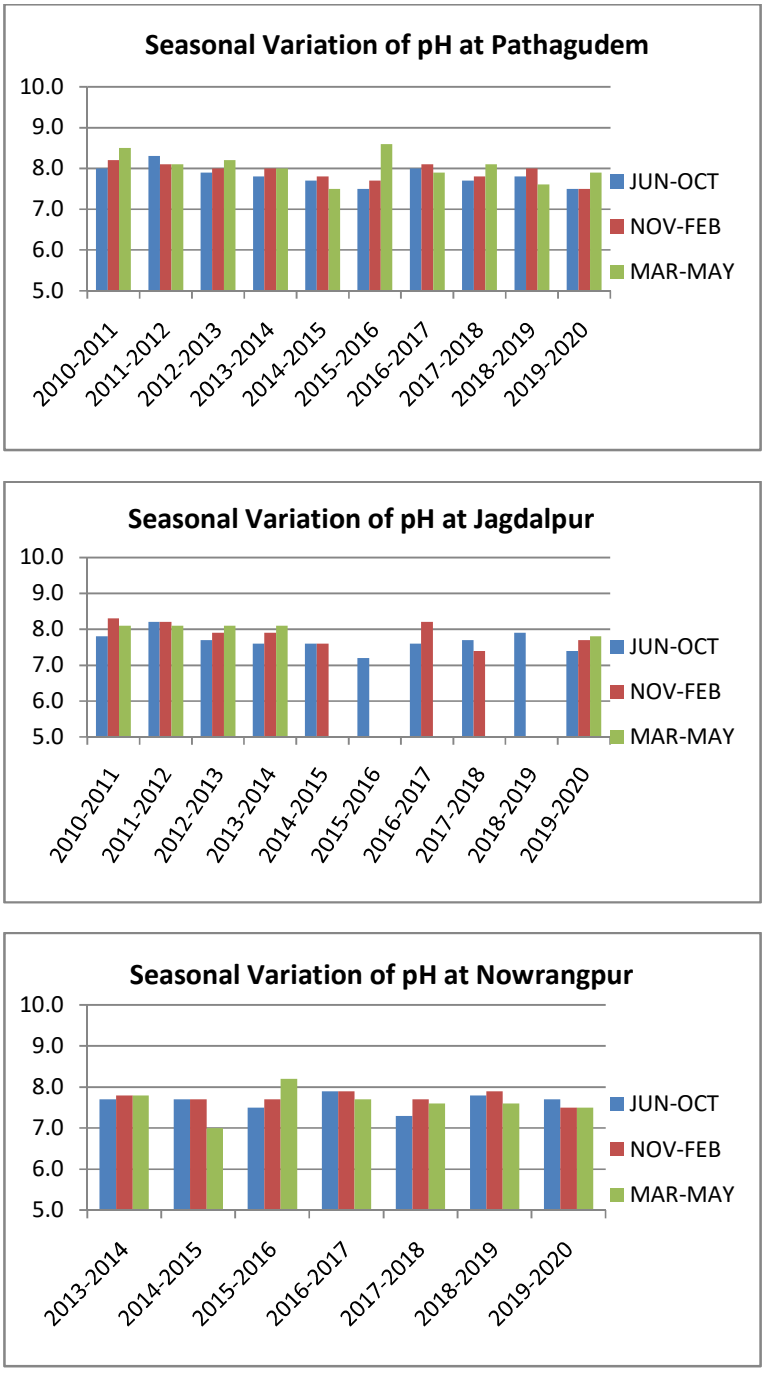
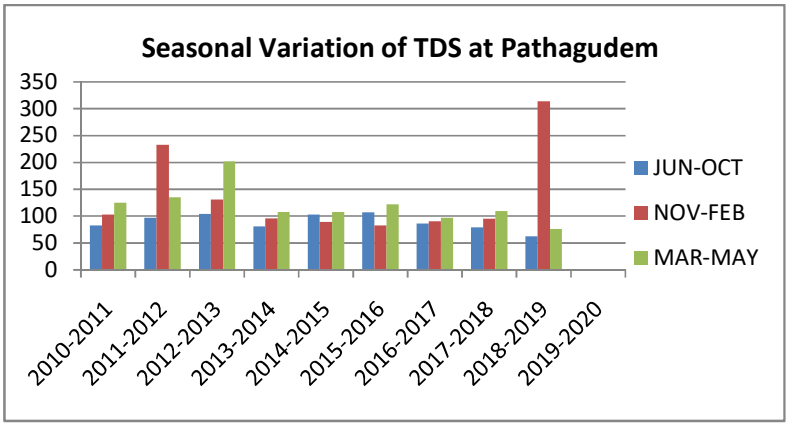
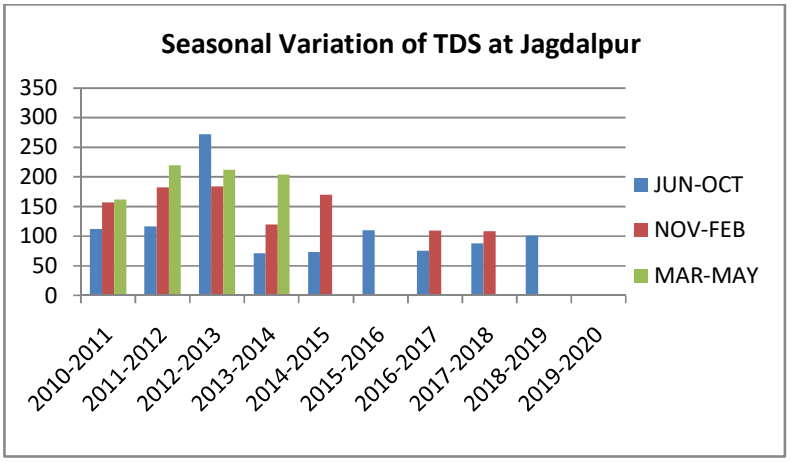


Figure 2: Average Seasonal Variation of pH values for the sites present on river Indravathi

Seasonal Variation of TDS on Indravathi River:

Total dissolved solids (TDS) refer to the residue left after evaporation of a known volume of water at 105°C, which has been filtered through a standard filter. It is approximately equal to the total content of dissolved substances in a water sample since approximately half of the bicarbonate ion, which is one of the dominant ions in waters, is lost as Co_2 during evaporation process. The levels of TDS are less than 500 mg/l, which falls under class-A as per BIS (BIS: 2296-1982).





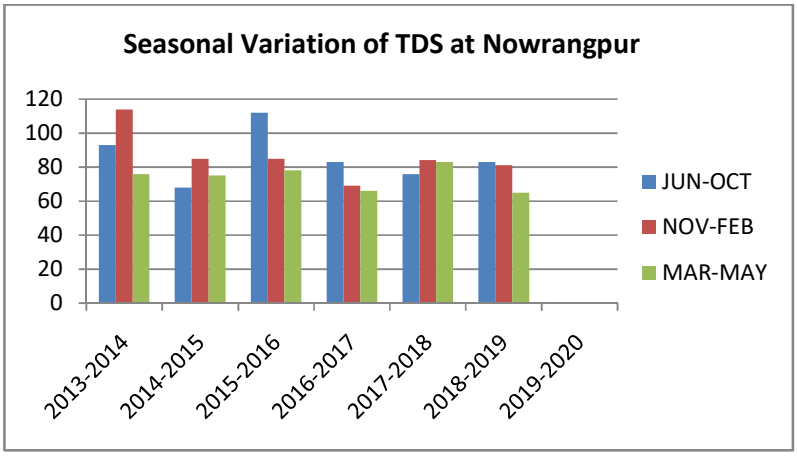


Figure 3: Average Seasonal Variation of TDS values for the sites present on river Indravathi

Seasonal Variation of DO on Indravathi River:

The dissolved oxygen content is one of the most important factors in stream health. Its deficiency directly affects the ecosystem of a river due to bioaccumulation and biomagnifications. The oxygen content in water samples depends on a number of physical, chemical, biological and microbiological processes. DO values also show lateral, spatial and seasonal changes depending on industrial, human and thermal activity. In the present study, the value of DO ranged from 5.0 – 8.0 mg/l respectively.

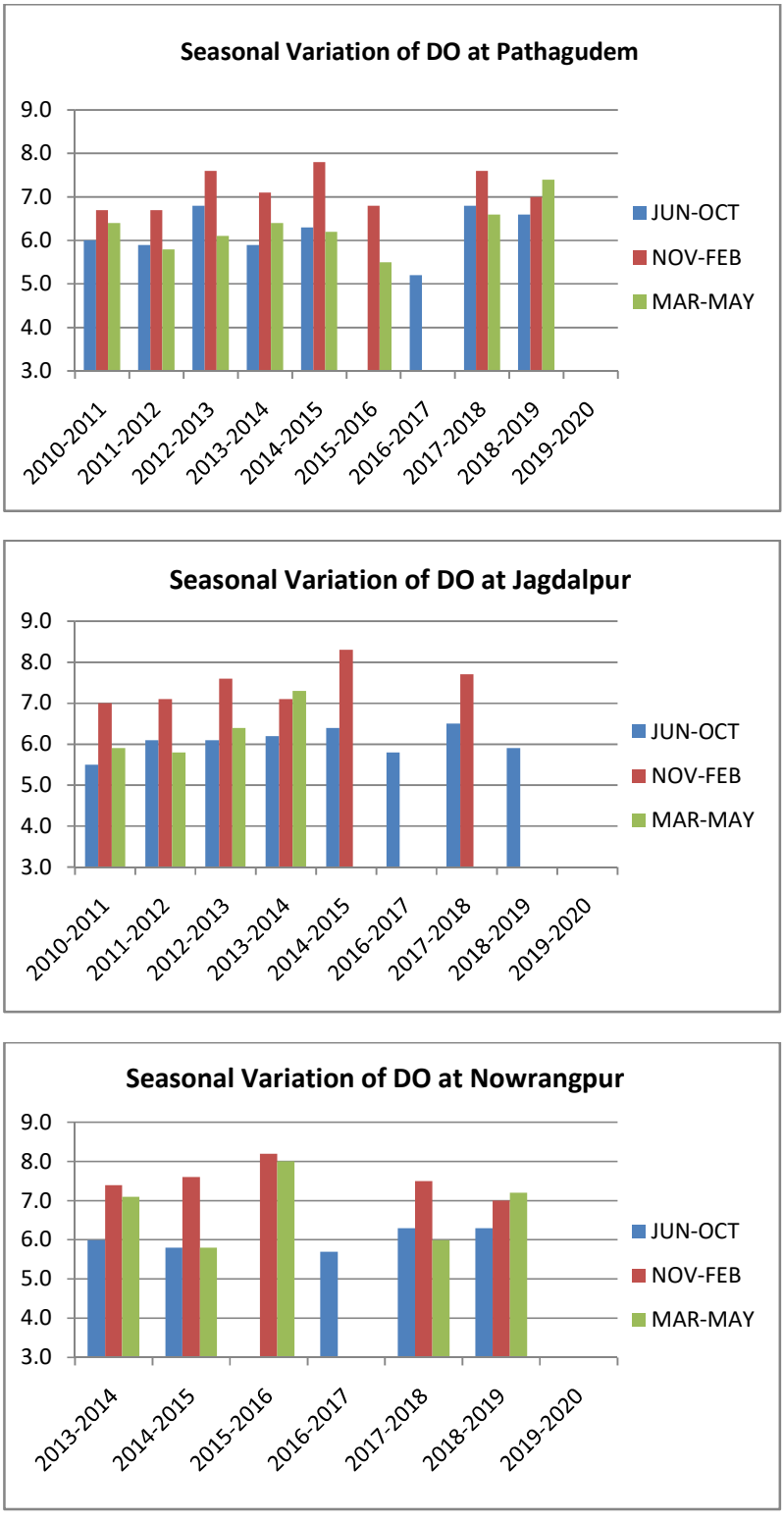
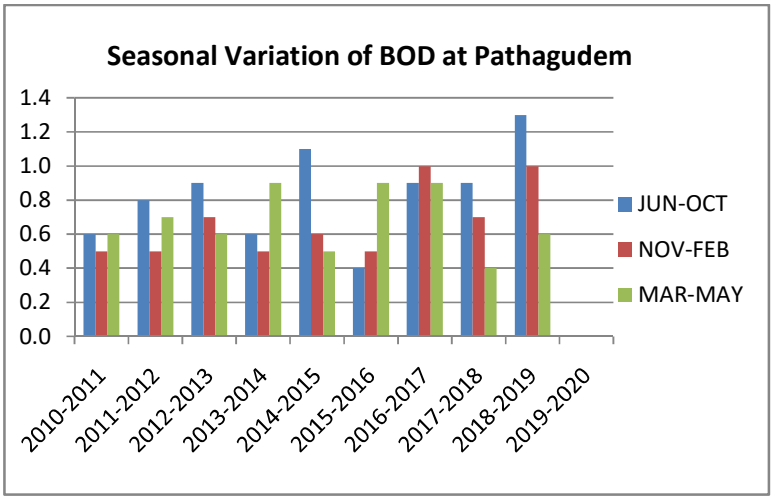
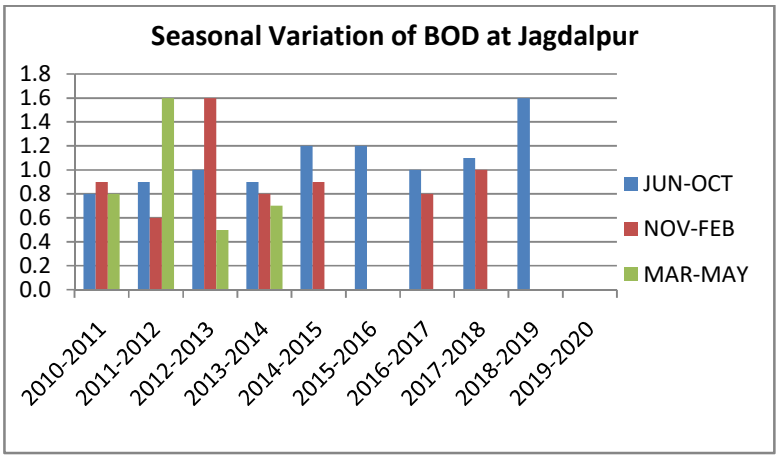


Figure 4: Average Seasonal Variation of DO values for the sites present on river Indravathi

Seasonal Variation of BOD on Indravathi River:

Micro-organisms utilise waste organic matter as food. In aerobic environment, the organic matter is biochemically converted to carbon dioxide and water. The biochemical oxygen demand (BOD) test measures the oxygen consumed in the reaction. The standard test is carried out under controlled laboratory conditions, at a constant temperature and over a specified time. Since not all organic matter is biochemically decomposable, the test measures the oxygen equivalence of the degradable matter only. As per BIS the class-A of drinking water should be less than 2mg/l (BIS:2296-1982).





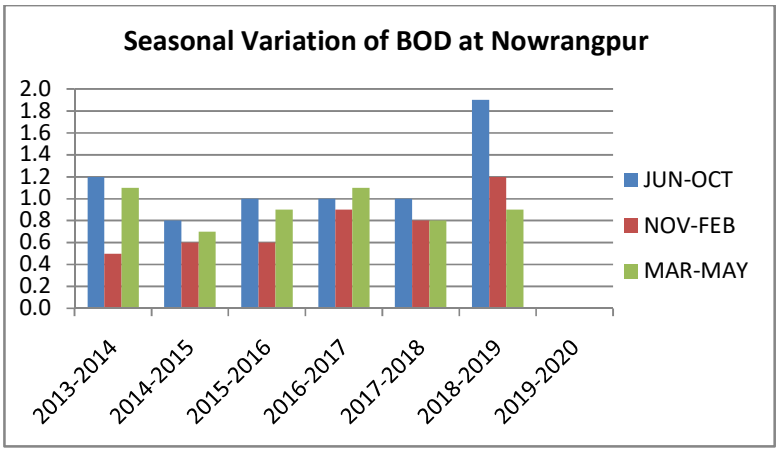


Figure 5: Average Seasonal Variation of BOD values for the sites present on river Indravathi

Tolerance limit relating to selected pollution parameters for inland surface waters required for different uses as prescribed by the Bureau of Indian Standards (BIS:2296-1982)

Sl. No	Constituents	Unit	Designated use class of inland surface water				
			A	B	C	D	E
1	pH		6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.0-8.5
2	EC at 25°C	µS/cm,Max	-	-	-	1000	2250
3	DO	mg/L, Min	6	5	4	4	-
4	BOD	mg/L, Max	2	3	3	-	-
5	Total coliform organisms	MPN/100 ml, Max	50*	500*	5000*	-	-
6	Colour,	Hazen units, Max	10	300	300	-	-
7	Odour		Un-objectionable	-	-	-	-
8	Taste		Tasteless	-	-	-	-
9	Total dissolved solids	mg/L, Max	500	-	1500	-	2100
10	Total Hardness	as $CaCO_3$, mg/L, Max	300	-	-	-	-
11	Calcium hardness	as $CaCO_3$, mg/L, Max	200	-	-		-
12	Magnesium	as $CaCO_3$, mg/L, Max	100	-	-	-	-
13	Iron	as Fe, mg/L, Max	0.3	-	50	-	-
14	Chloride	as Cl, mg/L, Max	250	-	600	-	600
15	Fluoride	as F, mg/L, Max	1.5	1.5	1.5	-	-
16	Sulphate	as SO_4,mg/L, Max	400	-	400	-	1000
17	Nitrate	as NO_3, mg/L, Max	20	-	50	-	-
18	Free Ammonia	as N, mg/L, Max	-	-	-	1.2	-
19	Arsenic	as As, mg/L, Max	0.05	0.2	0.2	-	-
20	Boron	as B, mg/L, Max	-	-	-	-	2
21	Cadmium	as Cd, mg/L, Max	0.01	-	0.01	-	-
22	Chromium	as Cr^{6+}, mg/L, Max	0.05	0.05	0.05	-	-
23	Copper	as Cu, mg/L, Max	1.5	-	1.50	-	-
24	Cyanide	as CN, mg/L, Max	0.05	0.05	0.05	-	-
25	Lead	as Pb, mg/L, Max	0.1	-	0.10	-	-
26	Manganese	as Mn, mg/L, Max	0.5	-	-	-	-
27	Mercury	as Hg mg/L, Max	0.001	-	-	-	-
28	Zinc	as Zn, mg/L, Max	15	-	15	-	-
29	Pesticides		Absent	-	Absent	-	-
30	Free carbon dioxide	as CO_2, mg/L, Max	-	-	-	6	-
31	Phenolic compound	as C_6H_5OH, mg/L,Max	0.002	0.005	0.005	-	-
32	Sodium percent,	Max	-	-	-	-	60
33	SAR	Max	-	-	-	-	26

A Drinking water source without conventional treatment but after disinfections

B Outdoor bathing-organised

C Drinking water source with conventional treatment followed by disinfections

D Propagation of wildlife, fisheries

E Irrigation, industrial cooling and controlled waste disposal

DESIGNATED BEST USE CLASSIFICATION OF INLAND SURFACE WATER

CLASS	DESIGNATED BEST USE	CRITERIA
A	Drinking water source without conventional treatment but after disinfection	pH: 6.5 to 8.5 Dissolved Oxygen: 6mg/l or more Biochemical Oxygen Demand: 2mg/l
B	Outdoor bathing (Organized)	pH: 6.5 to 8.5 Dissolved Oxygen: 5mg/l or more Biochemical Oxygen Demand: 3mg/l
C	Drinking water source with conventional treatment followed by disinfection	pH: 6.5 to 8.5 Dissolved Oxygen: 4mg/l or more Biochemical Oxygen Demand: 3mg/l
D	Propagation of wildlife and fisheries	pH: 6.5 to 8.5 Dissolved Oxygen: 4mg/l or more
E	Irrigation, industrial cooling and controlled waste disposal	pH: 6 to 8.5 Electrical Conductivity: Max. 2250mhos/cm

Conclusion:

Water quality seasonal average results clearly showed that above water quality parameters studied are within the permissible limit in all seasons since ten years time period.

- The seasonal average values of Electrical conductivity indicate that its less than Class –D as per Bureau of Indian Standards (BIS:2296-1982)
- The seasonal average values of pH indicate its within permissible limits of Class –A as per Bureau of Indian Standards (BIS:2296-1982)
- The seasonal average values of Total Dissolved Solids indicate that its less than Class –A as per Bureau of Indian Standards (BIS:2296-1982)
- The seasonal average values of DO indicate that its within permissible limits of Class –A& B as per Bureau of Indian Standards (BIS:2296-1982)
- The seasonal average values of BOD indicate that its within permissible limits of Class –A as per Bureau of Indian Standards (BIS:2296-1982)

From the above conclusion it can be assumed that there is less human activity and the pollution levels in the water are within permissible limits.

Seasonal Variation in Water Quality of Krishna River

Mukesh Kumar Yadav, Assistant Research Officer, Upper Godavari Division, KGBO, Central Water Commission

Abstract

Rivers are considered as vital and flowing freshwater ecosystems that are important for the sustenance of all life. They represent the major source of water used for human consumption such as culture, irrigation, and industrial purposes. Efficient management of these water resources requires information about the river water quality and its variability.

Assessment of seasonal changes in surface water quality is an important aspect for evaluating temporal variations of river pollution due to natural or anthropogenic inputs of point and non-point sources.

The present study focuses on the assessment of seasonal variation in surface water quality of Krishna river at one permanent water quality monitoring stations Huvinhedgi maintained by Central Water Commission (CWC). In this study, surface water quality data collected from these one monitoring stations were analyzed for six major physicochemical parameters namely Electrical Conductivity (EC), pH, Dissolved Oxygen (DO) Biochemical Oxygen Demand (BOD) and Fluoride (F^-) for three different seasons (Flood, Winter and Summer) for the period 20014-2019.

Introduction

Rivers are one of the most important multi-usage components. The important usages of rivers water are as such sources of drinking water, irrigation, fishery and hydro-power production .River basin has been a major source of water supply for many purposes and provides fertile lands ,which support the development of highly populated residential areas due to its favorable conditions. Good water quality resources depends on a large number of physic-chemical parameters and the magnitude and source of any pollution load; and to assess that, monitoring of these parameters is essential. The population explosion and increasing demands have exerted extra pressure on natural water resources like rivers and lakes. The changed physic-chemical characteristics of water have serious repercussions on aquaculture, fisheries and agricultural production.

The quality of surface water within a region is governed by both natural processes (such as precipitation rate, weathering processes and soil erosion) and anthropogenic effects (such as urban industrial and agricultural activities and the human exploitation of water resources).In recent years both the Anthropogenic influences as well as natural processes have increased exploitation of water resources and rendered the water bodies unsuitable for both primary and secondary use. Runoff water and discharge of sewage into rivers are two common ways through which various nutrients enter the aquatic ecosystems resulting in water pollution. Therefore, regularly monitoring and evaluating the quality of river water are required for integrated management of these water resources.

The River Krishna is the second largest eastward draining interstate river in Peninsular India. The basin of Krishna is situated between East longitudes 73^0 21’ to 81^0 09’ and North latitudes 13^0 07’

to 19^0 25’ in the Deccan Plateau covering large areas in the States of Maharashtra, Karnataka, Telangana and Andhra Pradesh.

The Krishna Basin is bounded on the North by the ridge, separating it from the Godavari basin and on the South and East by the Eastern Ghats and on the West by the Western Ghats. The basin is more or less triangular in shape with its base along the Western Ghats, the apex at Vijayawada and the river Krishna itself forming the median. All the major tributaries are originating in the Western Ghats and joining river Krishna at the base of the triangle in the upper two-thirds of its length.

The Krishna drains an area of 2,59,439 sq.km (based on geo spatial data sets) which is nearly 8% of the total geographical area of the country.

The State wise distribution of drainage area is shown in the Table given below.

Name of State	**Length (km)**	**Drainage area (sq.km)**	**Drainage area %**
Maharashtra	306	69,044	26.8
Karnataka	483	1,13,622	43.7
Telangana	612	51,388	19.8
Andhra Pradesh		25,385	9.8
Total	**1401**	**2,59,439**	**100.0**

The river Krishna rises in the Western Ghats at an altitude of 1337m just North of Mahabaleswar, about 64 km from the Arabian Sea and flows from West to East through the States of Maharashtra, Karnataka, Telangana and Andhra Pradesh before it joins the Bay of Bengal at downstream of Vijayawada.

There are about 13 major tributaries which join the river Krishna along its 1400 km course, out of which, six tributaries are on right bank and remaining seven are on left bank. Among the major tributaries, the Ghataprabha, Malaprabha and Tunga- Bhadra are the principal right bank tributaries which together contribute 35.45% of the total catchment area, whereas the Bhima, Musi and Munneru are the principal left bank tributaries which together contribute 35.62% of the total catchment area.

Sampling Location

The water samples were collected from the three different locations in the Krishna River, namely Huvinhedgi, Wadenapally and Vijayawada. The Central Water Commission (CWC) has permanent water quality monitoring station in these three locations.

Huvinhedgi Site

The Huvinhedgi site (16º29'25" N and 76º55'23" E) is located at Raichur district

inKarnataka. The drainage area of this site is around 55150 Sq. Km. This is a GDSQ (Gauge, Discharge, Silt and Water Quality) site.

Material and Method
Sampling and Analysis

Water samples were collected once in a month from preselected locations (i.e. station gauge line) throughout the year. The in-situ water quality parameters were measured at the site itself. The water samples were then transported to Krishna and Godavari River Water Quality

Laboratory Level-III (KGRWQL-III) with proper preservation for further analysis of physiochemical parameters. The KGRWQL (level-III), Hyderabad is NABL Accredited for 20 parameters (Certificate no. TC-6055) in accordance with the standard ISO/IES 17025:2017. Preservation and analysis of the water samples were carried out as per standard procedures and recommended protocols of APHA.

For the seasonal assessment of river water quality, five major physio-chemical parameters were taken into consideration i.e. Electrical Conductivity (EC), pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Fluoride (F^-). The whole study period was divided into three different seasons i.e. Flood (June - October), Winter (November – February) and Summer (March-May).

To study the seasonal variation of these physio-chemical parameters for river Krishna at site Huvinhedgi - maximum and minimum values for the parameters were computed and compared for different seasons for the period 2014-2019.

Table 1. Maximum values of Electrical Conductivity in µmho/cm at Huvinhedgi site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2014-15	1340	848	1335
2	2015-16	1599	1672	813.0
3	2016-17	1208	970	1043.0
4	2017-18	879	1156	-
5	2018-19	736	848	1335

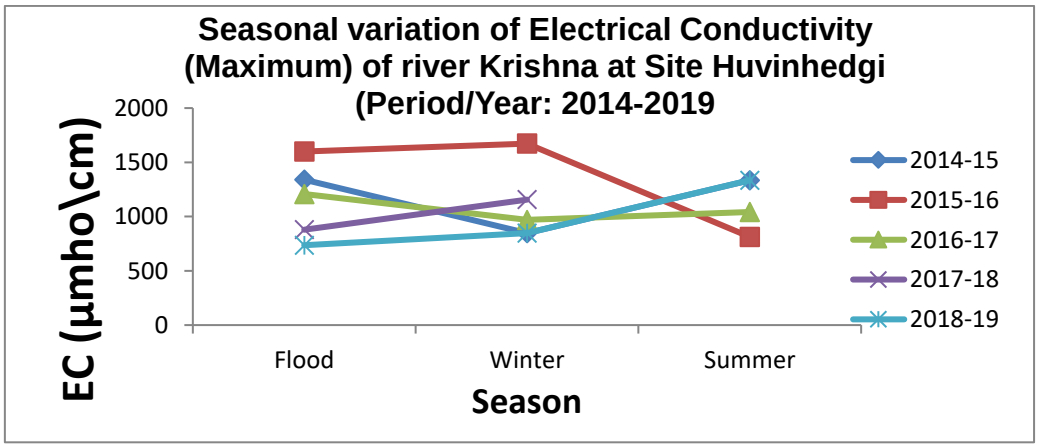


Figure 1 Seasonal variation of Electrical Conductivity (Maximum)

Table 2. Minimum values of Electrical Conductivity in µmho/cm at Huvinhedgi site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2014-15	335	691	103
2	2015-16	783	824	496
3	2016-17	275	458	975
4	2017-18	**364**	**733**	-
5	2018-19	282	535	248

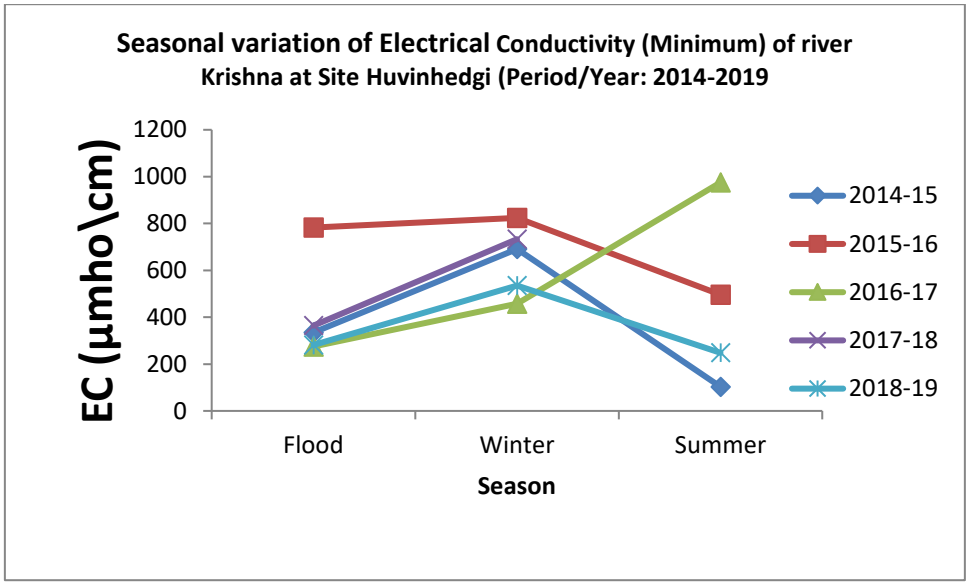


Figure 2 Seasonal variation of Electrical Conductivity (Minimum)

Table 3. Maximum values of pH at Huvinhedgi site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2014-15	**8.5**	**8.4**	**8.5**
2	2015-16	**8.4**	**8.6**	**8.3**
3	2016-17	**8.8**	**8.7**	**8.0**
4	2017-18	**8.4**	**8.2**	
5	2018-19	**8.4**	**8.3**	**8.3**

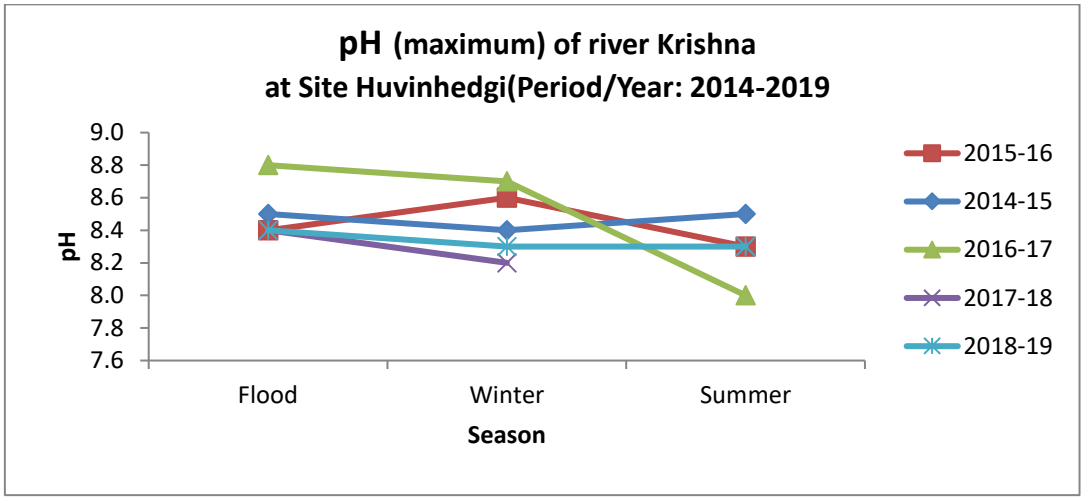


Figure 3 Seasonal variation of pH (Maximum)

Table 4. Minimum values of pH at Huvinhedgi site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2014-15	7.8	8.2	8.2
2	2015-16	8.0	8.0	7.2
3	2016-17	8.2	8.4	7.5
4	2017-18	7.6	8.0	
5	2018-19	8.0	8.1	7.9

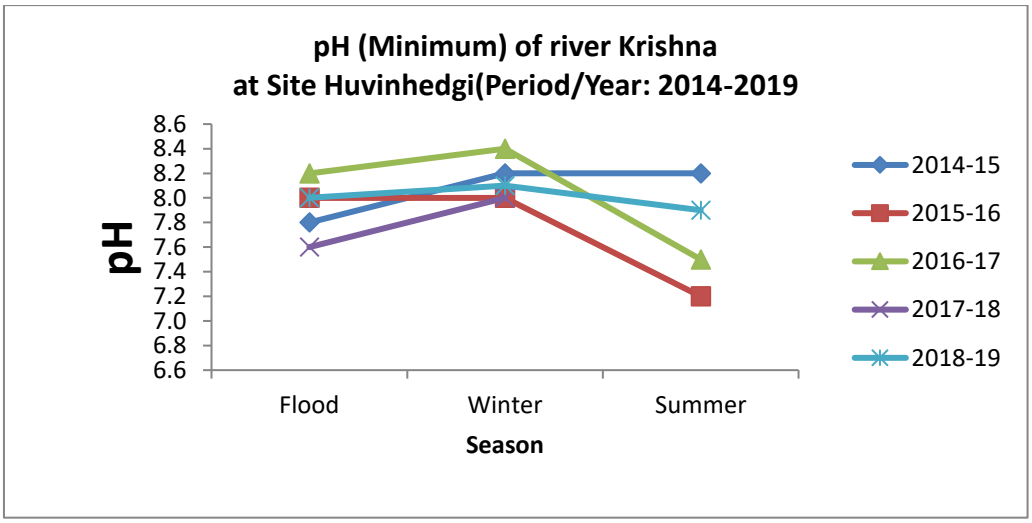


Figure 4 Seasonal variation of pH (Minimum)

Table 5. Maximum values of Dissolved Oxygen in mg/L at Huvinhedgi site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2014-15	7.30	7.80	6.50
2	2015-16	6.00	7.30	5.50
3	2016-17	7.00	8.80	4.30
4	2017-18	6.90	7.70	
5	2018-19	6.70	7.30	8.40

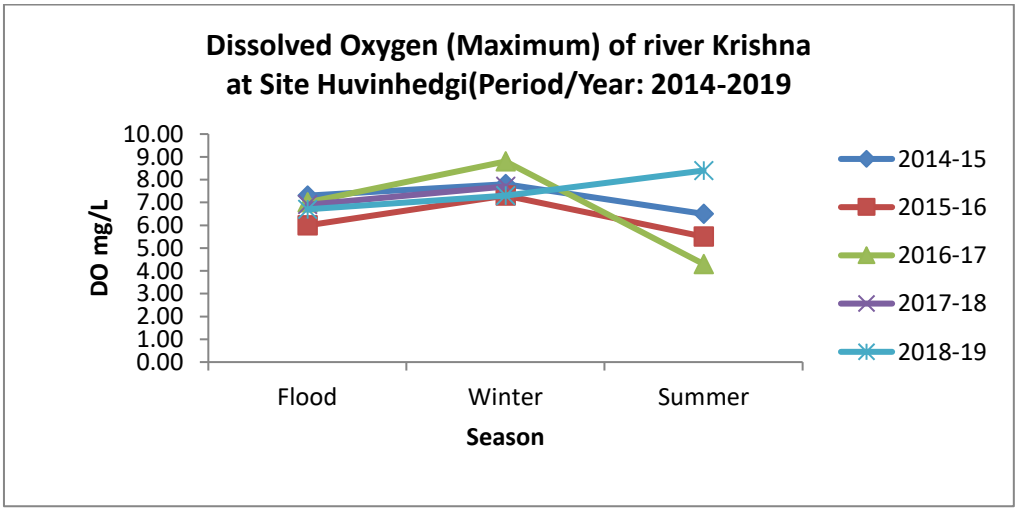


Figure 5 Seasonal variation of DO mg/L (Maximum)

Table 6. Minimum values of Dissolved Oxygen in mg/L at Huvinhedgi site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2014-15	4.7	6.4	4.0
2	2015-16	4.7	5.9	5.1
3	2016-17	5.5	5.4	4.3
4	2017-18	5.3	6.1	-
5	2018-19	5.4	6.1	8.4

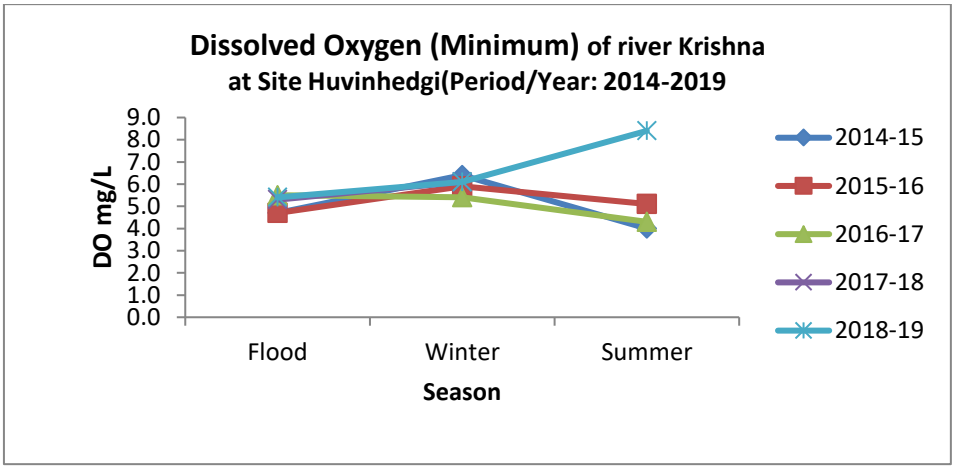


Figure 6 Seasonal variation of DO mg/L (Minimum)

Table 7. Maximum values of Bio Chemical Oxygen Demand in mg/L at Huvinhedgi site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2014-15	1.70	1.00	0.80
2	2015-16	1.50	3.40	3.30
3	2016-17	2.40	2.40	0.90
4	2017-18	1.30	1.40	
5	2018-19	3.70	1.40	1.60

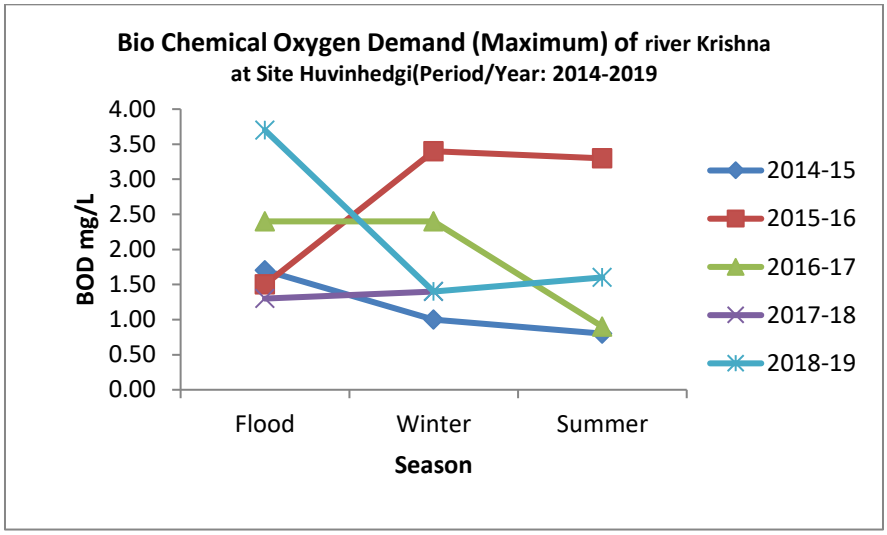


Figure 7 Seasonal variation of BDO mg/L (Maximum)

Table 8. Minimum values of Bio Chemical Oxygen Demand in mg/L at Huvinhedgi site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2014-15	0.6	0.6	0.7
2	2015-16	0.7	0.3	1.1
3	2016-17	0.7	0.4	0.9
4	2017-18	1.0	0.2	-
5	2018-19	0.3	0.6	0.4

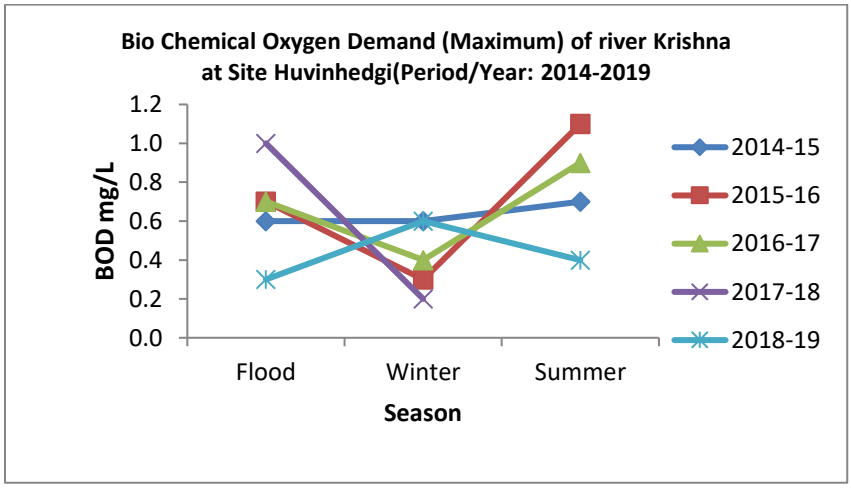


Figure 8 Seasonal variation of BDO mg/L (Minimum)

Table 9. Maximum values of Fluoride in mg/L at Huvinhedgi site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2014-15	1.10	1.00	1.30
2	2015-16	1.30	0.90	0.12
3	2016-17	1.41	1.43	0.60
4	2017-18	**0.83**	**1.01**	-
5	2018-19	0.90	1.02	0.52

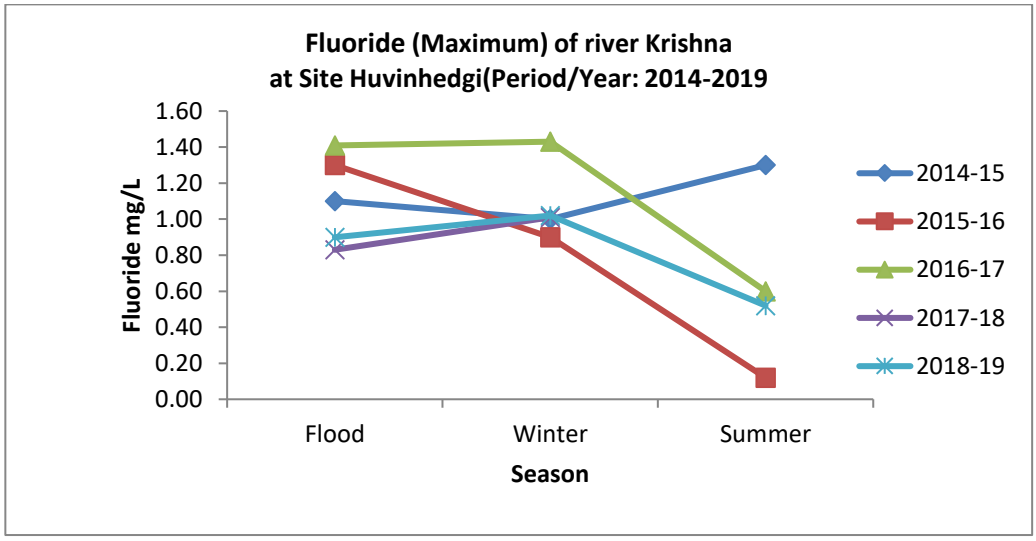


Figure 9 Seasonal variation of Fluoride mg/L (Maximum)

Table 10. Minimum values of Fluoride in mg/L at Huvinhedgi site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2014-15	**0.20**	**0.80**	**1.00**
2	2015-16	**0.66**	**0.14**	**0.10**
3	2016-17	**0.10**	**0.55**	**0.58**
4	2017-18	**0.29**	**0.79**	-
5	2018-19	**0.15**	**0.07**	**0.22**

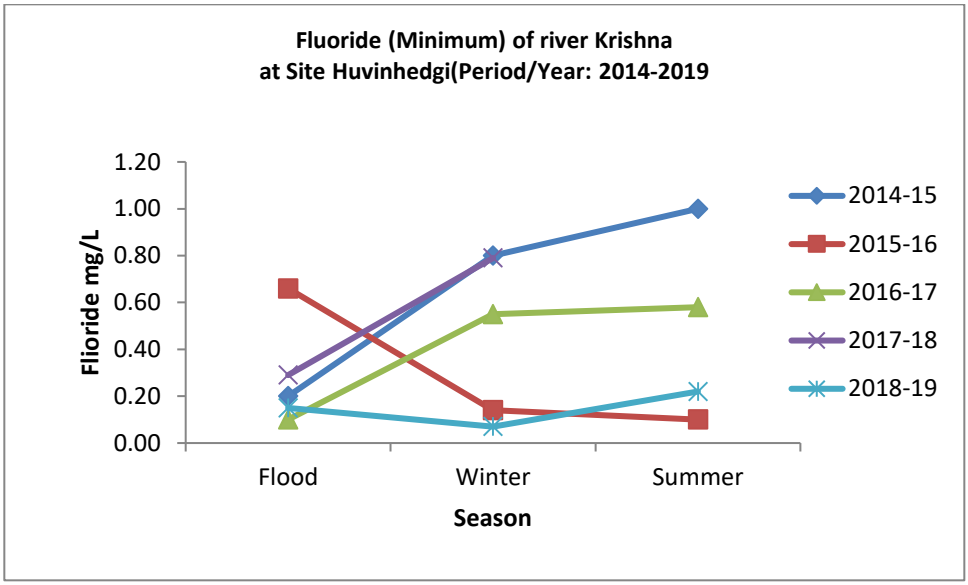


Figure 10 Seasonal variation of Fluoride mg/L (Minimum)

Results and Discussion

Electrical Conductivity (EC)

Conductivity is a measure of water's capability to pass electrical current. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved ionic compounds such as salts, alkalis acids. Conductivity is dependent on water temperature and salinity / TDS. Water flow and water level changes can also contribute to conductivity through their impact on salinity. Water temperature can cause conductivity levels to fluctuate daily.

Electrical conductivity of Krishna River at the site Huvinhedgi shows seasonal variation being maximum during Flood or winter season while minimum always during summer. High values of EC during flood or winter could be attributed to domestic and industrial waste.

pH

Potential of hydrogen (pH) is negative logarithm of the hydrogen ion concentration and shows the intensity of acidity or alkalinity of water. The pH of a water body is very important in determination of water quality as it influences most of the chemical and biochemical reactions such as solubility and metal toxicity. High or low pH values in a river have been reported to affect its river water ecosystem, causes of chemical reaction of in river water and alter the toxicity of other pollutants in one form or the other.

During the study, pH of Krishna River at the sites Huvinhedgi was found to be alkaline. The alkaline nature of water could be attributed to the presence of carbonates and bicarbonates. Seasonal variations in the pH values did not show much difference with slightly higher values during flood. Slight Fluctuations in pH values during different seasons of the year may be attributed to factors like removal of CO_2 by photosynthesis through bicarbonate degradation, dilution of waste with fresh water, reduction in salinity and temperature, and decomposition of organic matter. In general pH was not within the limits of BIS / WHO standard value.

Dissolved Oxygen (DO)

Dissolved oxygen (DO) is one of the most important parameters in water quality assessment and is a key test of water pollution. The value of DO is remarkably significant in determining the water quality criteria of an aquatic system. In the system where the rates of respiration and organic decomposition are high, the DO values usually remain lower than those of the system, where the rate of photosynthesis is high. The concentration of oxygen in natural waters is largely influenced by physical factors viz. temperature and salinity, dissolved oxygen solubility decreases as temperature and salinity increase. The main anthropogenic activity that leads to the change in dissolved oxygen concentration in the aquatic environment is the addition of organic matter mainly from sewage treatment works together with agricultural run-off, contributing to oxygen demand, also, the nutrient loading of the water bodies promotes the toxic algal blooms and leads to a destabilized aquatic ecosystem.

The seasonal variation of DO in water depends upon the temperature of the water body which influences the oxygen solubility in water. Seasonally, the values of DO of Krishna River at Huvinhedgi, were highest in winter and lowest in summer. The value of DO in summer is lower possibly due to less oxygen holding capacity of water at high temperature along with increase in DO assimilation for biodegradable organic matter by microorganism. High dissolved oxygen during winter could be attributed to greater dissolution of oxygen in winter at lower water temperature.

Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. It is required to assess the pollution of water where contamination occurred due to disposal of domestic and industrial effluents. As it is taken as an approximate measure of the amount of biochemically degradable organic matter present in the aquatic systems, which adversely affects the river water quality and biodiversity, the greater the decomposable organic matter present, the greater the oxygen demand and greater the BOD .

The unpolluted waters usually have BOD value of 2mg/L or less. The major source of organic contaminants entering the aquatic systems is the domestic sewage or the raw sewage which requires more oxygen for decomposition by bacteria thus, increasing the BOD.

BOD values of Krishna River at site Huvinhedgi, were found to be highest during winter followed by flood. The high values of BOD during winter could be attributed to the acceleration in the metabolic activities of various aerobic micro-organisms in the decomposition of organic matter at high suitable temperature, decrease in water flow and direct discharge of untreated domestic and industrial waste into the river.

Fluoride (F^-)

Fluoride, a naturally occurring element, exists in combination with other elements as fluoride compounds and is found as a constituent of minerals in rocks and soil. When water passes through and over the soil and rock formations containing fluoride, it dissolves these compounds, resulting in the small amounts of soluble fluoride present in virtually all water sources. Fluoride is extensively distributed in nature and enters the human body through drinking water. The amount of fluoride in water is governed by climate, composition of rocks and hydrogeology. Fluoride is the key aspect of water quality in water supply system. Fluoride has shown to cause a significant effect on human health. A correct proportion of fluoride has a beneficial role in the formation of teeth. Too low concentration of fluoride intake may be insufficient for preventing dental caries in the early ages of children. High concentration of fluoride exceeding 1.5 mg/L leads to teeth mottling viz dental fluorosis. Fluoride has an adequate sensitivity to cycle in the environment including plants, animals and human beings thereby causing toxicity. Fluoride is also absorbed by plants as the water is also used for irrigation. Thus fluoride can even enter food chain causing higher concentration of fluoride in food materials.

Fluoride concentration in Krishna River varied from 0.07 mg/L to 1.43 mg/L. Seasonally, Fluoride concentration in Krishna River for the sampling station Huvinhedgi was found to be maximum in winter. Fluoride concentration was found within the permissible limit of BIS. The Bureau of Indian Standards has recommended the limit of 1.5mg/L.

Conclusion

Surface water quality assessments are essential in providing sustainable and efficient water resource management. A parameter that can be significant in contribution to water quality variation for one season, may not be significant for another season. Therefore, when selecting water quality parameters for implementing environmental monitoring plans in river basins, the seasonal variations of parameters in assessment of water quality must be considered.

Physico-chemical parameters of Krishna River varied with different seasons. The majority of the water quality variables investigated exhibited seasonal fluctuations directly associated with the variation in climate. Such variables were associated with surface run-off due to large flow of effluents from anthropogenic sources, particularly at the start of the monsoon season. Further, the study revealed deterioration of water quality during the winter season, which may be attributed to decrease in flow volume and suitable temperature.

The results suggested the necessity of maintaining minimum flow requirement to keep the water in good condition and continuous monitoring to assess the impact of pollution loads. Thus, efficient management of the river is essential to prevent further deterioration of water quality where different water quality parameters should be targeted during different seasons.

Seasonal variation in water quality parameters of River Musi, at Damarcherla, Telengana

MINISTRY OF JAL SHAKTI
GOVERNMENT OF INDIA

KRISHNA & GODAVARI BASIN ORGANISATION

CENTRAL WATER COMMISSION

HYDERABAD

Seasonal variation in water quality parameters of River Musi, at Damarcherla, Telengana

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Abstract

Water is an important element of the physical environment and a valuable resource with numerous and varied uses. Rivers are the primary source of water for drinking, irrigation and other domestic purposes. The river shows strong seasonal dependence for various constituents and the water quality deteriorates sharply as municipal and Industrial wastes. River Musi is one of the tributaries of the Krishna River. Musi River is located at Vikarabad district and passes through the Hyderabad city with domestic and industrial discharge points on both sides, serves as an excellent disposal agent. The Objective of the study to investigate the seasonal variation in physico-chemical characterises of Musi River at sampling station of damarcherla is located 6.3 km above from Musi–Krishna sangaman at Wazirabad, Telengana. The analysis of river water quality containing 9 parameters were analyzed and obtain results considered influences on water quality with significant seasonal changes during the all seasons of water year 2018-2019.The data has been compare with the norms of surface water of Bureau of Indian Standards(BIS:2296-1982). The obtained results revealed that increase of pollution load in winter season indicate the increase in organic matter in river water due to the anthropogenic interferences at the surrounding area of sampling point.

Key words: Musi River, water Quality, Seasonal Variation, anthropogenic effect,

1. Introduction:

Rivers and their catchments are highly important parts of the natural heritage. Rivers have been utilized by mankind for thousands of years to the extent that few of them are now in their natural condition (Ngoye and Machiwa, 2004). The quality of surface water which depends on load of pollutants due to untreated sewage disposal and industrial effluents being disposed directly into the rivers. The polluted surface water is continuously increasing as a result of changes in the modes of industrials activities, agriculture production and increasing urbanization. Water quality assessment of rivers to achieve goals of any water quality management programme must contain evaluation of pollution from various sources. Pollutants entering a river system normally result from many transport pathways including storm water runoff, groundwater seepage and atmospheric deposition. These pathways are also seasonal-dependent. Therefore, seasonal changes in surface water quality must be considered when establishing a water quality management program (Ouyang *et al*., 2006).

Maintenance or improvement of water quality and control water quality degradation may require control of both point and non-point sources. Water quality is important to assess the

health of a watershed and to make necessary management decisions to control current and future pollution of receiving water bodies (Khadam and Kaluarachchi, 2006). The information on water quality and pollution sources is important for implementation of sustainable water –use management strategies (Sarkar *et al*., 2007; Zhou *et al*., 2007 and Bu *et al*., 2009). Due to high population growth rate (13.58 %), rapid urbanization, use of agriculture chemicals in Surroundings of damarcherla mandal, there have been incidences of toxic pollution from all point /Non point sources into the river. Hence, characterization of seasonal changes in surface water quality is an important aspect for evaluating temporal variations of river pollution due to natural or anthropogenic inputs of point and non-point sources like urban, agricultural, industrial, and domestic wastewaters, industrial wastewaters.

2. Study Site:

The study area is located near to Damarcherla village in Nalgonda district state of Telangana. Central water Commission was monitoring water quality at site Damarcherla since 01/01/1980 at the downstream of musi river (6.3 km bove from musi –krishna sangamam at wazirabad) under Lower Krishna sub-division-1,Nagarjunasagar dam control of Lower Krishna Division Hyderabad. Surface water samples were collected from river Musi at site damarcherla which lies at latitude 16°44’21” and longitude 79°40’11”. This site is designated as Trend station due to influence of human activity. So water quality is monitored twelve in a year. Water samples from the site were collected in one plastic bottle for analysis of physicochemical parameters and in sterile glass bottles for DO & BOD analysis and transported to the laboratory in ice-boxes, processed within 1-4 hrs and stored at 4-5°C for further analysis.

Water Sampling Location (16°44'21.0"N, 79°40'11.0" E) at Damarcherla on Musi River

3. Methodology:

3.1 Sample collection and Analysis:

The seasons chosen for sampling were flood season (June-November), winter season (December-February) and summer season (March-April) during water year 2018-2019. The samples were taken morning hours (08:00AM to 09:00AM). The cumulative rainfall observed at damarcherla site during 2018-2019 is 581mm. All samplings represent instantaneous water quality at the particular time. Water samples were collected in polyethylene bottles, transported to the laboratory, and analyzed. Water samples were analyzed for most water quality influencing nine physicochemical parameters, which included pH, conductivity, DO, BOD, COD, Nitrate, Phosphate total hardness and fluoride. The parameters were determined using the standard methods mentioned in Table 1 for the examination of water and wastewater (APHA 23 rd edition 2017).

Table 1: List of physicochemical parameters and their test methods

S. No.	Parameters	Unit	Method used
1.	pH		pH meter
2	Electrical Conductivity	µs/cm	Conductivity meter
3.	Dissolved Oxygen (DO)	Mg/L	Winkler method
4.	Biochemical Oxygen Demand (BOD)	Mg/L	5 days incubation at 20° C and titration of initial and final DO
5.	Chemical Oxygen Demand	Mg/L	Open Reflux Method
6.	Nitrate	Mg/L	Ion Selective Method
7.	Phosphate	Mg/L	Ascorbic Acid Method
8.	Total Hardness as CaCO3	Mg/L	EDTA titration
9.	Fluoride	Mg/L	Ion Selective Method

4. Results and Discussions:

The water samples were analyzed for physicochemical characteristics. The physicochemical parameters were analyzed namely, pH, EC, DO, BOD5, COD, Nitrate, Phosphate, Total Hardness and Fluoride results are given in Table 2.

Table 2: Monthly Results of Physico-chemical parameters in the Musi River at damarcherla site during water year 2018-19.

Sample Collection Date	Temperature ˚C	Discharge (Cumec)	pH	EC (µs/cm)	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	NO3-N (mg/L)	Total Hardness (as CaCO3) mg/L	O-PO4 (mg/L)	F (mg/L)
02/07/2018	28	5.486	8.2	1928	5.1	0.2	17.2	1.20	391.1	0.20	1.3
14/08/2018	26	25.467	8.2	1581	5.6	2.7	85.2	1.20	376.2	0.10	1.1
04/09/2018	27.5	19.242	7.6	1237	5.1	2.1	16.4	0.00	326.2	0.20	1.0

03/10/2018	29	22.641	7.9	1293	7.0	1.0	16.0	0.80	328.1	0.20	1.1
01/11/2018	25	21.69	8.1	1608	7.6	2.6	16.4	0.70	375.7	0.40	0.1
03/12/2018	23	7.469	8.4	2381	5.8	0.4	11.5	1.20	214.8	0.10	1.2
28/01/2019	28	35.09	7.8	1134	4.7	0.7	5.2	2.90	207.8	0.20	1.0
01/02/2019	22	7.58	7.8	1387	2.5	3.3	6.3	2.00	332.0	0.10	1.0
01/03/2019	25	9.965	7.6	1393	4.9	0.4	8.4	0.70	320.2	0.10	1.0
01/04/2019	26	10.87	7.9	929	4.9	0.1	14.3	0.50	310.7	0.10	0.9
01/05/2019	28	5.612	7.9	838	5.6	1.3	9.4	0.80	300.7	0.20	1.0

Table 3 - Tolerance limit relating to selected pollution parameters for inland surface waters required for different uses as prescribed by the Bureau of Indian Standards (BIS: 2296-1982)

Sl. No.	Constituents	Unit	Designated use class of inland surface water				
			A	B	C	D	E
1	pH		6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
2	EC at 25°C	µS/cm, Max	-	-	-	1000	2250
3	DO	mg/L, Min	6	5	4	4	-
4	BOD	mg/L, Max	2	3	3	-	-
5	Total Hardness	as CaCO3, mg/L, Max	300			-	-
6	Fluoride	as F, mg/L, Max	1.5	1.5	1.5	-	-
7	Nitrate	as NO3, mg/L, Max	20	-	50	-	-

A-Drinking water source without conventional treatment but after disinfections
B-Outdoor bathing-organized
C-Drinking water source with conventional treatment followed by disinfections
D-Propagation of wildlife, fisheries
E-Irrigation, industrial cooling and controlled waste disposal.

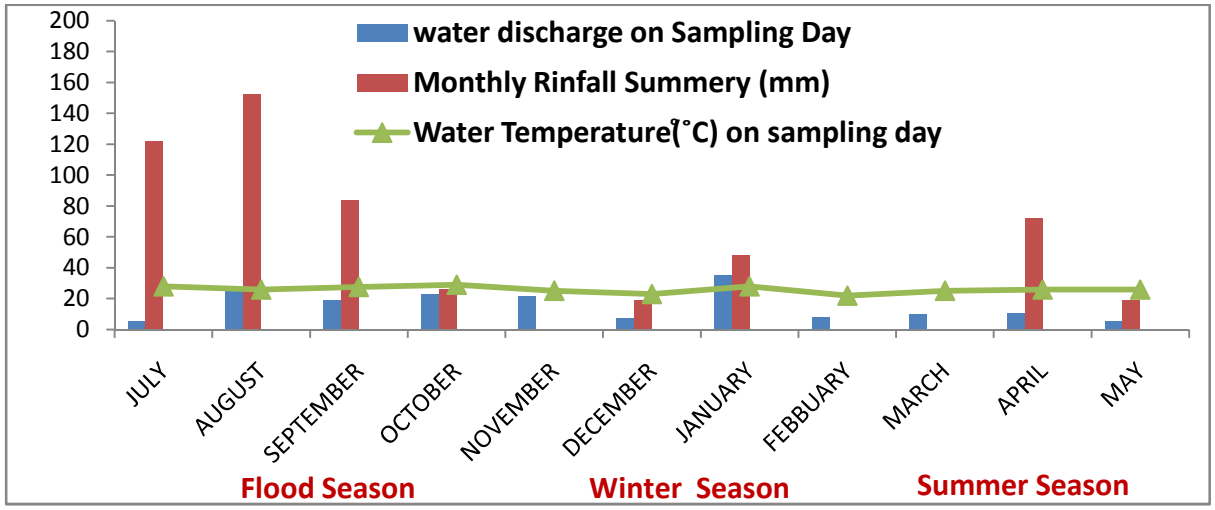

Figure 01: Monthly rainfall summery (mm), water discharge (m^3/sce), Water Temperature (˚C).

4.1 pH:

pH is way of expressing the hydrogen ion concentration in water. It is related to the acidic or alkaline nature of water. The pH levels recorded during the study are presented in Table: 1 and its monthly variations are shown in Fig: 2. The maximum tolerance limits for all classes of water as per IS 2296-1982 is 6.5-8.5. PH balance is important in maintaining desirable aquatic ecological conditions in natural water. In water with low dissolved solids, which consequently have a low buffering capacity (i.e. low internal resistance to pH change). High of pH can affect the palatability of water. p H values govern the characteristics of several other important parameters like Ammonia toxicity, chlorine disinfection efficiency, and metal solubility. Seasonal variation of pH value at dameracherla site on Musi River is well within the limits and there is no significant change.

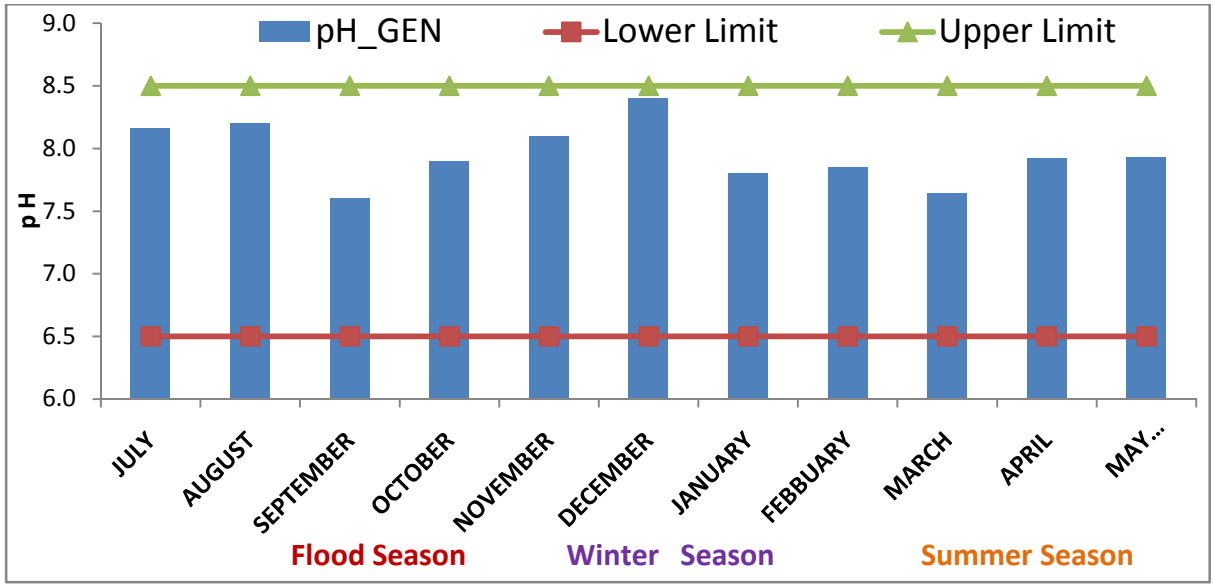

Figure 02: Monthly Variation of p H Levels at Damarcherla site on River Musi .

4.2 Electrical conductivity:

Conductivity is related to the ionic content of the sample which is in turn a function of the dissolved (ionisable) solids concentration. Conductivity is the order of the dissolved solids content of the water. Conductivity in water can be altered by discharge of domestic sewage and industrial effluents into the river stream. As shown in the Fig: 03, in month of July electrical conductivity little high comparatively with other months in flood season (Monsoon). In beginning of monsoon season river runoff is carryout the accumulate pollutants from domestic, industrial and agriculture waste. Fig : 01 represents the In flood season from July to October electrical conductivity gradually decrease but in month of November, water discharge was recorded in river stream at sampling point even no rain fall which leads to sudden increase in electrical conductivity due to discharge of domestic sewage and industrial waste into river stream .The electrical conductivity values are recorded during the study is presented in Table: 1 and its monthly variations in different seasons are shown in Fig: 2. the maximum tolerance limit of

electrical conductivity for class D waters is 1000 and Class E waters are 2250 according to the IS 2296-1982. The electrical conductivity levels are represents status of Musi River at damarcherla site classified as range in Calss D & Class E waters.

Conductivity	*Classification*
<600 µS/cm	Freshwater
600-6000 µS/cm	Moderately saline
>6000 µS/cm	Saline

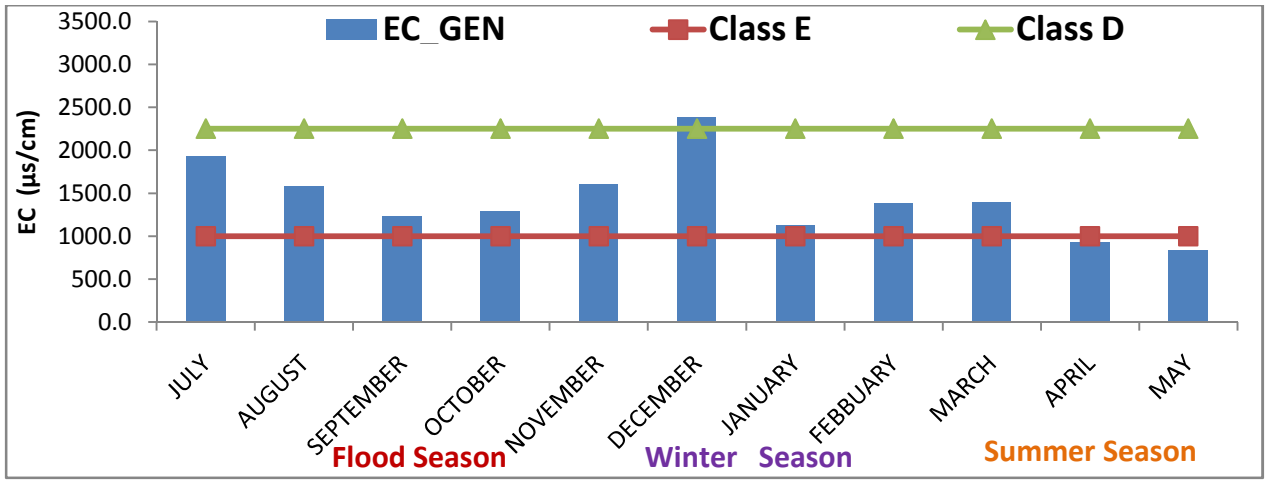

Figure 04: Monthly Variation of Electrical Conductivity Levels at Damarcherla site on River Musi

4.3 Dissolved oxygen (DO):

The dissolved oxygen content is one of the most important factors in stream health. Its deficiency directly affects the ecosystem of a river due to bioaccumulation and biomagnifications. The oxygen content in water samples depends on a number of physical, chemical, biological and microbiological processes. Dissolved Oxygen values also show lateral, spatial and seasonal changes depending on industrial, human and thermal activity. The Dissolved Oxygen levels are recorded during the study presented in table:1 and its monthly variation presented in Fig: 04 .In flood season, where there was peak rain fall . Dissolved oxygen content in water body gradually increase due to the increased current flow that enables the diffusion and mixing of atmospheric oxygen into the water. In winter season dissolved oxygen depletion was observed from December to February due to increase impact of organic load into the water. They attributed of this seasonal fluctuation in relation to temperature and biological activity (i.e. photosynthesis and respiration) Biological respiration, decomposition processes, reduces DO concentrations. The maximum tolerance limit of Dissolved Oxygen for class A waters is 6 mg/L , Class B waters are 5 mg/L and Class C waters are 4 mg/L according to the IS 2296-1982. The

Dissolved Oxygen levels are represents status of Musi River at damarcherla site classified as range in Class A & Class B in flood and summer season but in in winter season particularly in moth of February Dissolved oxygen level very low (2.0 mg/L).

DO Level (in ppm)	Water Quality
0.0 - 4.0	Poor Some fish and macro invertebrate populations will begin to decline.
4.1 - 7.9	Fair
8.0 - 12.0	Good
12.0 +	Retest Water maybe artificially aerated.

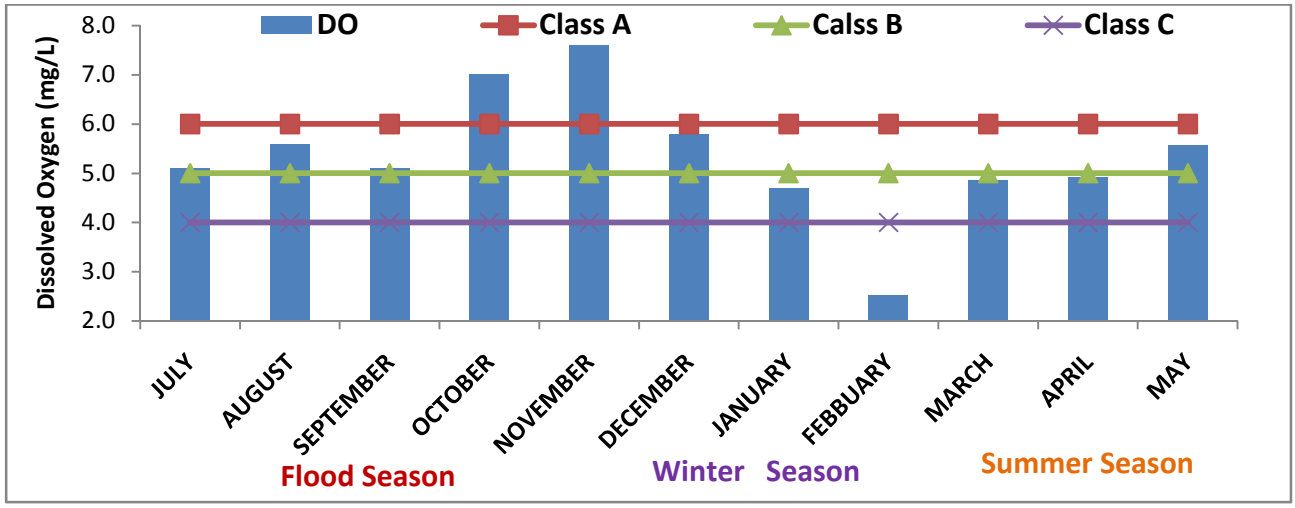

Figure 5: Monthly Variation of Dissolved Oxygen Levels at Damarcherla site on River Musi.

4.4 Biochemical Oxygen Demand (BOD):

The biochemical oxygen demand (BOD) is an approximate measure of the amount of biochemically degradable organic matter present in a water sample. It is defined by the amount of oxygen required for the aerobic micro-organisms present in the sample to oxidise the organic matter to a stable inorganic form. The presence of toxic substances in a sample may affect microbial activity leading to a reduction in the measured BOD.

The BOD load in different months at damarcherla site are presented in Table: 01 the monthly variation in BOD Is shown in Fig: 5. Low BOD concentration in moth of july (flood season) and april (summer season) indicates toxic substances may discharge in river stream from domestic and industrial waste. Where as in month of February (winter season) high BOD load (3.3 mg/L) as compare with other seasons due to receiving organic and inorganic matter from waste water inflows from domestic and industrial effluents by rain fall recorded in January month. Seasonal variation in level of BOD ranging between 0.1-3.3 as indicated by dissolved oxygen levels. . The maximum tolerance limits of Bio Chemical Oxygen Demand (BOD) as per IS 2296-1982 for

class A waters is 2 mg/L and class B & C waters is 3 mg/L. The average seasonal variation in Biochemical Oxygen Demand levels are represents status of Musi River at damarcherla site classified as range in Class A & Class B.

BOD Level (in ppm)	Water Quality
1-2	Very Good :There will not much organic waste present in the water
3-5	Fair: Moderately Clean
6-9	Poor: considerably Polluted Usually indicates present of organic matter but decomposes this waste by bacteria.
>100	Ver y Poor : High polluted Contains organic waste

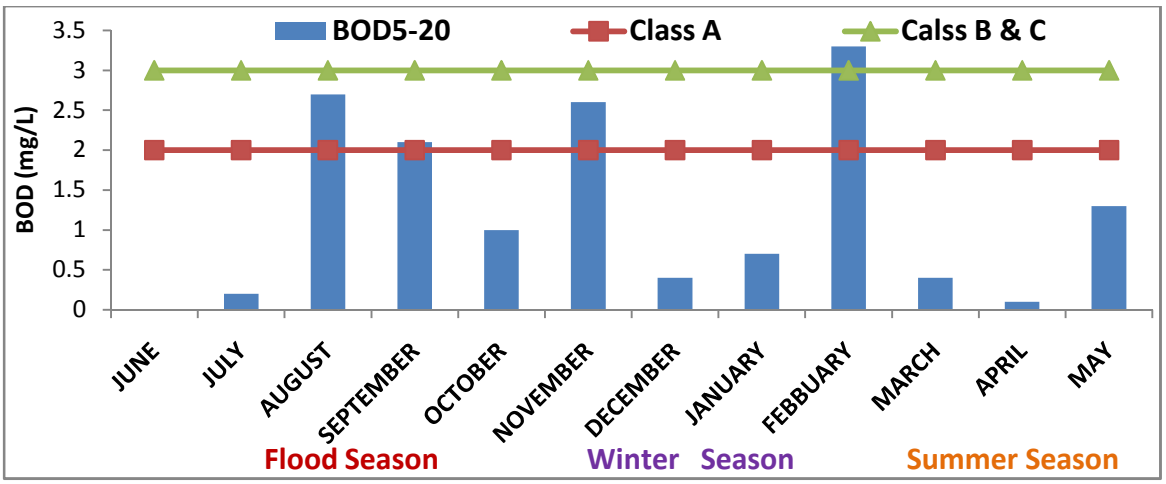

Figure 6: Monthly Variation of Biochemical Oxygen Demand Levels at Damarcherla site on River Musi.

4.5 Chemical Oxygen Demand (COD):

The chemical oxygen demand (COD) is a measure of the oxygen equivalent of the susceptibility to oxidation of the organic and inorganic materials present in water bodies and in the effluents from domestic sewage and industrial plants. Seasonal variations in water quality and accumulated pollutants from point / Non point source in river stream are supported by the variations in rainfall. The Chemical Oxygen Demand concentrations as resulted different seasons at damarcherla site are presented in Table: 01 the monthly variation in COD is shown in Fig: 5 The COD value in the Flood season was reported high where there was peak rain fall in month of august indicates the considerable pollutants from industrial effluent.

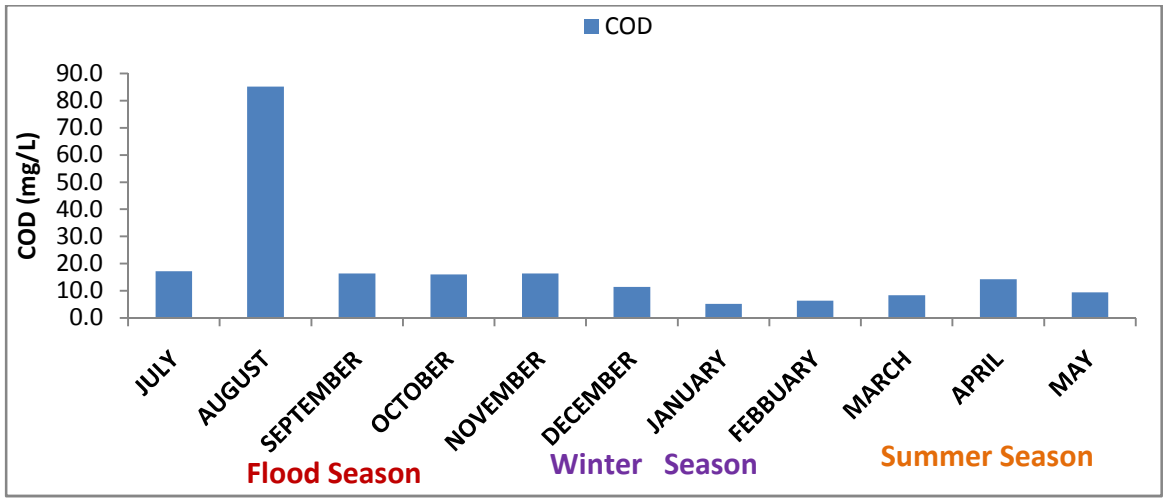

Figure 7: Monthly Variation of Chemical Oxygen Demand Levels at Damarcherla site on River Musi

4.6 Nitrate and Phosphate:

The Nitrate & Phosphate concentration values at damarcherla site are presented in Table: 01, the monthly variation of Nitrate & Phosphate Concentration is shown in Fig: 7. Nutrient concentrations are considerable; however the seasonal variations in flow indicate flushing of the nutrients without getting accumulated in the sediment. The intensive human impact on the river basins leads to considerable inputs of nitrogen and phosphorous. Nutrients are subjected to bio-chemical transformations and partly enter the bottom sediments. However, long term accumulation of nutrients is not foreseen due to flushing effect of wet flows during flood season. Phosphates are significant in flood season. This is attributable to disposal of domestic and industrial wastewaters and agriculture waste (Fertilizers) into the river.

NO_3- Level *(in ppm)*	Water Quality	Phosphate Level *(in ppm)*	Water Quality
0 - 1.0	Excellent	0.0 - 1.0	Excellent
1.1 - 3.0	Good	1.1 - 4.0	Good
3.1 - 5.0	Fair	4.1 - 9.9	Fair
5.0 or g reater	Poor	10.0 or greater	Poor

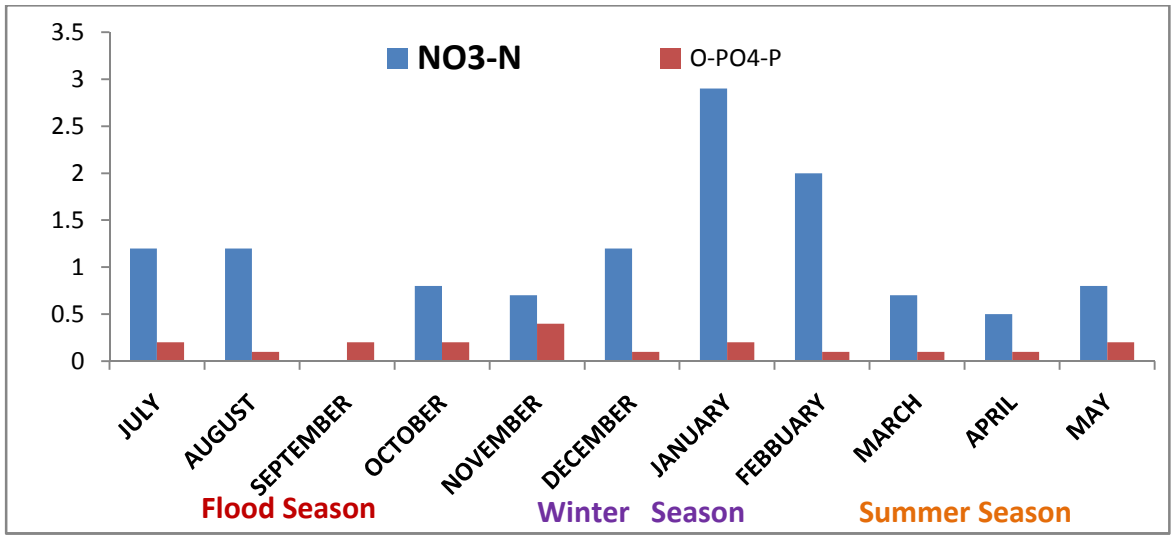

Figure 8: Monthly Variation of Nitrite & Phosphate Levels at Damarcherla site on River Musi

4.7 Total Hardness (as CaCO3):

Hardness is one of the important Hydro geochemical characteristics to determine the suitability of water for domestic drinking and industrial purposes. Hardness is caused principally due to the dissolved contents of carbonates and sulphates of calcium and magnesium. The results of hardness at damarcherla site are presented in Table: 01, the monthly variation of hardness is shown in Fig: 7 shows in flood season from July to November higher value then Class A, then variation in winter season have slightly decrease compare with other seasons .which may be significant pollutants due to the discharge of industrial and domestic sewage, which puts large amount of alkaline ions into the river system. The maximum tolerance limits of Total Hardness (as $CaCO_3$) as per IS 2296-1982 for class A waters is 300 mg/L. The average seasonal variation in Total Hardness shows no significant changes of Musi River at damarcherla site classified class A water.

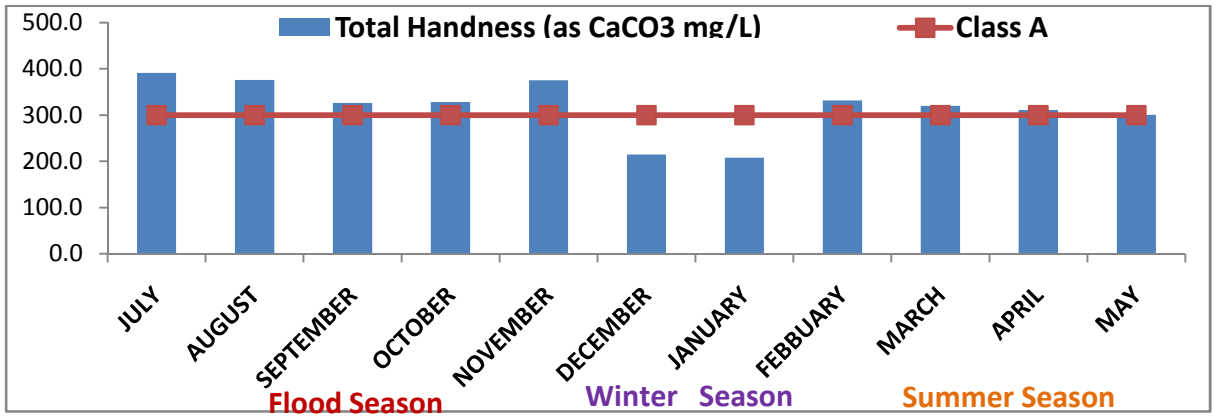

Figure 9: Monthly Variation of Total Hardness Levels at Damarcherla site on River Musi

4.8 Fluoride:

Fluoride originates from the weathering of fluoride-containing minerals and enters surface waters with run-off waste from certain industrial processes (such as metal-and chemical-based manufacturing) . The Fluoride levels recorded during the study are presented in Table: 1 and its monthly variations are shown in Fig: 2. Measurement of fluoride content is especially important when a water body is used for drinking water supply. At high concentrations fluoride is toxic to humans and animals and can cause bone diseases. The maximum tolerance limits of Fluoride as per IS 2296-1982 for class A waters is 1.5 mg/L. The average seasonal variation in Fluoride concentration represents no significant change in Musi River at damarcherla site.

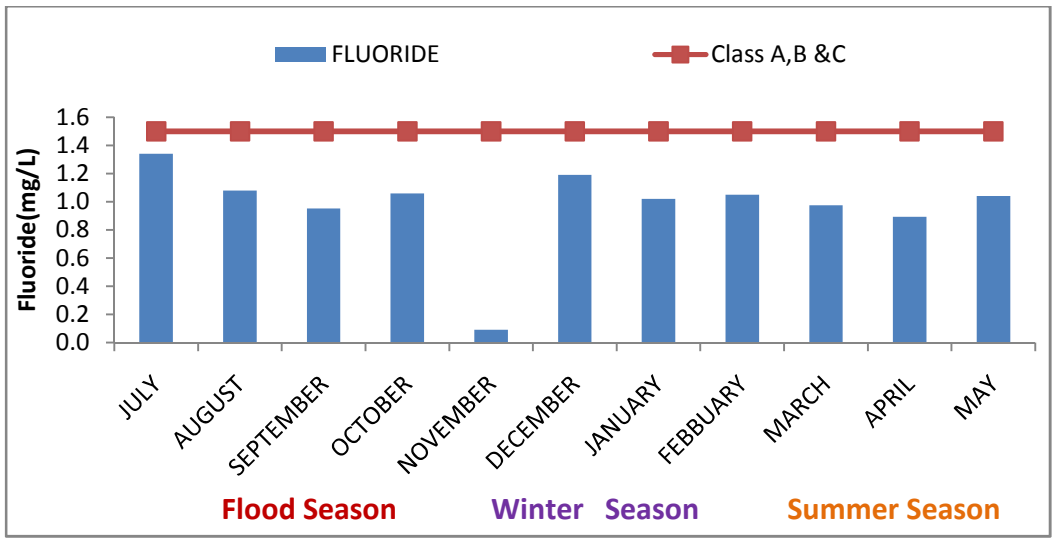

Figure 10: Monthly Variation of Fluoride Levels at Damarcherla site on River Musi.

5. Conclusion:

The Seasonal variations effect on water quality of Musi River at damarcherla due to anthropogenic activities like agriculture and industrial use of water and discharge into the river without any pre-treatment. The pollution load is more prominent as supported by variations in rain fall especially in flood season and winter season. The validity of the results obtained at damarcherla site on Musi River indicated the correlation found between the variables. The obtained BOD values show the contamination of water indicates depletion of dissolved oxygen in the river water. The study suggested the importance of greater attention for awareness about water contamination and need to implement the common effluent treatment plants (CETPs) for pre-treatment of the domestic and industrial effluents before entering into the river stream can help in improving the water quality of this river.

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STUDY OF WATER QUALITY PARAMETERS ON SABARI RIVER AT SITE KONTA

Sabari river merging into Godavari near Kunavaram, Khammam district

KRISHNA & GODAVARI BASIN ORGANISATION

CENTRAL WATER COMMISSION

HYDERABAD

Prepared By

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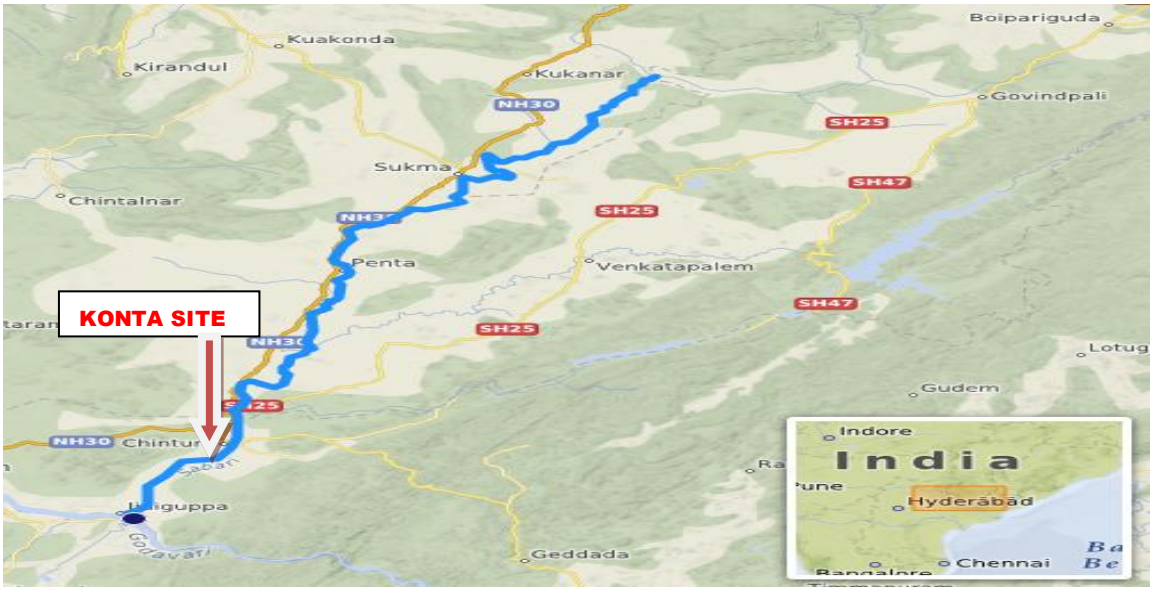
Table of Contents

Introduction:

Sabari River is one of the main tributaries of Godavari. It originates from the western slopes of Eastern Ghats in Odisha state from Sinkaram hill ranges at 1370 m MSL. The Sabari river basin receives nearly 1250 mm annual average rainfall. It forms common boundary between Chhattisgarh and Odisha states and later enters into Andhra Pradesh to merge with River Godavari.

Sileru River is the major tributary of Sabari which joins Sabari River at tri-junction boundary point of Andhra Pradesh, Chhattisgarh and Odisha. Central water Commission has water quality monitoring station on Sabari River at site konta of Dantewara district Chhattisgarh.



Flowing Path of River Sabari

Study Area:

Water Quality Site description and sample collection:

Central water Commission was monitoring water quality at site konta since 5.05.1968 at the left bank of Sabari River under Bhadrachalam sub-division control of Lower Godavari Division Hyderabad. Surface water samples were collected from river Sabari at site konta which lies at latitude 17°47'56" and longitude 81°23'34". This site is designated as Trend station due to influence of human activity. So water quality is monitored twelve in a year. Water samples from the site were collected in one plastic bottle for analysis of physicochemical parameters and in sterile glass bottles for DO & BOD analysis and

transported to the laboratory in ice-boxes, processed within 1-4 hrs and stored at 4-5°C for further analysis.

Following Physicochemical properties were studied pH, Electrical Conductivity, Dissolved Oxygen, Biochemical Oxygen Demand, Chloride and Sulphate of water samples data is considered for study the water Quality seasonal Average from 2009-2019 period annually. Water quality year commences from 1st June of the calendar year and extends to 31st may of the next calendar and covers one complete hydrological cycle. Every water quality year is split in to three seasons as Flood, winter and summer of which average values are extracted to predict the water quality. Flood seasons covers from June to October, winter seasons covers from November to February and summer season covers from March to May of one cycle/year.

Water Quality Standards:

The Physico-chemical parameters like pH, electrical conductance, Chloride, Sulphate, Dissolved Oxygen and Bio-chemical Oxygen demand are main constituents defining the quality of river water in surface water. Presence of these parameters in river water beyond the permissible limit is considered as polluted river water quality. CPCB has identified water quality requirements in terms of a few chemical characteristics, known as primary water quality criteria (Table 1).

Further, Bureau of Indian Standards (BIS) known as Indian Standard Institute (ISI) vide its document BIS 10500:2012 has recommended water quality standards for drinking water (Table 2).

Table 1: Designated Best Uses of Water by CPCB

Designated Best Use	Class	Criteria
Drinking Water Source without conventional treatment but after disinfection	**A**	1.Total Coliforms Organism MPN/100 ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6 mg/L or more 4. Biochemical Oxygen Demand 5 days 20 °C, 2 mg/L or less
Outdoor bathing (Organized)	**B**	1.Total Coliforms Organism MPN/100 ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5 mg/L or more 4. Biochemical Oxygen Demand 5 days 20 °C, 3 mg/L or less
Drinking water source after conventional treatment and disinfection	**C**	1. Total Coliforms Organism MPN/100 ml shall be 5000 or less 2. pH between 6 and 9 3. Dissolved Oxygen 4 mg/L or more 4. Biochemical Oxygen Demand 5 days 20 °C, 3 mg/L or less
Propagation of Wild life and Fisheries	**D**	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4 mg/L or more 3. Free Ammonia (as N) 1.2 mg/L or less
Irrigation, Industrial Cooling, Controlled Waste disposal	**E**	1. pH between 6.0 and 8.5 2. Electrical Conductivity at 25 °C micro mhos/cm, maximum 2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2 mg/L
	Below-E	Not meeting any of the A, B, C, D & E criteria

Table 2: Drinking Water Quality Standards, BIS: 10500, 2012*

S. No.	Characteristic	Requirement (Acceptable Limit)	Permissible limit in the absence of Alternate source
Essential Characteristics			
1	Colour, Hazen units, Max	5	15
2	Odour	Agreeable	Agreeable
3	Taste	Agreeable	Agreeable
4	Turbidity NTU, Max	1	5
5	pH Value	6.5 -8.5	No relaxation
6	Total Hardness (as $CaCO_3$) mg/L, Max.	200	600
7	Iron (as Fe), mg/L, Max	0.3	No relaxation
8	Chlorides (as Cl), mg/L, Max	250	1000
9	Residual free chlorine, mg/L, Minimum	0.2	1.0
Desirable Characteristics			
10	Total Dissolved solids, mg/L, Max	500	2000
11	Calcium (as Ca) mg/L, Max.	75	200
12	Magnesium (as Mg) mg/L, Max	30	100
13	Copper (as Cu), mg/L, Max	0.05	1.5
14	Manganese (as Mn) mg/L, Max	0.1	0.3
15	Sulphates (as SO_4), mg/L, Max	200	400
16	Nitrate (as NO_3) mg/L, Max.	45	No relaxation
17	Fluorides (as F), mg/L, Max	1	1.5
18	Ammonia (as total ammonia-N) mg/L	0.5	No relaxation
19	Mercury (as Hg), mg/L, Max	0.001	No relaxation
20	Cadmium (as Cd), mg/L, Max	0.003	No relaxation
21	Selenium (as Se), mg/L, Max	0.01	No relaxation
22	Total Arsenic (as As), mg/L, Max	0.01	No relaxation
23	Cyanides (as CN), mg/L, Max	0.05	No relaxation
24	Lead (as Pb), mg/L, Max	0.01	No relaxation
25	Zinc (as Zn), mg/L, Max	5	15
26	Total Chromium (as Cr), mg/L, Max	0.05	No relaxation
27	Total Alkalinity mg/L, Max	200	600
28	Aluminum (as Al) mg/L, Max	0.03	0.2
29	Boron mg/L, Max	0.5	1.0
30	Mineral oil, mg/L, Max	0.5	
31	Poly Nuclear Aromatic Hydrocarbons, PAH's, mg/L, Max	0.0001	No relaxation
32	Anionic detergents (as MBAS), mg/L, Max	0.2	1
33	Total Coliform	Shall not be detected in any 100 of sample	
36	Phenolic Compounds, mg/L, Max	0.001	0.002

**** Limits have been given for specific parameters only as per Drinking Water Quality Standards, BIS: 10500, 2012.***

Results and Discussions:

The water samples were analyzed for physicochemical characteristics. The physicochemical parameters were analyzed namely, pH, EC, DO, BOD5, Chloride and Sulphate are presented.

pH:

The pH values of the samples ranged from 7.0-8.5, where most of the water samples of all seasons tested in the study were found to be in the permissible range of pH value recommended by several health and pollution control organizations e.g. WHO, CPCB, BIS i.e. 6.5-8.5. The pH of Sabari river was showing alkaline character throughout the study period (2009-2019) in all seasons (Figure 1).

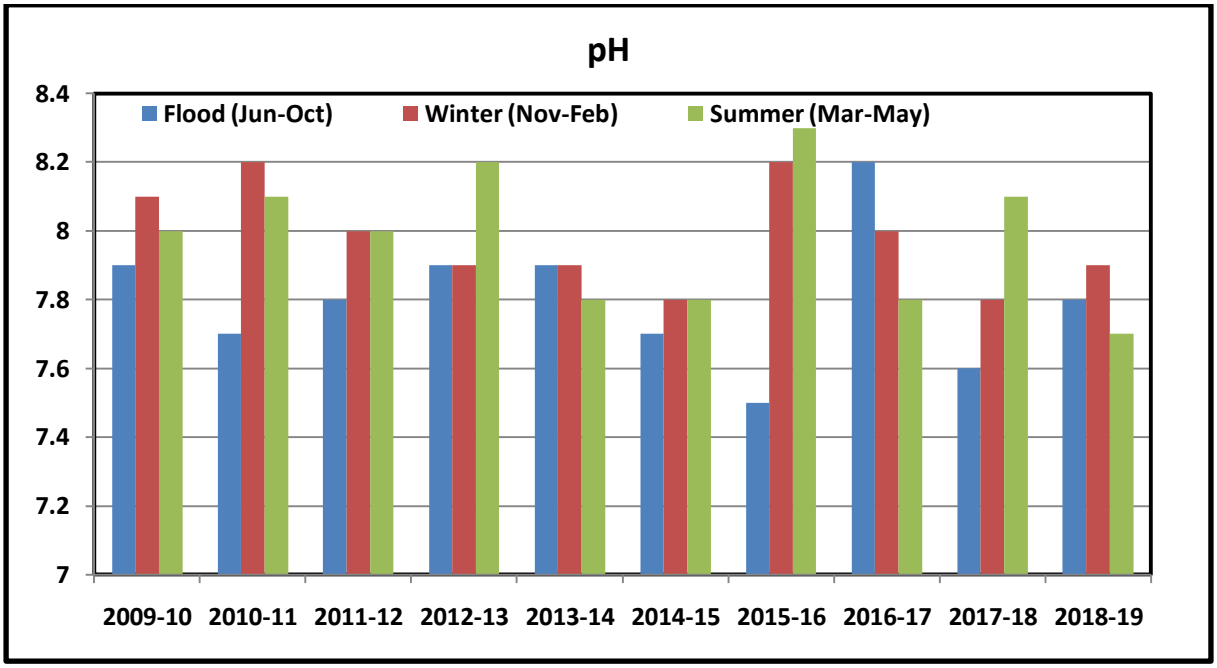


Figure 1: Seasonal Variation of pH values for the period 2009-2019 at site Konta

Electrical conductivity:

Electrical conductivity usually used for indicating the total concentration of ionized constituents of water. Electric conductivity is varying much having high Average value 383 µS/cm in winter season of water Quality year 2015-16 was recorded (Figure 2).

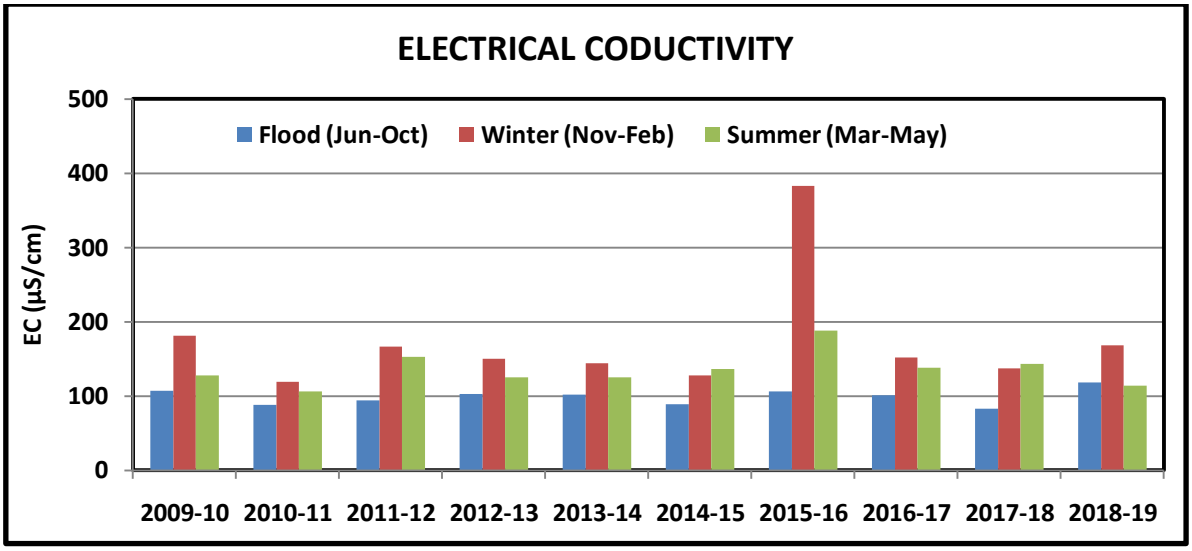


Figure 2: Seasonal Variation of EC values for the period 2009-2019 at site Konta

Dissolved oxygen (DO):

The dissolved oxygen content is one of the most important factors in stream health. Its deficiency directly affects the ecosystem of a river due to bioaccumulation and biomagnifications. The oxygen content in water samples depends on a number of physical, chemical, biological and microbiological processes. DO values also show lateral, spatial and seasonal changes depending on industrial, human and thermal activity in the present study, the value of DO ranged from 6.0 – 8.0 mg/l respectively. As the DO values at all seasons are in desirable limit and can use for drinking water source after disinfection as it meets the class A designated use of water by CPCB.

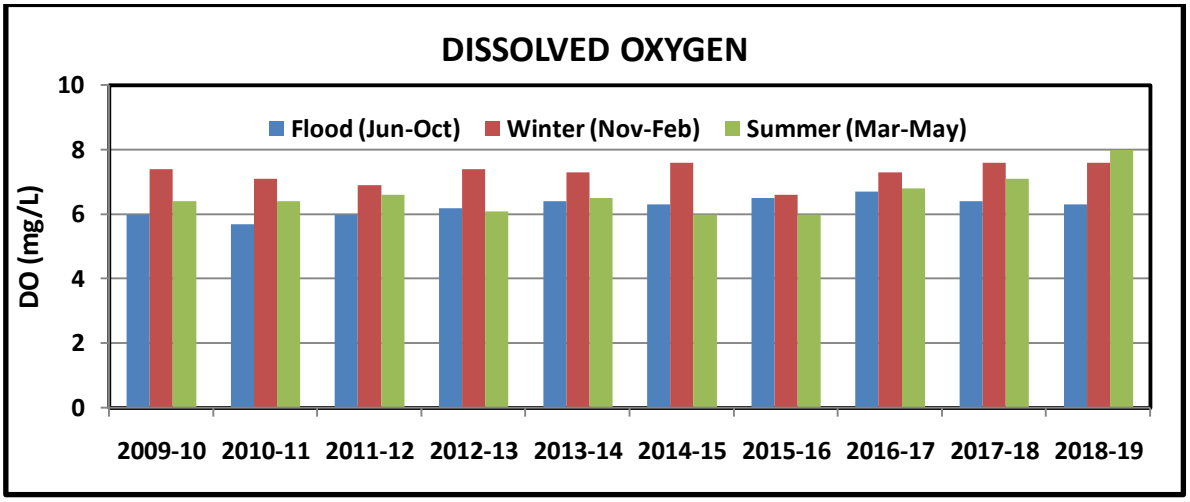


Figure 3: Seasonal Variation of DO values for the period 2009-2019 at site Konta

Biochemical Oxygen Demand (BOD):

BOD is a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in the water and increases the biochemical oxygen demand. The Average value for BOD was found to be maximum 2.6 mg/l in Flood season of water quality year 2017-18 shown in Figure 4.

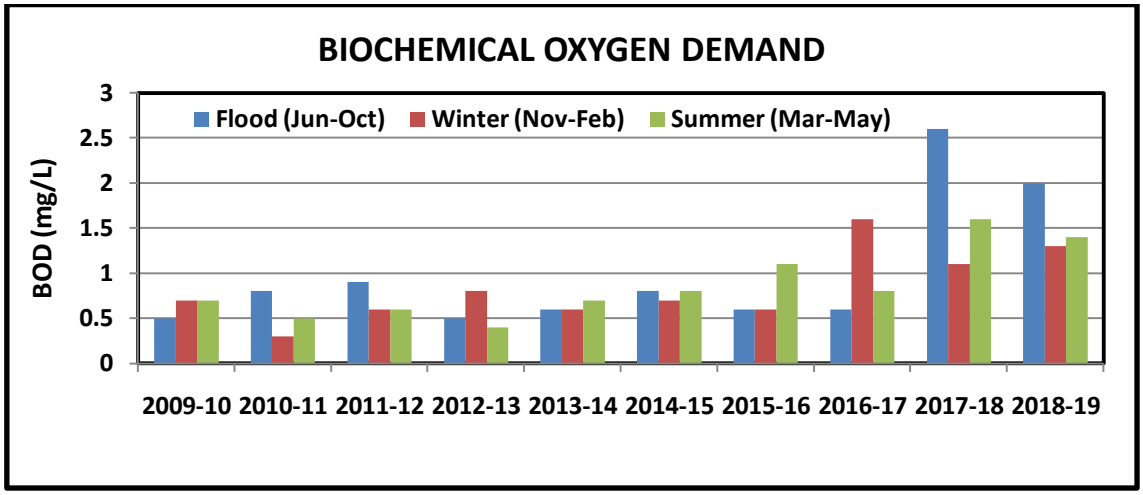


Figure 4: Seasonal Variation of BOD values for the period 2009-2019 at site Konta

Chloride:

It occurs naturally in all types of waters. High concentration of chlorides is considered to be the indicators of pollution due to organic wastes of animal or industrial origin. Chlorides are troublesome in irrigation water and also harmful to aquatic life. The chloride average values showed (Figure 5) very narrow changes in all seasons for the period 2009-2019. Higher concentration of chloride is hazardous to human consumption and creates health problems. Desirable limit of chloride by BIS (2012) for drinking purpose is 250 mg/l.

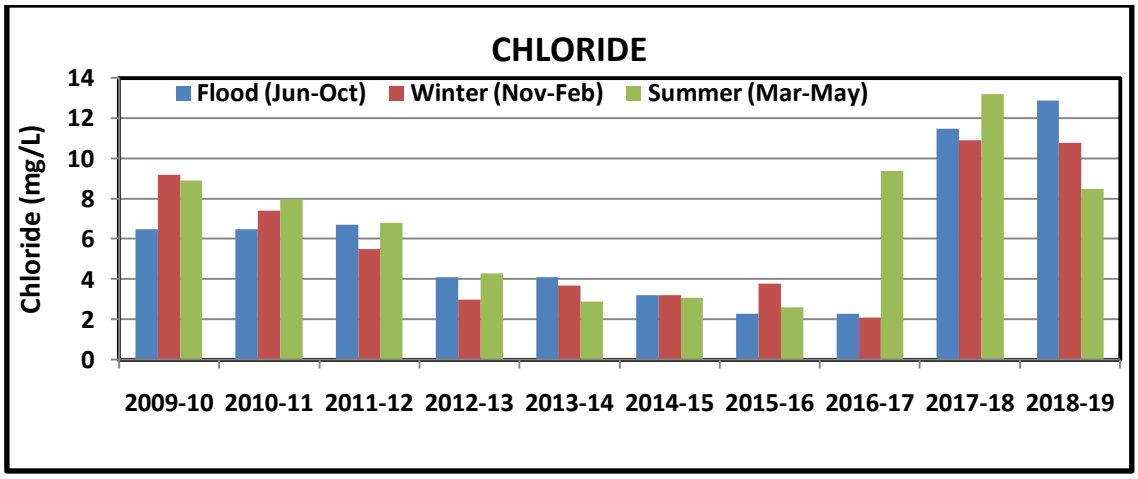


Figure 5: Seasonal Variation of Chloride values for the period 2009-2019 at site Konta

Sulphate:

It is a substance that occurs naturally in drinking water. Sulphate gives a bitter or medicinal taste to water if it exceeds a concentration of 250 mg/l. This may make it unpleasant to drink the water. The sulphate content of natural waters is an important consideration in determining their suitability for public and industrial supplies. SO4 was recorded at all seasons for the period 2009-2019 mg/l were found to be in the permissible range as shown in (Figure 6). High concentration of sulphate could cause respiratory problems in human beings.

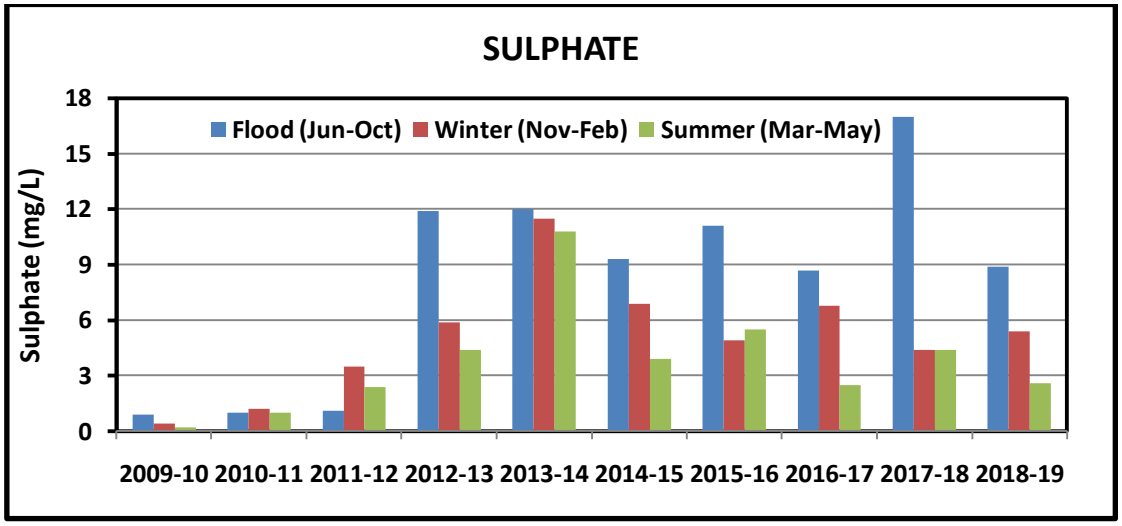


Figure 6: Seasonal Variation of Sulphate values for the period 2009-2019 at site Konta

Table 3: Seasonal average values of physicochemical parameters studied at site konta of river sabari

SEASON	PARAMETER	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
FLOOD	pH	7.9	7.7	7.8	7.9	7.9	7.7	7.5	8.2	7.6	7.8
	EC (µS/cm)	107	88	94	103	102	89	106	101	83	118
	DO (mg/l)	6	5.7	6	6.2	6.4	6.3	6.5	6.7	6.4	6.3
	BOD(mg/l)	0.5	0.8	0.9	0.5	0.6	0.8	0.6	0.6	2.6	2
	CHLORIDE(mg/l)	6.5	6.5	6.7	4.1	4.1	3.2	2.3	2.3	11.5	12.9
	SULPHATE(mg/l)	0.9	1	1.1	11.9	12	9.3	11.1	8.7	17	8.9
WINTER	pH	8.1	8.2	8	7.9	7.9	7.8	8.2	8	7.8	7.9
	EC(µS/cm)	181	119	166	150	144	128	383	152	137	168
	DO(mg/l)	7.4	7.1	6.9	7.4	7.3	7.6	6.6	7.3	7.6	7.6
	BOD(mg/l)	0.7	0.3	0.6	0.8	0.6	0.7	0.6	1.6	1.1	1.3
	CHLORIDE(mg/l)	9.2	7.4	5.5	3	3.7	3.2	3.8	2.1	10.9	10.8
	SULPHATE(mg/l)	0.4	1.2	3.5	5.9	11.5	6.9	4.9	6.8	4.4	5.4
SUMMER	pH	8	8.1	8	8.2	7.8	7.8	8.3	7.8	8.1	7.7
	EC(µS/cm)	128	106	153	125	125	136	188	138	143	114
	DO(mg/l)	6.4	6.4	6.6	6.1	6.5	6	6	6.8	7.1	8
	BOD(mg/l)	0.7	0.5	0.6	0.4	0.7	0.8	1.1	0.8	1.6	1.4
	CHLORIDE(mg/l)	8.9	8	6.8	4.3	2.9	3.1	2.6	9.4	13.2	8.5
	SULPHATE(mg/l)	0.2	1	2.4	4.4	10.8	3.9	5.5	2.5	4.4	2.6

Conclusion:

- The seasonal average values indicate that during flood season, river water is more affected than during winter & summer. This could be due to the fact that the microbial activity gets increased thereby keeping DO level at a very satisfactory range during entire flood season.
- The seasonal average values show that the sabari river waters are bacteriologically safe and suitable for growth of any type of crops in general.
- The water quality of river sabari and its tributary sileru stream indicates that pH and conductivity are meeting the desired water quality criteria.
- Water quality seasonal average results clearly showed that above water quality parameters studied are within the permissible limit in all seasons since ten years time period.
- To sustaining the desired level of water quality of river sabari and stretches the municipalities and industries need to treat their wastewater and effluent before discharging.

MINISTRY OF JAL SHAKTI
GOVERNMENT OF INDIA

KRISHNA & GODAVARI BASIN ORGANISATION

CENTRAL WATER COMMISSION

HYDERABAD

STUDY OF SEASONAL VARIATION OF WATER QUALITY PARAMETERS ON TUNGABHADRA RIVER AT SITE MANTRALAYAM

By

Mallula Rupavathi

Senior Research Assistant

KGRWQL

Introduction

Tungbhadra River is a holy river in the south india that flows from Karnataka to Andhra Pradesh. The river is formed when Tunga and Bhadra rivers meet, thus, giving it the name TungaBhadra. Tungabhadra river was earlier known by the name Pampa. Tourists visiting the Tungabhadra river can explore innumerable idols of Lord Shiva.

Mantralayam is a pilgrim village located in Kurnool district in Andhra Pradesh. It lies on the banks of the Tungabhadra River on the border with neighbouring Karnataka state. The village is known for the brindavan of Raghavendra Swami, a saint who lived in 17th Century and who entered into a samadhi alive in front of his disciples. Thousands of people visit the Raghavendra *Matth* and temples which are located on the banks of Tungabhadra River.

Tungbhadra River

Site description and sample collection:

Central water Commission was monitoring water quality at site mantralayam since 01.08.1977 at the right bank of tungabadra river under Kurnool sub-division control of Lower Krishna Division Hyderabad. Surface water samples were collected from Tungabhadra River at site Mantralayam which lies at latitude 15°56'43" and longitude 77°25'38". This site is designated as Trend station due to influence of human activity. So water quality is monitored twelve in a year. Water samples from the site were collected in one plastic bottle for analysis of physicochemical parameters and in sterile glass bottle for bacteria and 300 ml glass bottle

for DO & BOD analysis and transported to the laboratory in ice-boxes, processed within 1-4 hrs and stored at 4-5°C for further analysis.

Present study focused on:

Following Physicochemical properties were studied pH, Electrical Conductivity (EC), Dissolved Oxygen (D.O), Biochemical Oxygen Demand (B.O.D), Chloride and Sulphate of water samples. The data is considered for the study of seasonal variation of water Quality since 2013-2019. Water quality year commences from 1st June of the calendar year and extends to 31st may of the next calendar and covers one complete hydrological cycle. Every water quality year is split in to three seasons as Flood (June to October), winter (November to February), and summer (March to May) of which average values are extracted to predict the water quality.

Results and Discussions:

The water samples were analyzed for physicochemical characteristics. The physicochemical parameters were analyzed namely, pH, EC, D.O, B.O.D (5 days incubation at 20^{o} C), Chloride and Sulphate are presented.

pH:

The pH values of the samples are between the ranges 7.2-8.5. The most of the water samples of all seasons tested in the study were found to be in the permissible range of pH value recommended by several health and pollution control organizations such as WHO, CPCB, BIS i.e. 6.5-8.5. The pH of Tungabhadra river was showing alkaline character throughout the study period (2013-2019) in all Seasons (Figure 1).

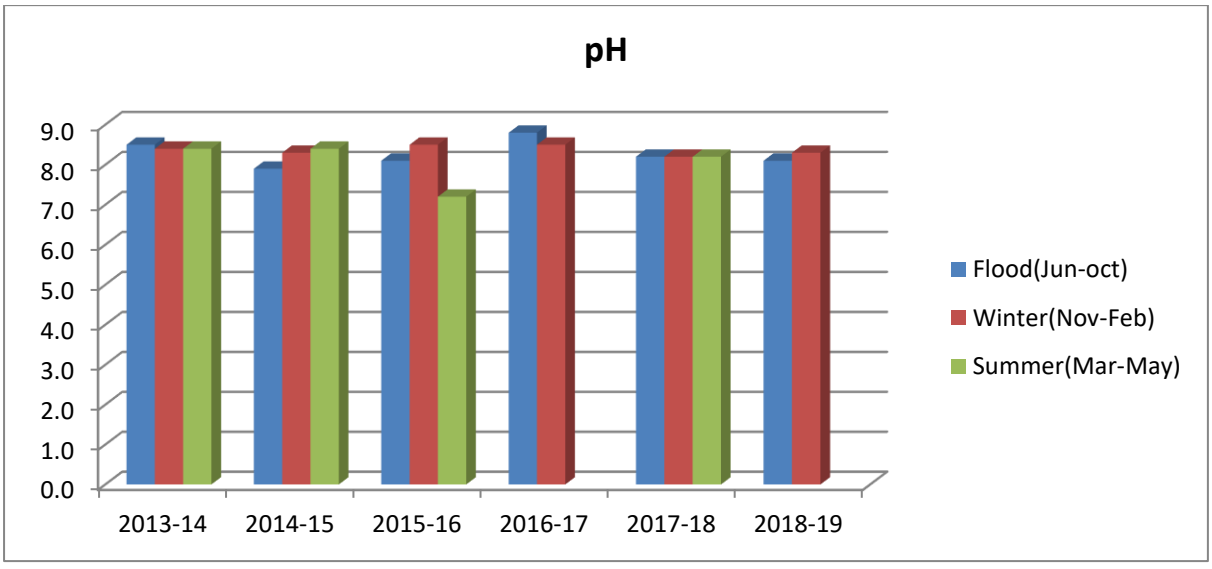


Figure 1: Average Seasonal Variation of pH values for the period 2013-2019 at site Mantralayam

Electrical conductivity:

Electrical conductivity usually used for indicating the total concentration of ionized constituents of water. Electric conductivity is varying much having high Average value 1781µS/cm in winter season of water Quality year 2015-16 was recorded (Figure 2).

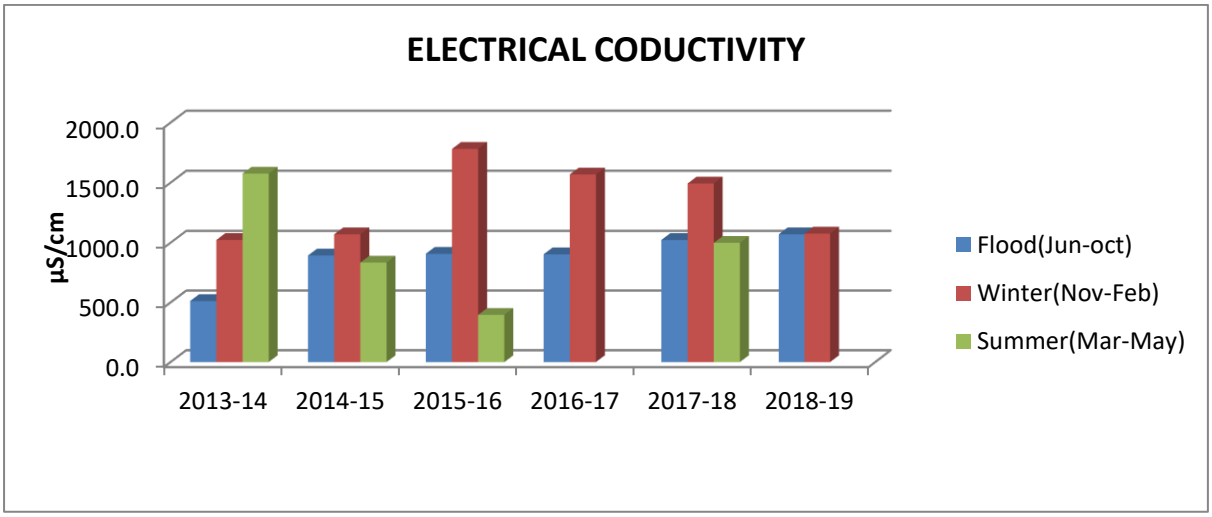


Figure 2: Average Seasonal Variation of EC values for the period 2013-2019 at site Mantralayam

Dissolved oxygen (DO):

The dissolved oxygen content is one of the most important factors in stream health. Its deficiency directly affects the ecosystem of a river due to bioaccumulation and biomagnifications. The oxygen content in water samples depends on a number of physical, chemical, biological and microbiological processes. DO values also show lateral, spatial and seasonal changes depending on industrial, human and thermal activity. In the present study, the value of D.O ranged between 4.3 – 6.6 mg/l.

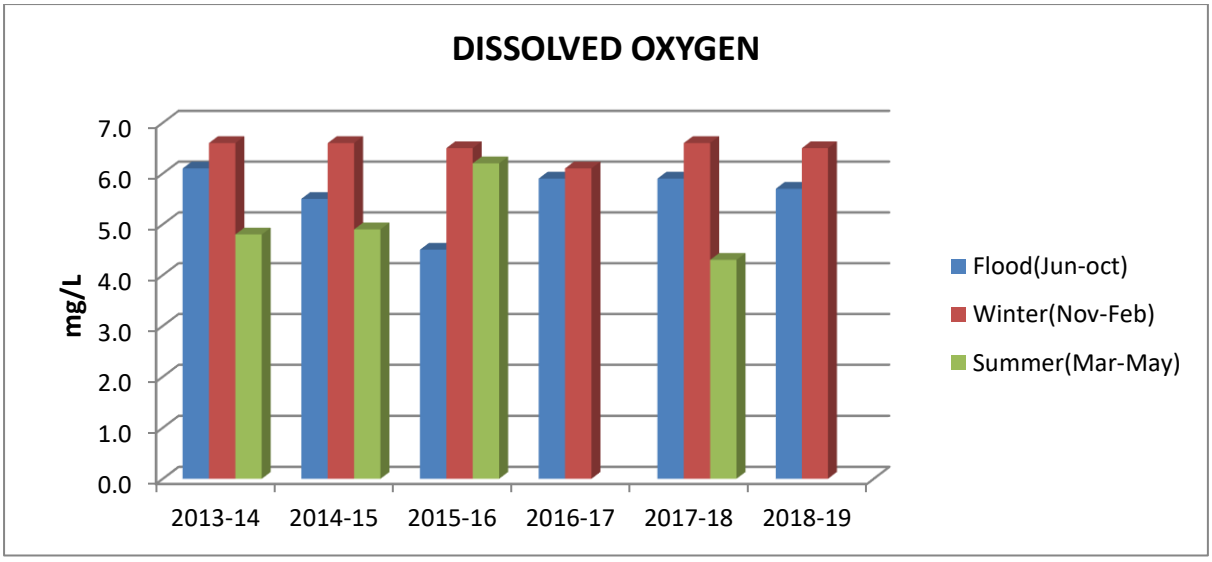


Figure 3: Average Seasonal Variation of DO values for the period 2013-2019 at site Mantralayam

Biochemical Oxygen Demand (B.O.D):

B.O.D is a measure of the oxygen in the water that is required by the aerobic organisms. The biodegradation of organic materials exerts oxygen tension in the water and

increases the biochemical oxygen demand. The Average value for BOD was found to be maximum 2.0 mg/l in Flood season of water quality year 2015-16 shown in Figure 4.

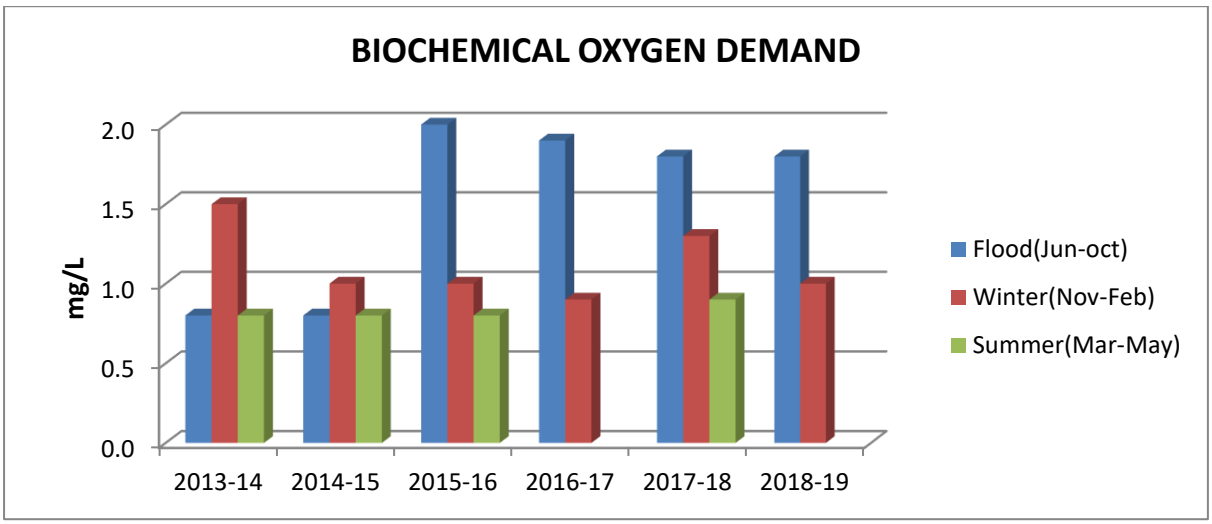


Figure 4: Average Seasonal Variation of BOD values for the period 2013-2019 at site Mantralayam

Chloride:

It occurs naturally in all types of waters. High concentration of chlorides is considered to be the indicators of pollution due to organic wastes of animal or industrial origin. Chlorides are troublesome in irrigation water and also harmful to aquatic life. The chloride average values showed (Figure 5) very narrow changes in all seasons for the period 2013-2019. Higher concentration of chloride is hazardous to human consumption and creates health problems. Desirable limit of chloride by ISI (1991) for drinking purpose is 250 mg/l.

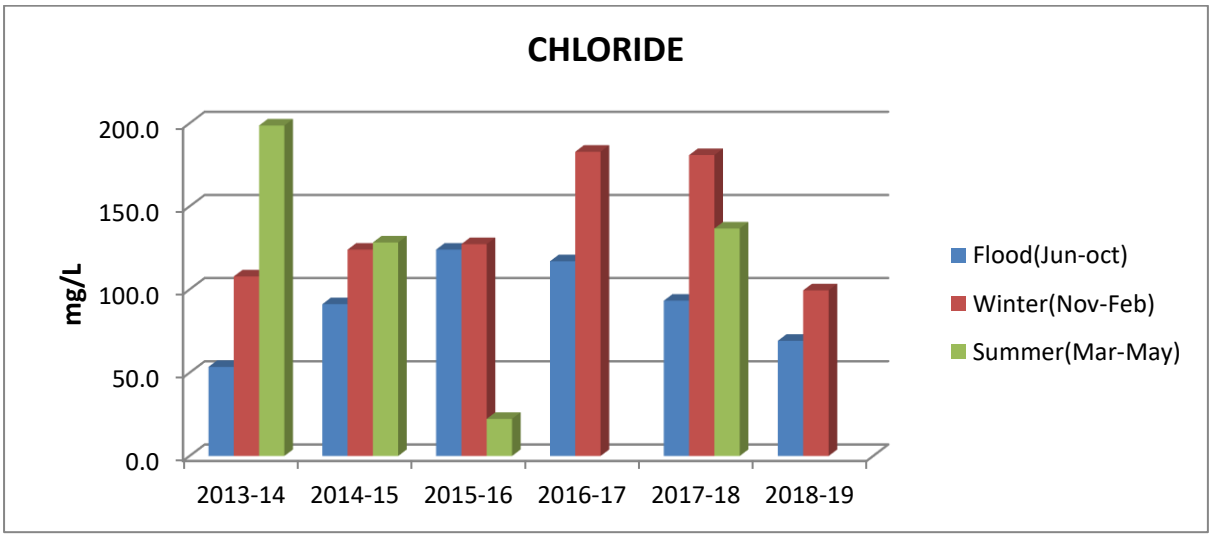


Figure 5: Average Seasonal Variation of Chloride values for the period 2013-2019 at site Mantralayam

Sulphate:

It is a substance that occurs naturally in drinking water. Sulphate gives a bitter or medicinal taste to water if it exceeds a concentration of 250 mg/l. This may make it unpleasant to drink the water. The sulphate content of natural water is an important consideration in determining their suitability for public and industrial supplies. Sulphate was recorded at all seasons for the period 2013-2019 mg/l were found to be in the permissible range as shown in (Figure 6). High concentration of sulphate could cause respiratory problems in human beings.

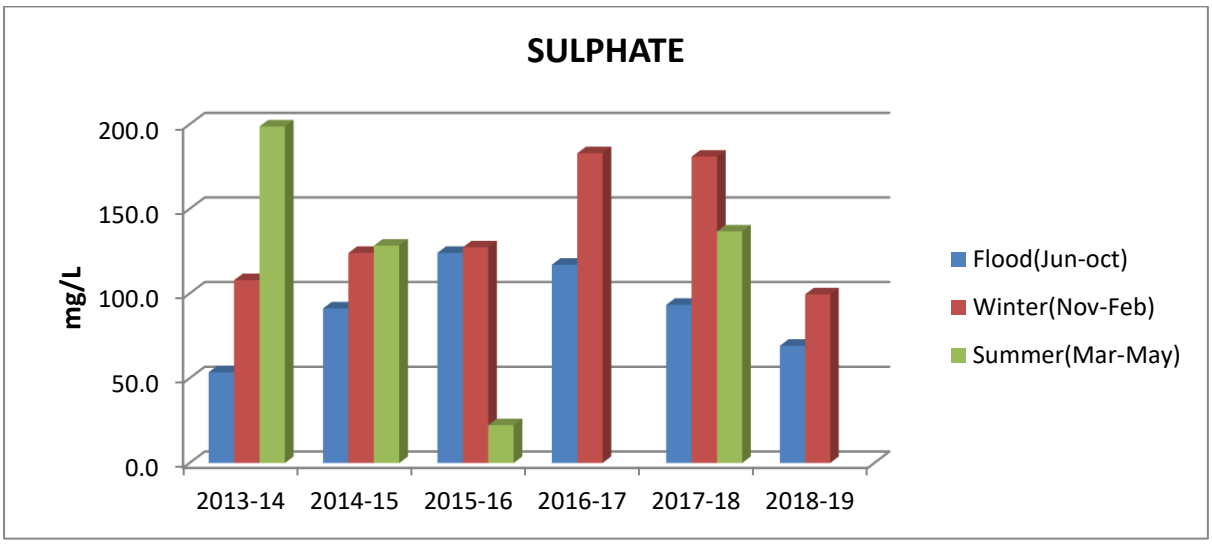


Figure 6: Average Seasonal Variation of Sulphate values for the period 2013-2019 at site Mantralayam

SEASON	PARAMETER	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
FLOOD	pH	8.5	7.9	8.1	8.8	8.2	8.1
	EC (µS/cm)	512.0	893.0	907.0	903.0	1023.0	1070.0
	DO (mg/l)	6.1	5.5	4.5	5.9	5.9	5.7
	BOD(mg/l)	0.8	0.8	2.0	1.9	1.8	1.8
	CHLORIDE(mg/l)	53.5	91.2	124.0	117.0	93.3	69.2
	SULPHATE(mg/l)	55.8	124.4	10.6	10.9	10.4	16.4
WINTER	pH	8.4	8.3	8.5	8.5	8.2	8.3
	EC(µS/cm)	1023.0	1070.0	1781.0	1568.0	1493.0	1076.0
	DO(mg/l)	6.6	6.6	6.5	6.1	6.6	6.5
	BOD(mg/l)	1.5	1.0	1.0	0.9	1.3	1.0
	CHLORIDE(mg/l)	107.9	124.0	127.3	182.9	180.9	99.5
	SULPHATE(mg/l)	95.3	191.9	212.8	288.5	285.4	73.7
SUMMER	pH	8.4	8.4	7.2		8.2	
	EC(µS/cm)	1575.0	834.0	395.0		999.0	
	DO(mg/l)	4.8	4.9	6.2		4.3	
	BOD(mg/l)	0.8	0.8	0.8		0.9	
	CHLORIDE(mg/l)	198.7	128.3	22.3		136.7	
	SULPHATE(mg/l)	191.0	191.3	26.8		165.6	

TABLE: Seasonal average values of physicochemical parameters studied at site Mantralayam of river Tungabhadra

Conclusion:

The seasonal average values indicate that during flood season, river water is more affected than during winter & summer. This could be due to the fact that the microbial activity get increased thereby keeping DO level at a very satisfactory range during entire flood season.

Water quality seasonal average results clearly showed that above water quality parameters studied are within the permissible limit in all seasons since six years time period.

STUDY OF SEASONAL VARIATION IN THE WATER QUALITY OF BHARATAPUZHA RIVER

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South Western Rivers Division, Kochi

INDEX

1.0 INTRODUCTION:

Bharathapuzha is the largest river basin in Kerala. It is spread over two states namely Tamil Nadu and Kerala. Out of 6186 Sq.km. of drainage area, 4400 Sq.km is in Kerala and the remaining 1786 Sq.km lies in Tamil Nadu. Originating in Tamil Nadu, the river flows through a total length of 251 kms. There are 5 water quality stations in this basin viz, Mankaraand Kumbidion the main river, Pudurand Ambarampalayamon its tributary Aliyar, Pulamantholeon its tributary Pulanthodu.(Ref: WQ Year Book CWC)

The main objective of this study is to compare the data for seasonal variation of Water Quality parameters and a comparison with maximum acceptable/Tolerance limit as per Indian standard (Annexure-1 and Annexure-2). The maximum, minimum and average value since inception along with last year (2018-19) average in tabular form is attached as Annexure-3 & 4. The yearly minimum and maximum value is also presented in tabular form as Annexure-5 & 6. .

For this study, the data has been taken which are available with West Flowing Rivers Water Quality laboratory since inception.

Two HO sites of Central Water Commission namely Kumbidi and Mankara on Bharatapuzha River have been taken for this study and the scenario is prepared based on the data available for these 2 sites. As it is merely an interpretation of 2 point data on a river it may not represent the scenario of whole Bharatapuzha river. Data is available for these sites once in two month which means maximum six data available for one year.

2.0 Study location and sampling site:

History Sheet of the two study points on Bharatapuzha River:

Site : KUMBIDI Code : KR000C9	Site : MANKARA Code : KR000K4
State : Kerala District: Palakkad Basin : WFR from Tadri to Kanyakumari Independent River :Bharathapuzha Division : South Western Rivers Division, Kochi Sub-Division :Chaliyar Sub Division, Calicut Drainage Area : 5755 Sq. Km. Latitude : 10°51'16" Longitude : 76°01'12" Zero of Gauge (m) : 4.000 (m.s.l) 01/06/1978 - 31/05/2007 2.000 (m.s.l) 01/06/2007 Date of start : Gauge : 01/06/1978 Discharge : 08/01/1979 Sediment : 24/06/1980 Water Quality: 03/12/1979	State : Kerala District Palakkad Basin : WFR from Tadri to Kanyakumari Independent River :Bharathapuzha Division : South Western Rivers Division, Kochi Sub-Division: South Western Rivers Sub Division-2, Kochi Drainage Area : 2775 Sq. Km. Latitude : 10°45'40" Longitude : 76°29'10" Zero of Gauge (m) : 45.830 (m.s.l) 26/05/1984 - 31/05/1989 45.000 (m.s.l) 01/06/1989 Date of start : Gauge : 26/05/1984 Discharge : 21/06/1985 Sediment : 24/09/2013 Water Quality : 02/06/1986

3.0 Sampling and analysis of River water samples:

The water samples are collected once in two months from Baseline stations (Kumbidi and Mankara), usually on the first working day, from the main flowing portion of the river stream. At each station 1000mL(General), 300mL(DO), 300mL(BOD) and 500mL(Microbiological) river water samples are collected at a point of maximum flow & depth in the cross section at a depth of 20cm to 30cm below the water surface in a polythene/glass bottle with double screw cap. The bottles are labeled with the requisite details of the sample water and sent through a special messenger to the respective water quality laboratory for detailed analysis. Standard methods for the examination of water & waste water (American Public Health Association) is followed for analysis. The data is analysed for the study of seasonal variation of Water Quality and for comparing with acceptable limit as per Indian standard.

4.0 RESULTS AND DISCUSSION:

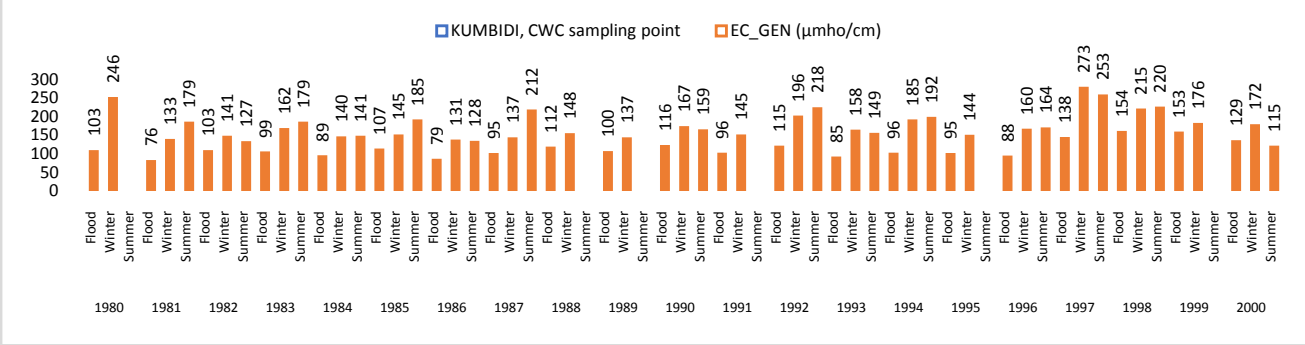
4.1 Electrical Conductivity(EC):

Kumbidi WQ site:

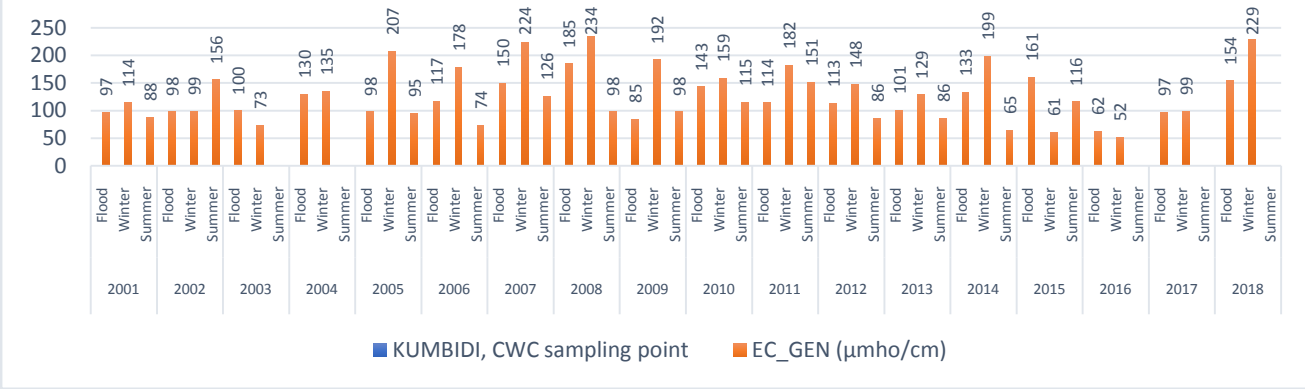
The Electrical Conductivity (EC) for Kumbidi WQ sites lies in the range of 24 to 390 (µmho/cm). The yearly Average values of EC during Non-monsoon (Dry season) is generally higher when compared to the values during monsoon (Wet season).

The maximum, minimum and average value during Non-monsoon is significantly high compared to value during Monsoon season. The EC values are within the maximum tolerance limit.

Graph(1)SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(2):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

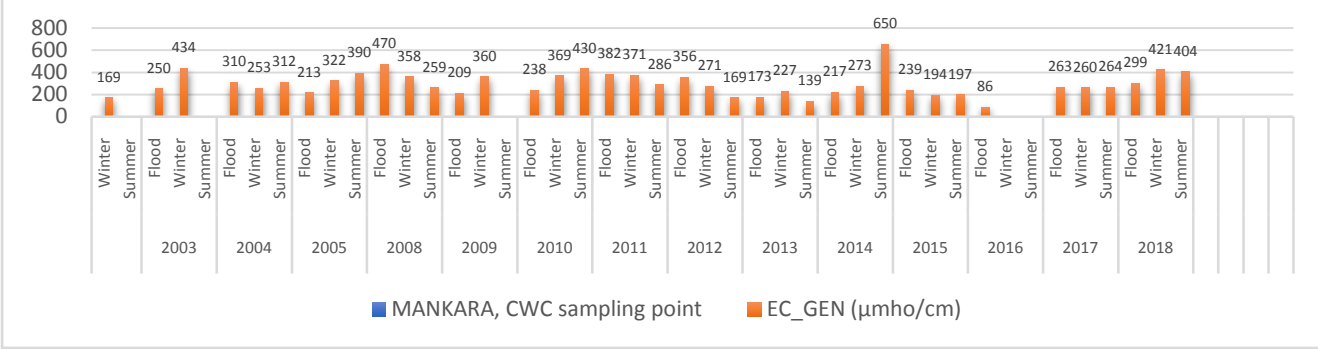


Mankara WQ site:

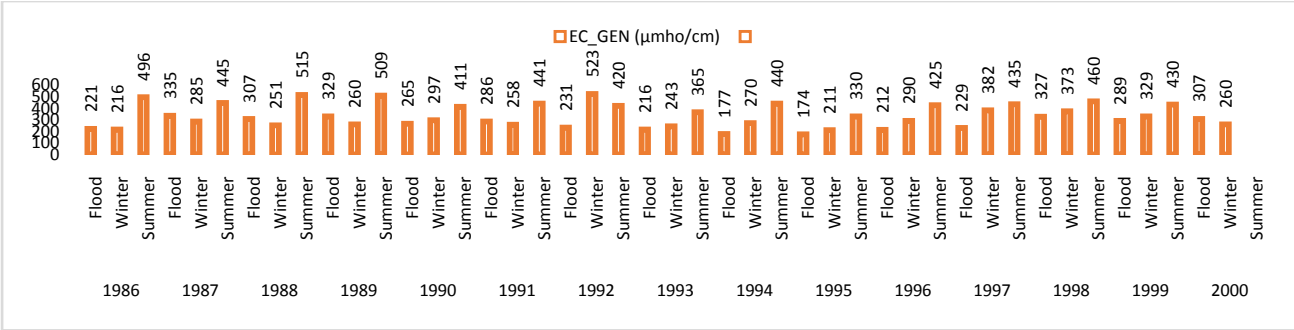
The Electrical Conductivity (EC) for Mankara WQ sites lies in the range of 21 to 900 µmho/cm. The yearly Average values of EC during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

During Non-monsoon maximum, minimum and average value is significantly high compared to Monsoon season. The EC data for Mankara site is within the maximum tolerance limit.

Graph(3):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(4):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



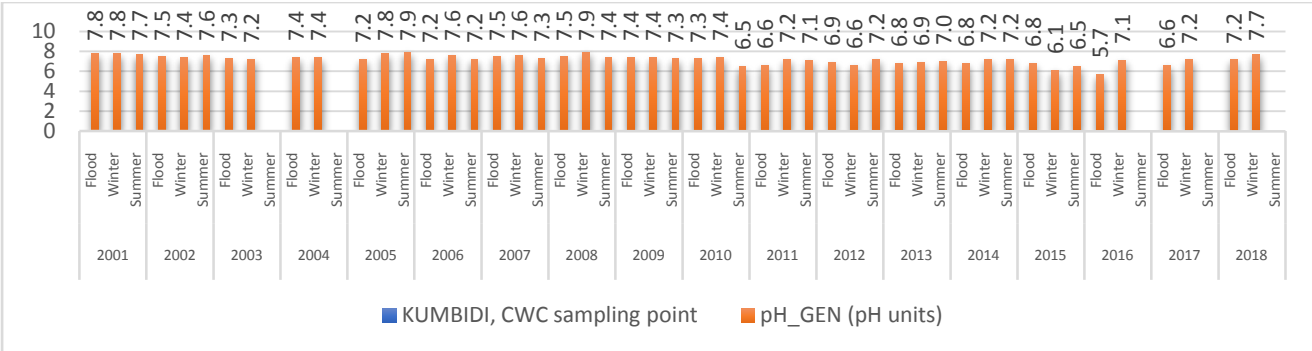
4.2 pH

Kumbidi WQ site:

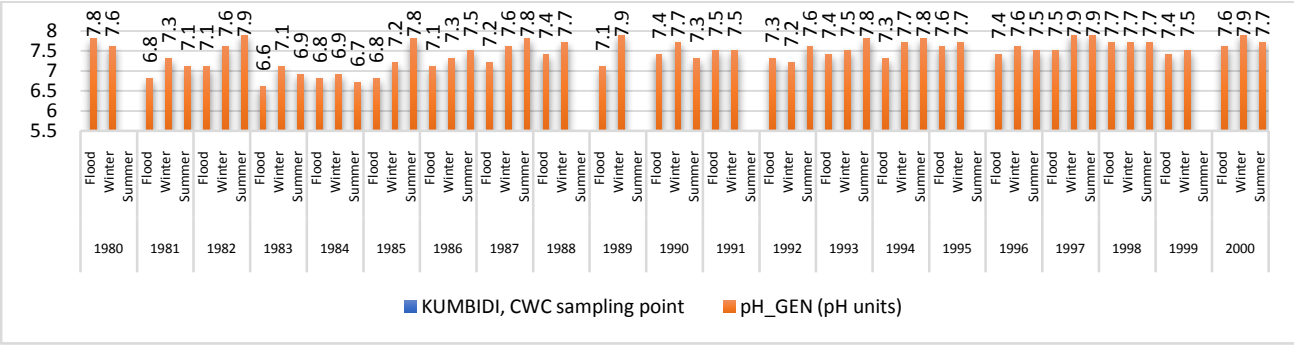
The pH value for Kumbidi WQ site ranges from minimum 5.6 to maximum 8.3 and the yearly Average values lies in the range of 6.5 to 7.9. The yearly Average values of pH during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season).

The pH values during Non-monsoon period is marginally high compared to monsoon season. pH values below tolerance limit has been observed atKumbidi WQ site only for the years 2016-17, 2015-16 and 2011-12 .

Graph(5):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



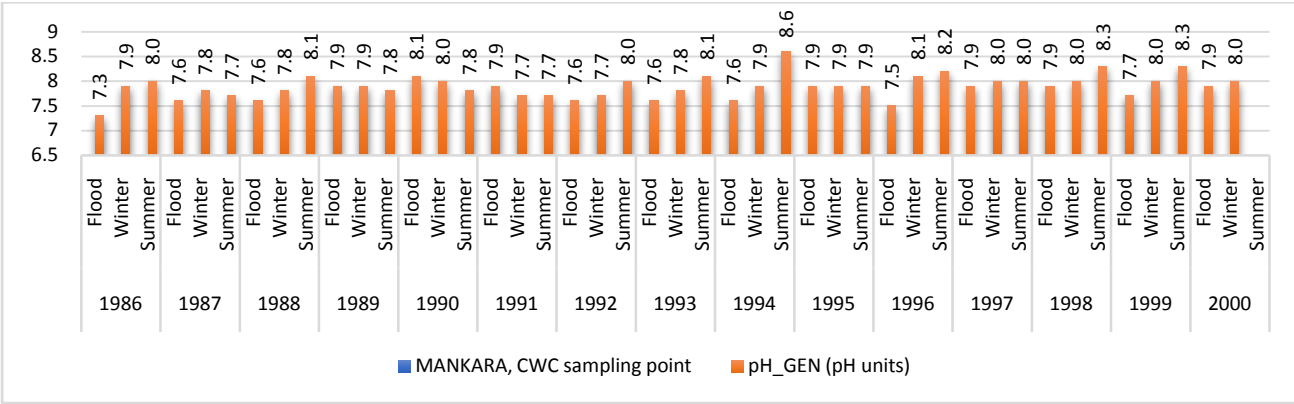
Graph(6):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



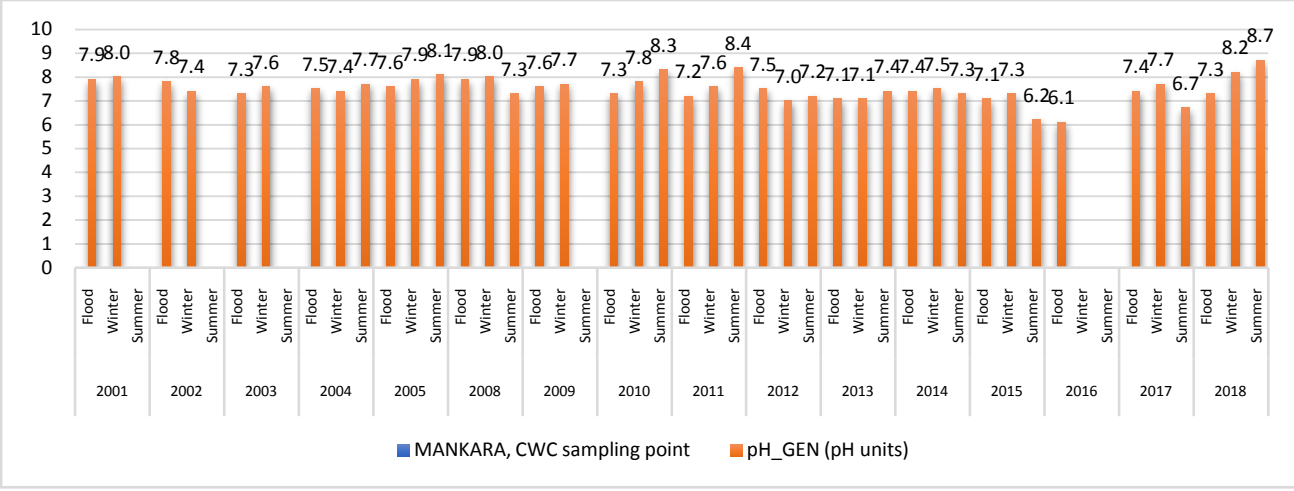
Mankara WQ site:

The pH value for MankaraWQ site ranges from minimum 5.6 to maximum 8.6 and the yearly Average value lies in the range of 7.1 to 8.0 .The yearly Average values of pH during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season). The Non-monsoon pH values for Mankara WQ site are higher than the monsoon period value. pH values are within the tolerance limit. However for the years 2016-17 and 2015-16, it is observed that the values are below the minimum of tolerance limit.

Graph(7):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA RIVER



Graph(8):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA RIVER



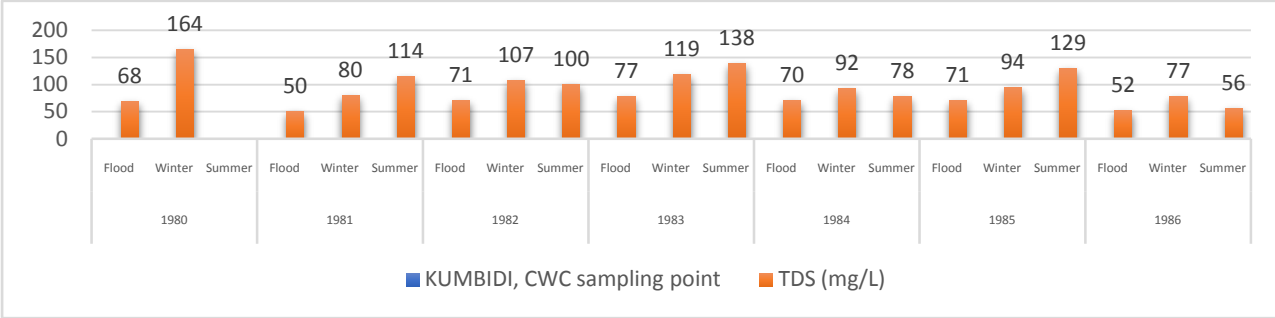
4.3 Total Dissolved Solid(TDS)

Kumbidi WQ site:

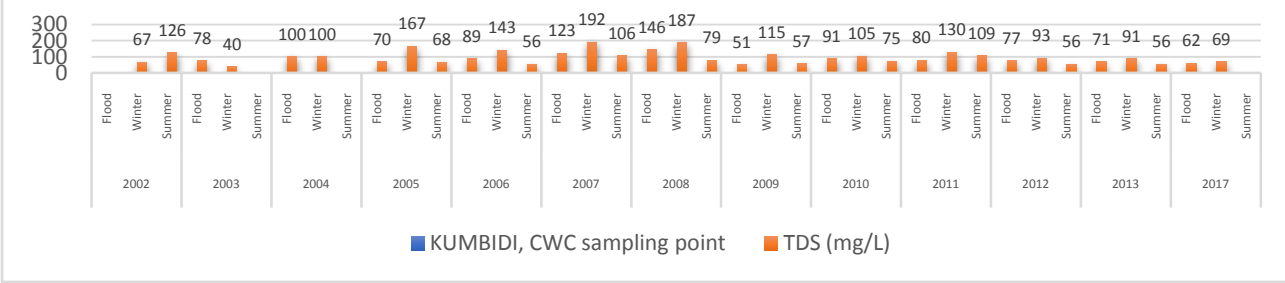
The TDS values for KumbidiWQ site ranges from minimum 26 to maximum 256 mg/L and the yearly Average values lies in the range of 59.0 to 140.3 mg/L. The yearly Average values of TDS during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The average values for TDS is significantly higher during Non-monsoon compared to values during Monsoon season. The maximum and minimum values of TDS are higher during monsoon compared to during Non-monsoon season. The TDS values for Kumbidi WQ sites are within the tolerance limit.

Graph(9):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(10):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

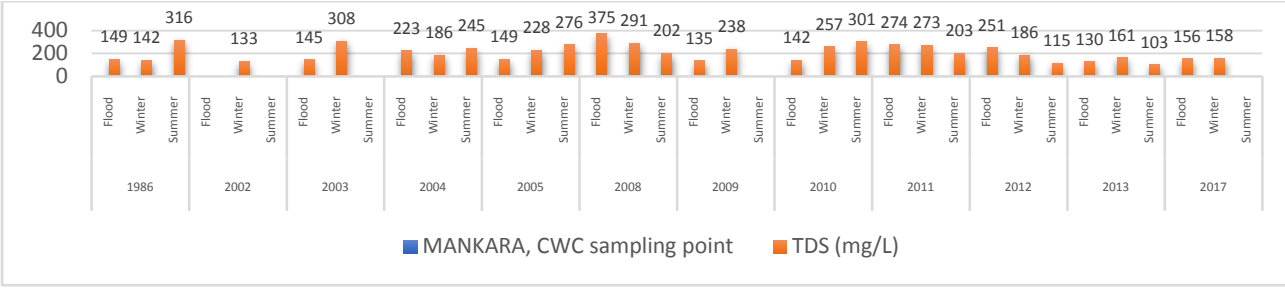


Mankara WQ site:

The TDS values for MankaraWQ site ranges from minimum 36 to maximum 322 mg/L and the yearly Average values lies in the range of 133 to 289.3 mg/L. The yearly Average values of TDS during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The average and minimum values of TDS during Non-monsoon is significantly higher compared to the values during Monsoon season. The maximum value of TDS during monsoon is marginally higher during the Non-monsoon season. The TDS values for Mankara WQ site are within the tolerance limit.

Graph(11):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA RIVER



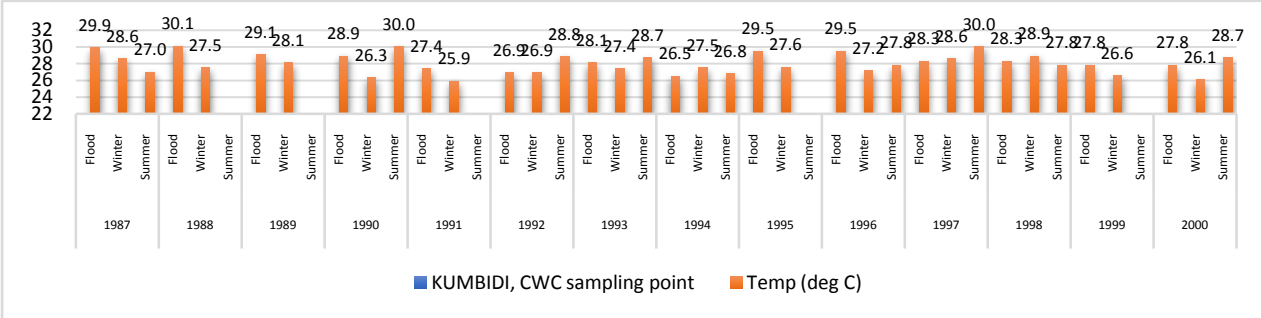
4.4 Temperature

Kumbidi WQ site:

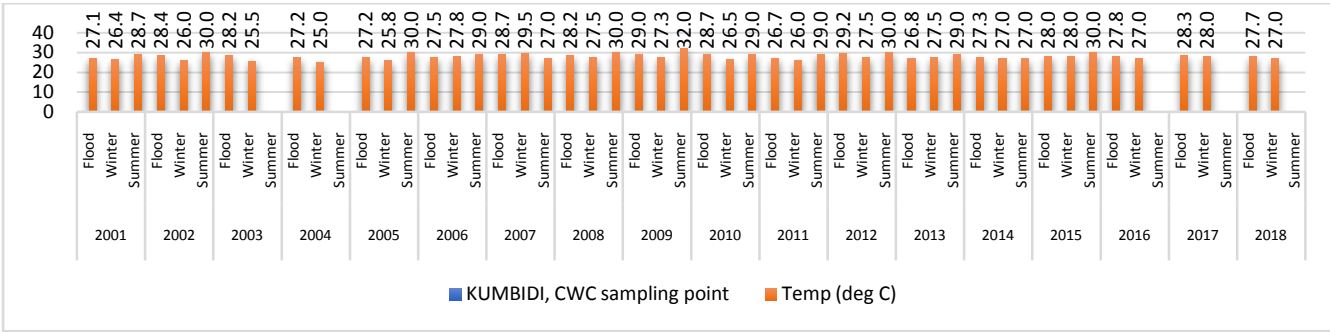
The Temperature values for Kumbidi WQ site ranges from minimum 23 to maximum 32 Deg Celsius and the yearly Average values lies in the range of 25 to 30 Deg Celsius.The yearly Average values of Temperatureduring Non-monsoon (Dry season) is generally lower when compared to the values during monsoon (Wet season).

The maximum, average and minimum and last year average values during monsoon is higher compared to the values during non-monsoon season.

Graph(12):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(13):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

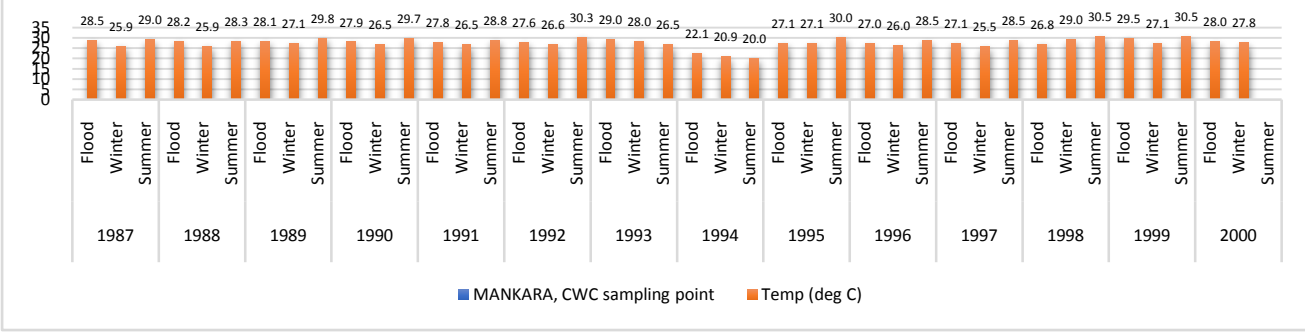


Mankara WQ site:

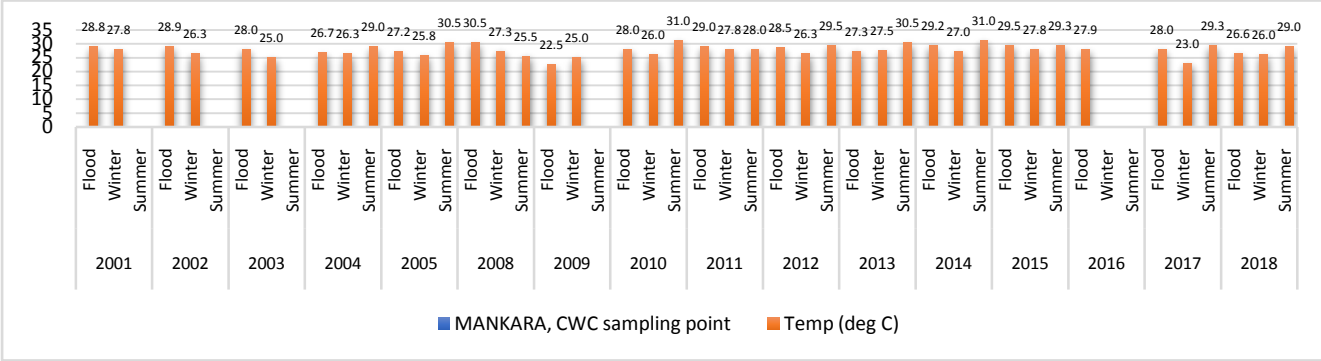
The Temperature values for MankaraWQ site ranges from minimum 17.5 to maximum 35.5 Deg Celsius and the yearly Average values lie in the range of 21.0 to 29.0 Deg Celsius. The yearly Average values of temperature during Non-monsoon (Dry season) is generally lower when compared to the values during monsoon(Wet season) .

The maximum, average and minimum values during Monsoon is higher compared to during non-monsoon season except the last year average value during Non-monsoon which is marginally higher compared to during monsoon season .

Graph(14):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA RIVER



Graph(15):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA RIVER



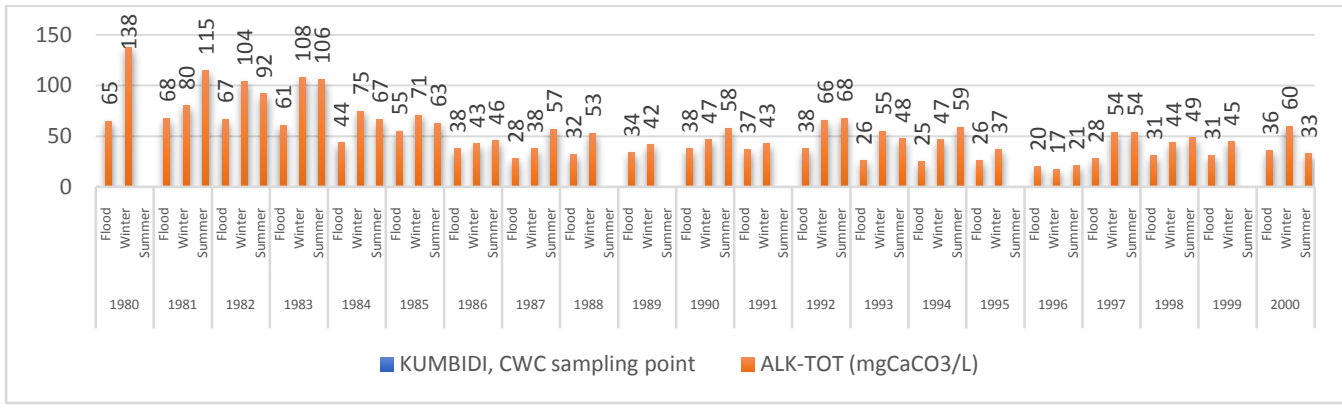
4.5 Tot-Alkalinity

Kumbidi WQ site:

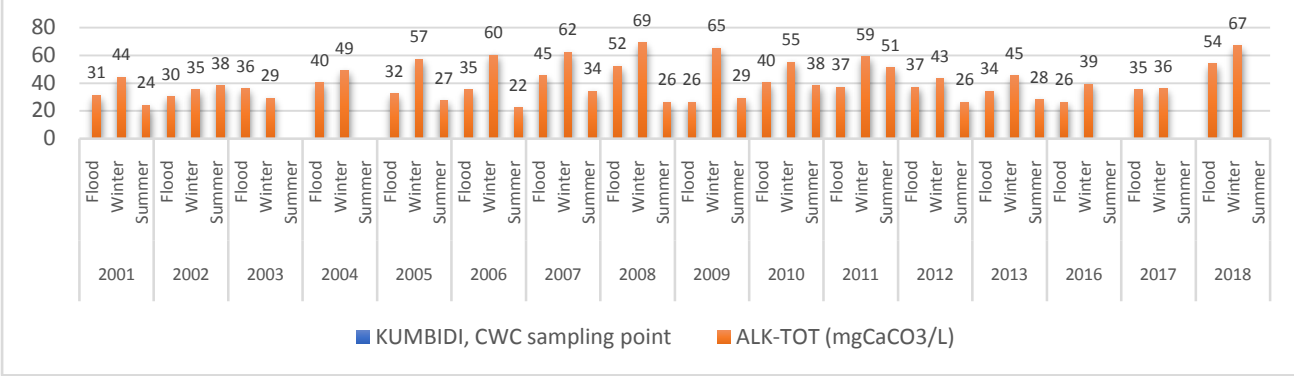
The Tot-Alkalinity values for Kumbidi WQ site ranges from minimum 8 to maximum 159 mg CaCO3/L and the yearly Average values lie in the range of 19.3 to 101.5 mg CaCO3/L.The yearly Average values of Tot-Alkalinity during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season).

The Total alkalinity values for maximum, average and last year average during Non-monsoon is higher compared to during monsoon season. The total alkalinity minimum value during monsoon is higher compared to during Non-monsoon period. The T-Alkalinity for Kumbidi WQ site is within the acceptable limit .

Graph(16):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(17):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

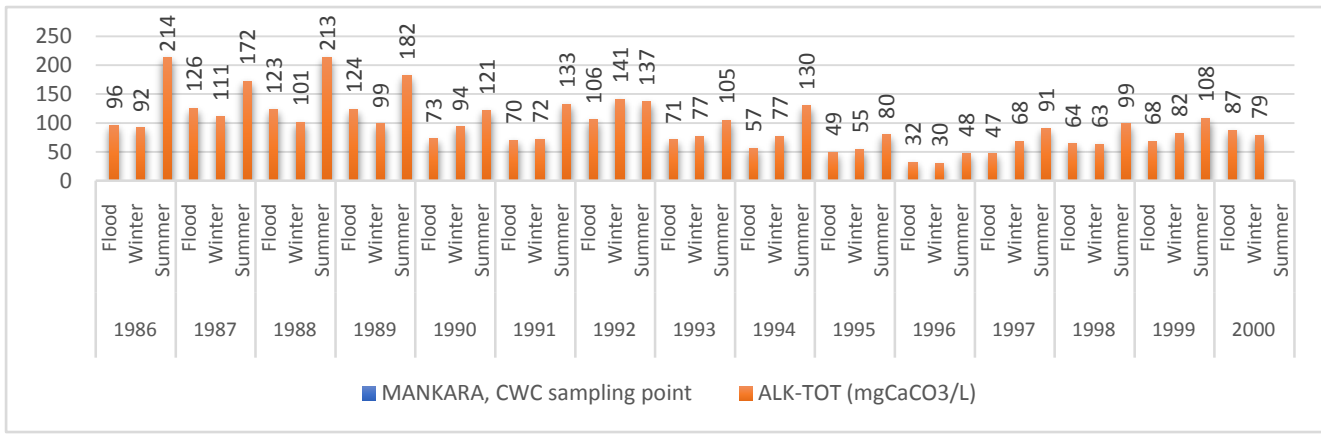


Mankara WQ site:

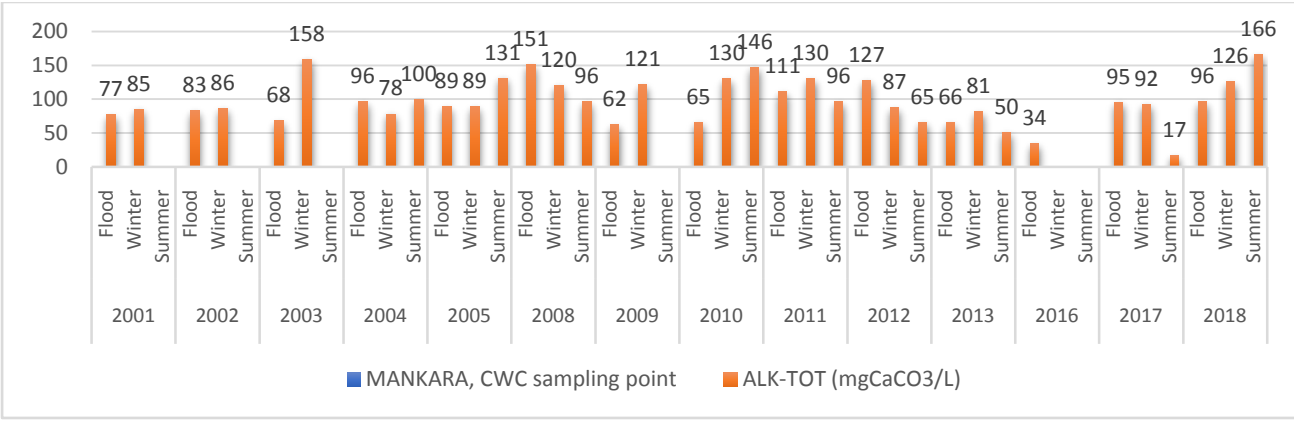
The Tot-Alkalinity values for MankaraWQ site ranges from minimum 17 (Year 2017-18) to maximum 231(Year 1989-90) mg CaCO3/L and the yearly Average values lies in the range of 68 to 145.6 mg CaCO3/L.

The yearly Average values of Tot-Alkalinity during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season). The maximum, average and last year average value during Non-monsoon is higher compared to the values during monsoon season. The minimum value during monsoon is higher compared to during Non-monsoon period. The T-Alkalinity for Mankara WQ site is within the acceptable limit.

Graph(18):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(19):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



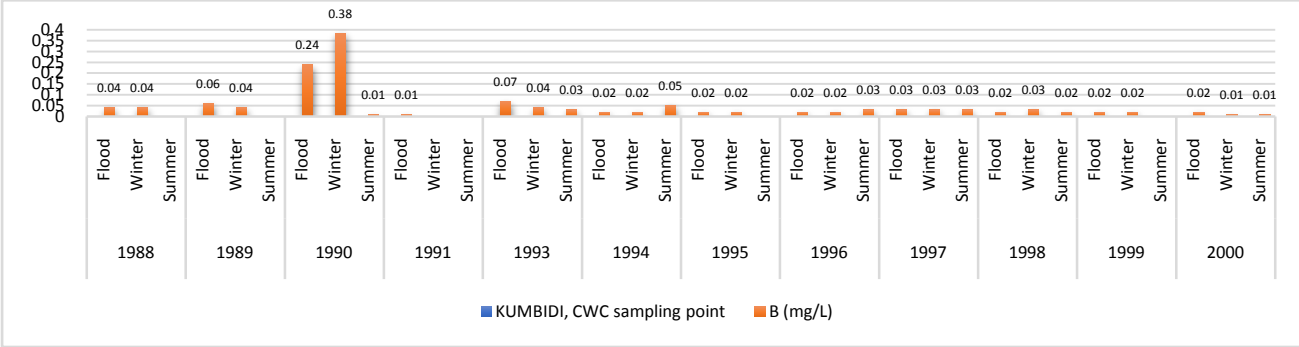
4.6 Boron

Kumbidi WQ site:

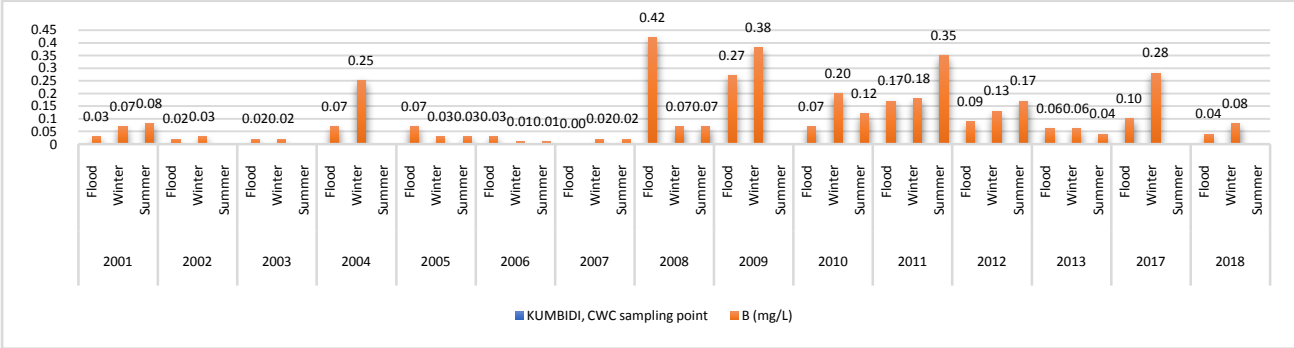
The Boron values for Kumbidi WQ site ranges from minimum 0.01 to maximum 0.46 mg/L (except 0.75mg/L during 1990-91 and 2009-10) and the yearly average value lies in the range of 0.023 to 0.210mg/L. The yearly average values of Boron during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season).

The maximum and last year (2018-19) average of Boron values during Non-monsoon is marginally high compared to during monsoon. The average values since inception during Non-monsoon and monsoon has no difference. The Boron values for Kumbidi WQ site is within the tolerance limit. The values are within the acceptable limit except 0.75mg/L during 1990-91 and 2009-10.

Graph(20):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(21):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

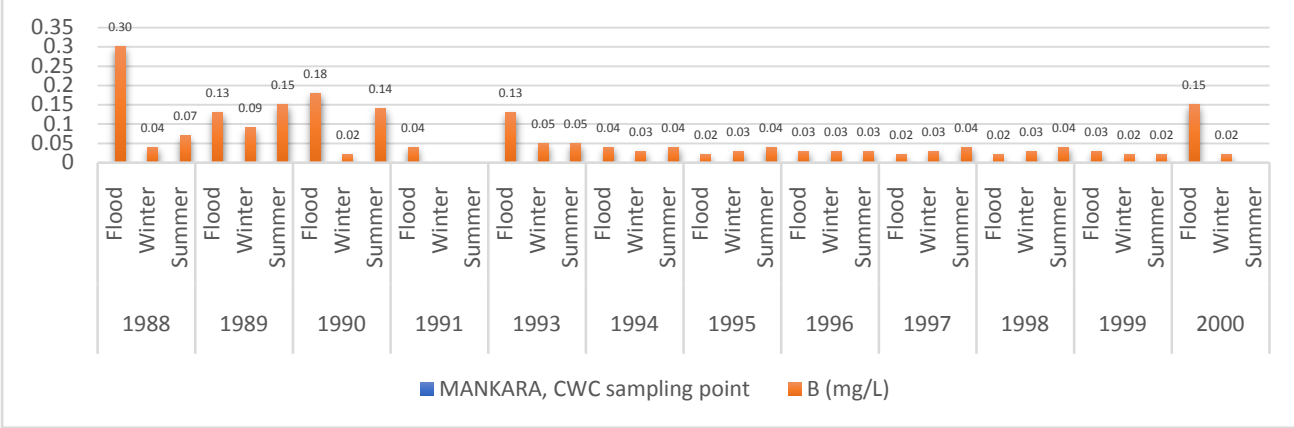


Mankara WQ site:

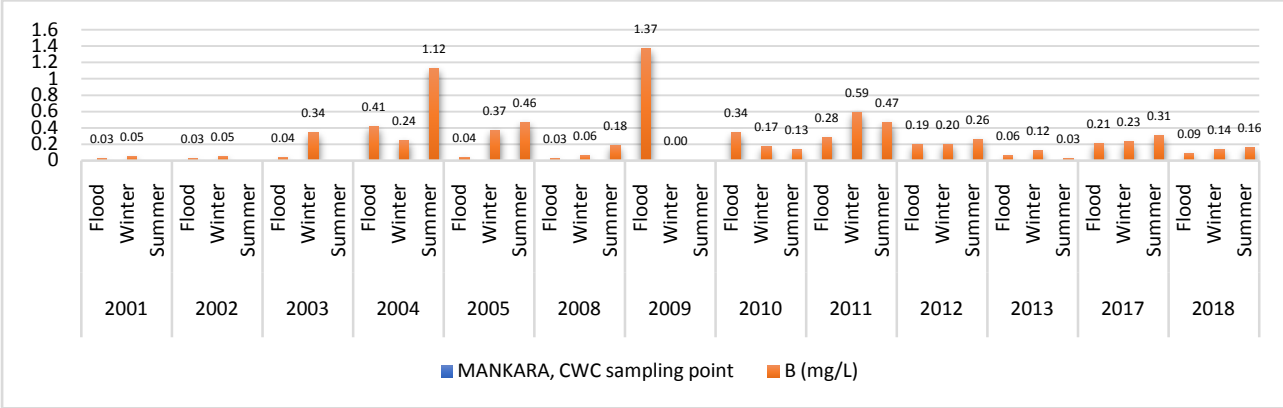
The Boron values for MankaraWQ site ranges from minimum 0.01 to maximum 0.47 mg/L(except 0.66mg/L (2011-12), 1.37mg/L (2009-10) and 1.12mg/L (2004-05) and the yearly average value lies in the range of 0.03 to 0.59 mg/L. The yearly Average values of Boron during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum, average and minimum Boron values during monsoon are marginally high compared to during non-monsoon.The last year (2018-19) average during non-monsoon is higher compared to during monsoon. The Boron values for MANKARA WQ site is within the tolerance limit. The values are within the acceptable limit (except 0.66mg/L (2011-12), 1.37mg/L(2009-10) and 1.12mg/L(2004-05) .

Graph(22):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(23):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



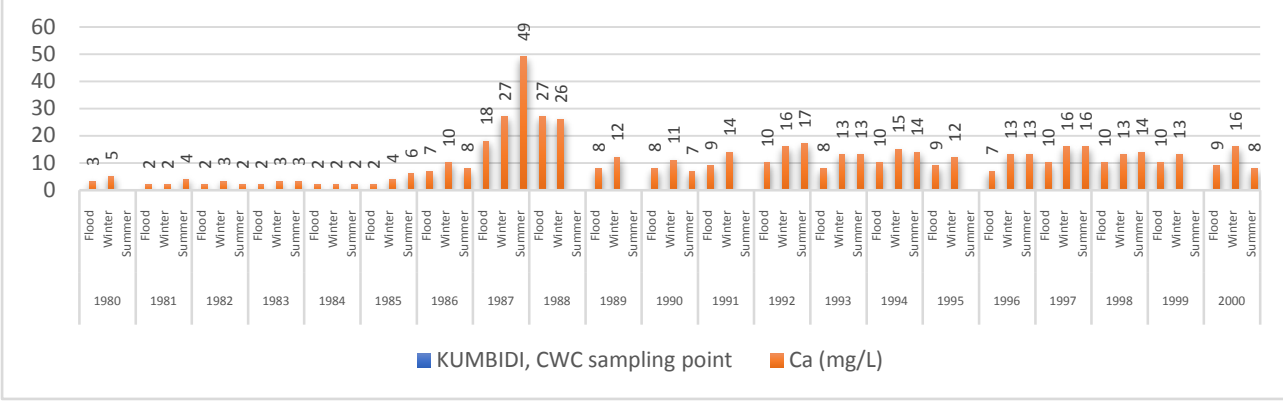
4.7 Calcium

Kumbidi WQ site:

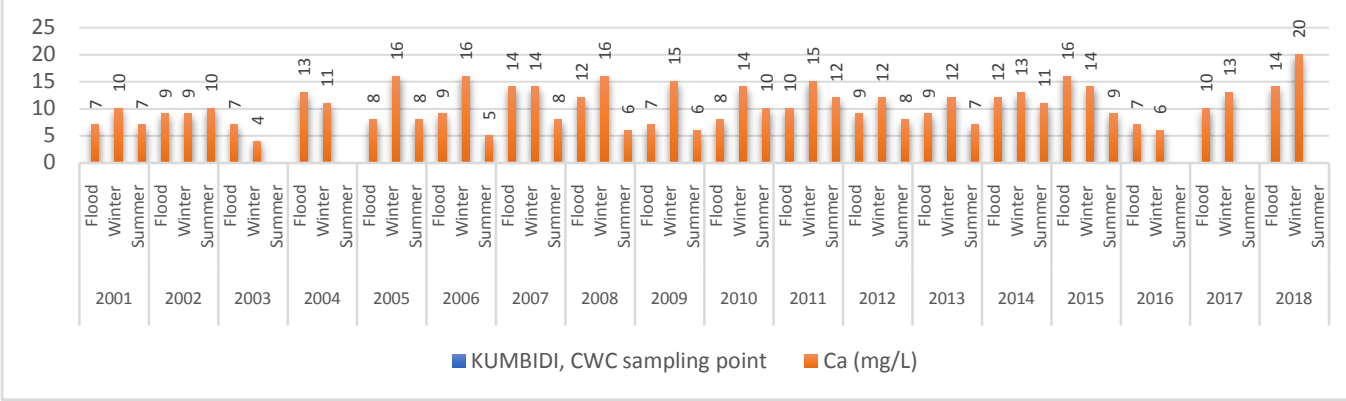
The Calcium value for Kumbidi WQ site ranges from minimum 1 to maximum 62 mg/L and the yearly Average value lies in the range of 2 to 31.3 mg/L. The yearly Average value of Calcium during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum, average and last year average values during Non-monsoon is higher compared to during monsoon and the minimum observed value is same during monsoon and non-monsoon period. The calcium values for Kumbidi WQ site are within the acceptable and tolerance limit.

Graph(24):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(25):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

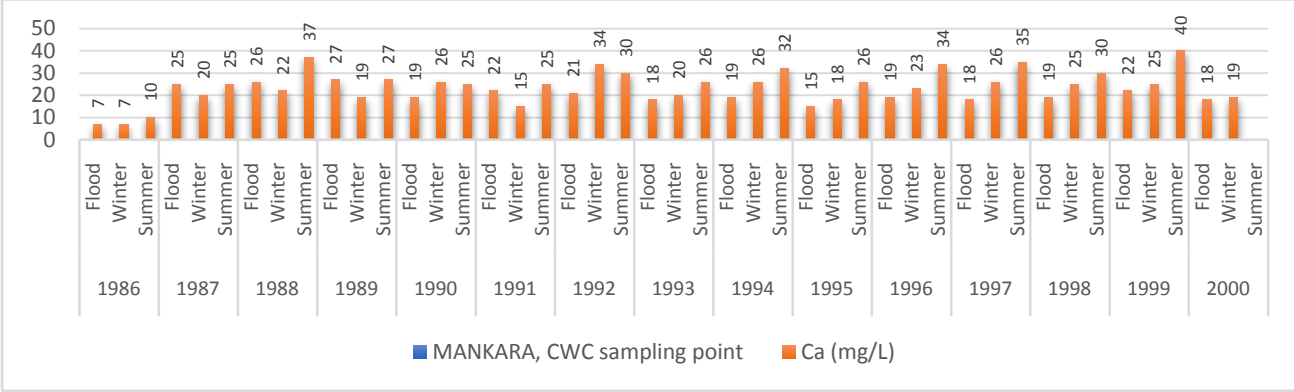


Mankara WQ site:

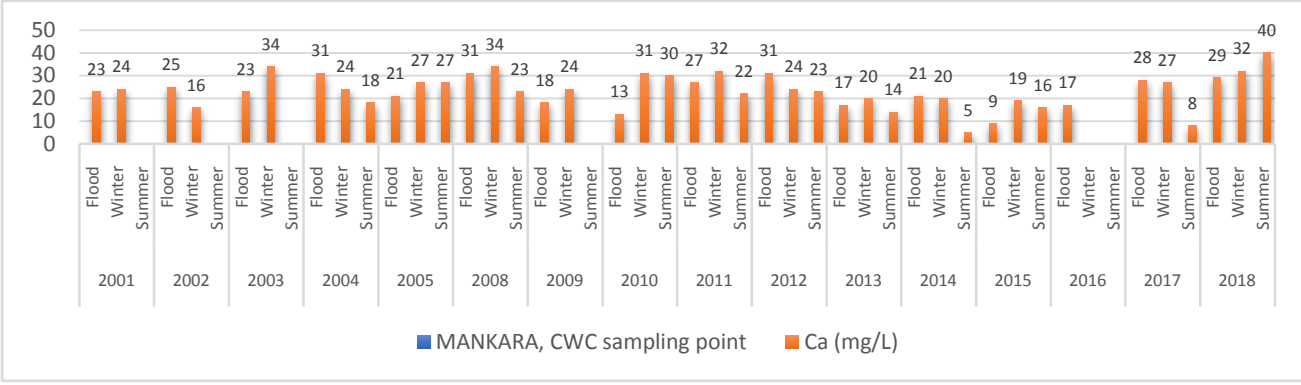
The Calcium values for Mankara WQ site ranges from minimum 4 to maximum 51 mg/L and the yearly Average values lie in the range of 8 to 29 mg/L. The yearly Average values of Calcium during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum, minimum, average and last year average calcium values for Mankara WQ site during non-monsoon is higher compared to during monsoon period. The calcium values for Mankara WQ site are within the acceptable and tolerance limit.

Graph(26):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(27):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



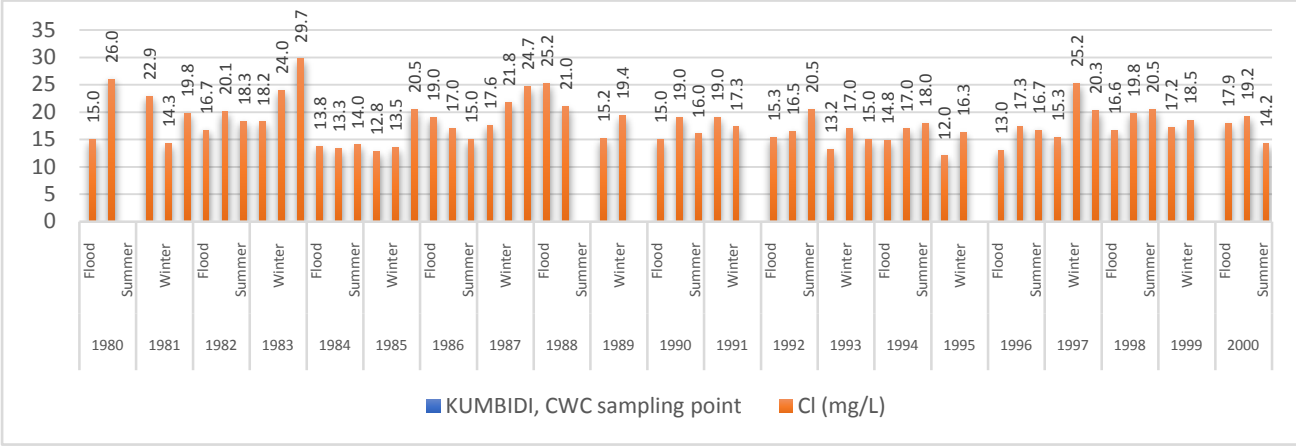
4.8 Chloride

Kumbidi WQ site:

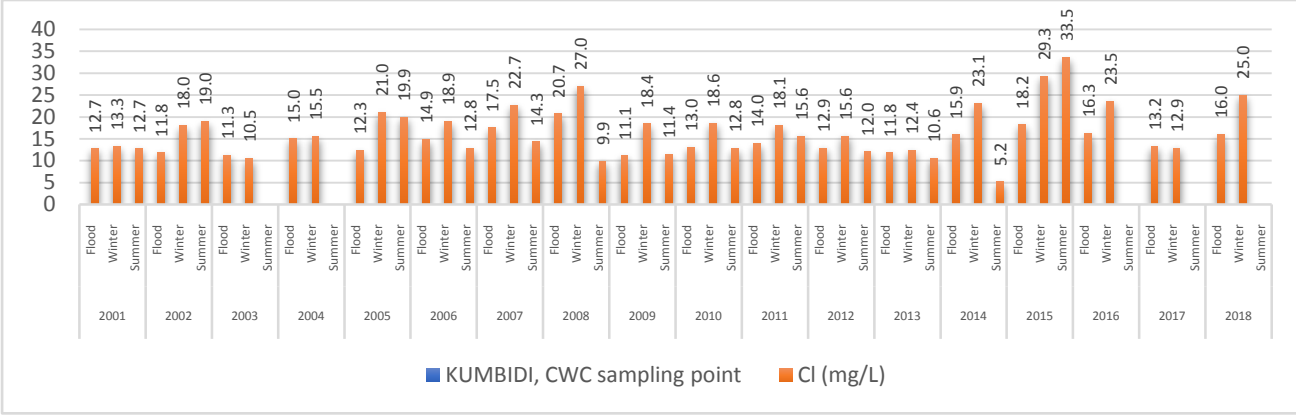
The Chloride values for Kumbidi WQ site ranges from minimum 5.2 to maximum 44.6 mg/L and the yearly Average value lies in the range of 12.9 to 27 mg/L. The yearly average values of Chloride during Non-monsoon (Dry season) is generally higher when compared to the values during monsoon (Wet season).

The maximum and minimum values during monsoon period are high compared to during non-monsoon and the average values during non-monsoon is higher compared to the values during monsoon season. The chloride values for Kumbidi WQ site are within the acceptable and tolerance limit.

Graph(28):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(29):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

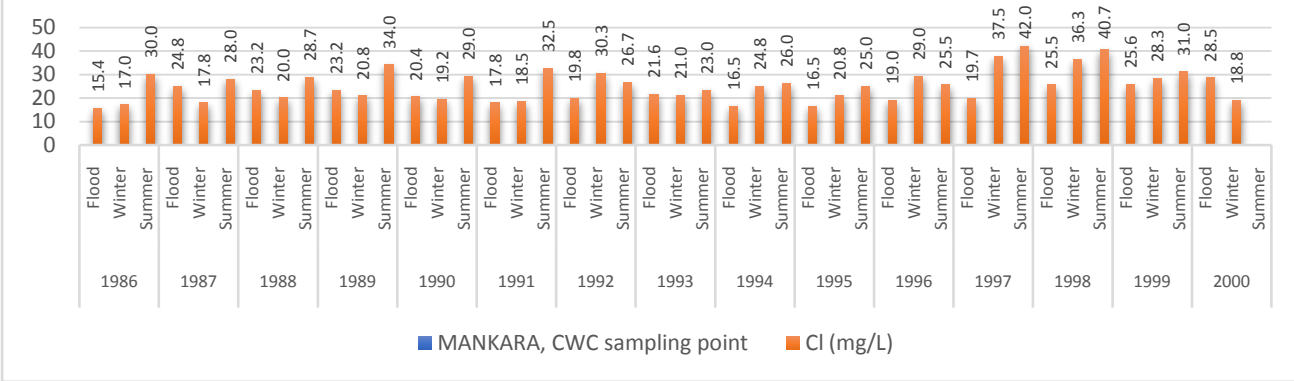


Mankara WQ site:

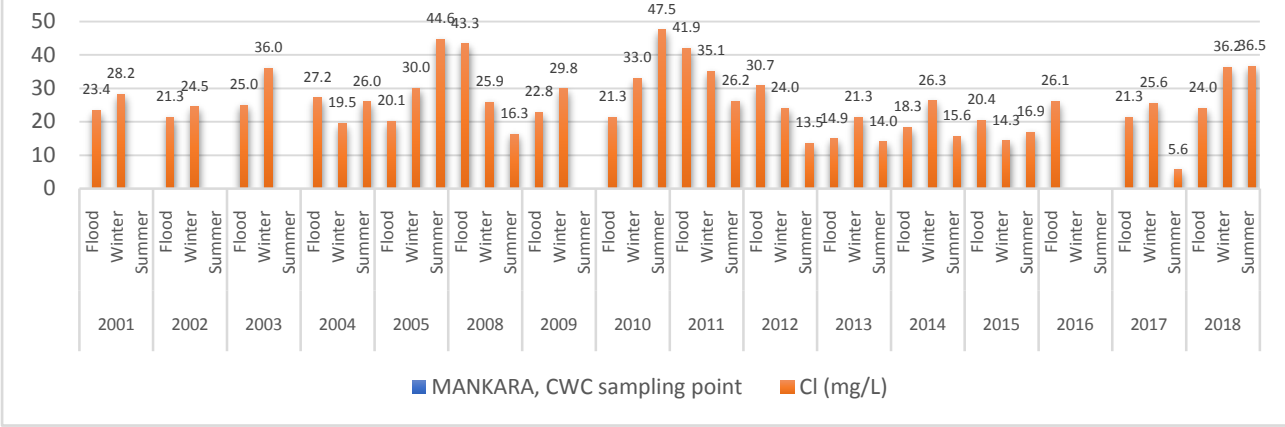
The Chloride values for Mankara WQ site ranges from minimum 5.6 to maximum 70.3 mg/L and the yearly average values lies in the range of 17.5 to 33.9 mg/L.The yearly Average values of Chloride during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season).

The Non-monsoon average values are higher compared to the values during monsoon. The maximum and minimum values during monsoon is significantly higher compared to during non-monsoon season. The chloride values for Mankara WQ site are within the acceptable and tolerance limit.

Graph(30):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(31):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



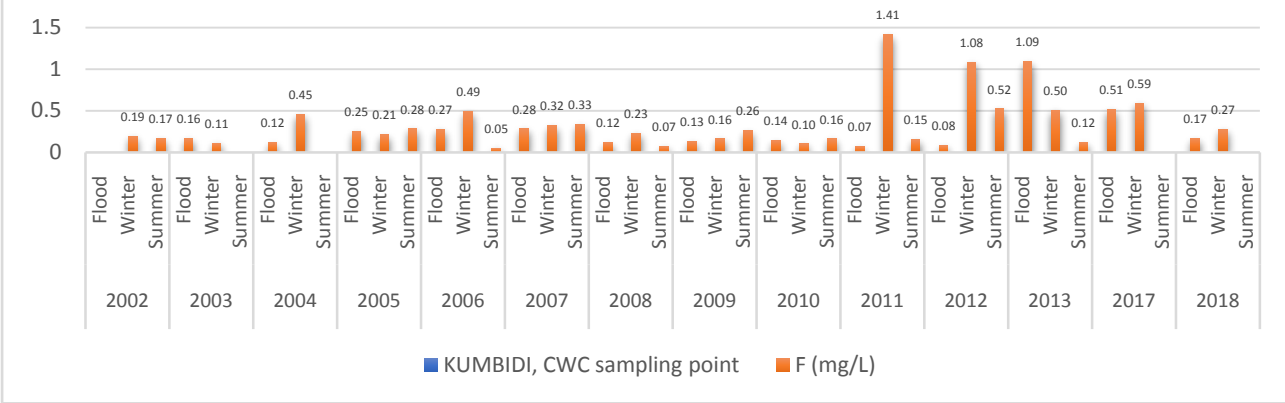
4.9 Fluoride

Kumbidi WQ site:

The Fluoride values for Kumbidi WQ site ranges from minimum 0.03 to maximum 0.79 mg/L (except 2.32 during 2011-12 ,1.19 during 2012-12 and 1.6 during 2013-14 and the yearly average value lies in the range of 0.14 to 0.5 mg/. The yearly Average values of Fluoride during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

During non-monsoon the fluoride values are high compared to during monsoon period. Most of fluoride values are within the acceptable limit (except few mentioned above)

Graph(32):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

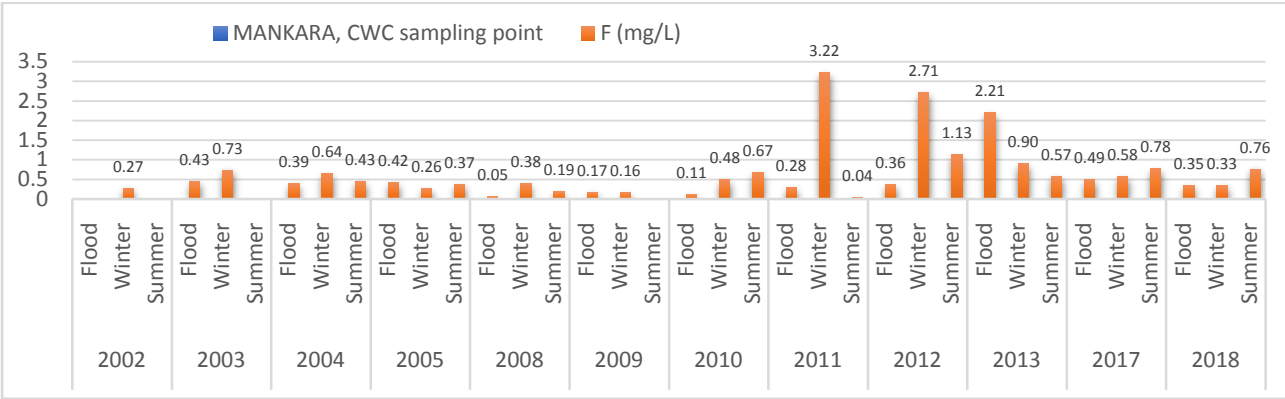


Mankara WQ site:

The Fluoride values for Mankara site lies in the range of 0.02 to 0.78 mg/L (except for 2011-12 (3.3 mg/L), 2012-13(3.81 mg/L) and 2013-14(2.74 mg/L) and the yearly average values lies in the range of 0.2 to 1.18 mg/L. The yearly Average values of Fluoride during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon (Wet season).

During non-monsoon the maximum and average values are high compared to during monsoon period and minimum values during monsoon is marginally high compared to the values during non-monsoon period. Fluoride yearly average values are within the acceptance limit .

Graph(33):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



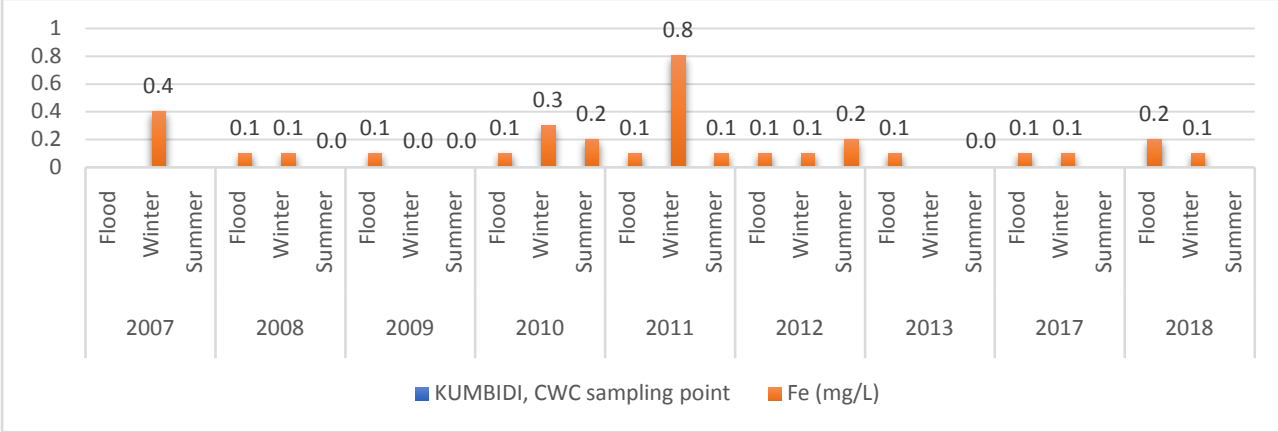
4.10 Iron

Kumbidi WQ site:

The Iron content at Kumbidi site lies in the range of 0.1 to 0.2 mg/L (except 0.7 mg/L(2007-08), 0.6 mg/L(2010-11) and 1.5 mg/L(2011-12) and the yearly average value lies in the range of 0.1 to 0.2 mg/L. The yearly Average values of Iron during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

During non-monsoon the maximum and average iron values are high compared to during monsoon period. But the last year average values during monsoon is marginally high compared to during non-monsoon. Iron yearly average values are within the acceptable limit.

Graph(34):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

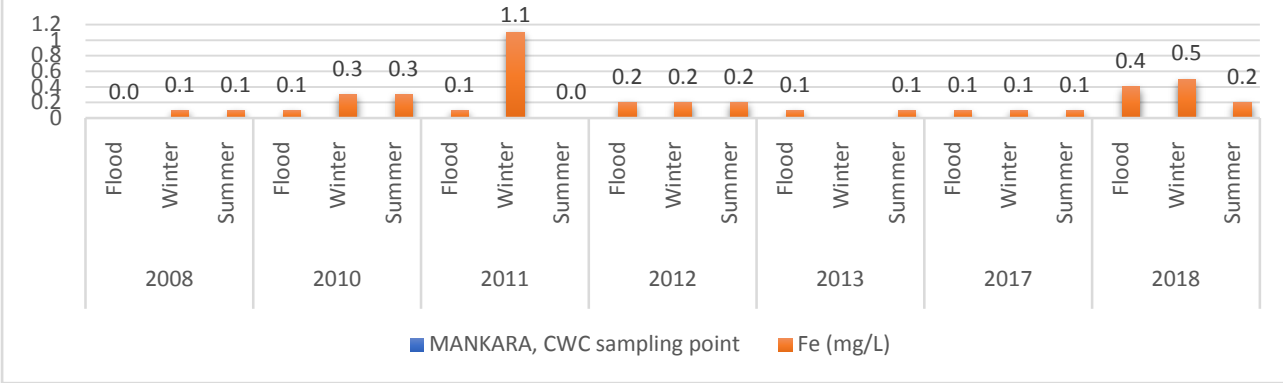


Mankara WQ site:

The Iron content atMankara site lies in the range of 0.01 to 0.2 mg/L (except 1.5mg/L-2011-12, 0.5mg/L -2010-11 and 0.6mg/L -2018-19 and the yearly average value lies in the range of 0.1 to 0.2 mg/L (only during the year 2011 winter average is showing high value of 1.1 mg/L). The yearly average values of Iron during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum and average Iron values during non-monsoon are high compared to during monsoon period. The minimum and last year average values are same. Most of Iron values are within the acceptable limit (Except few mentioned above).

Graph(35):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



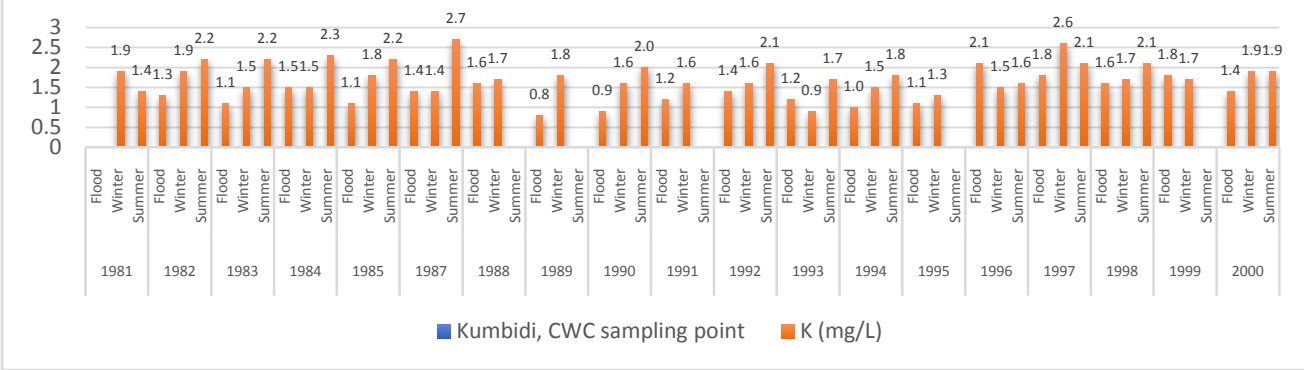
4.11 Potassium

Kumbidi WQ site:

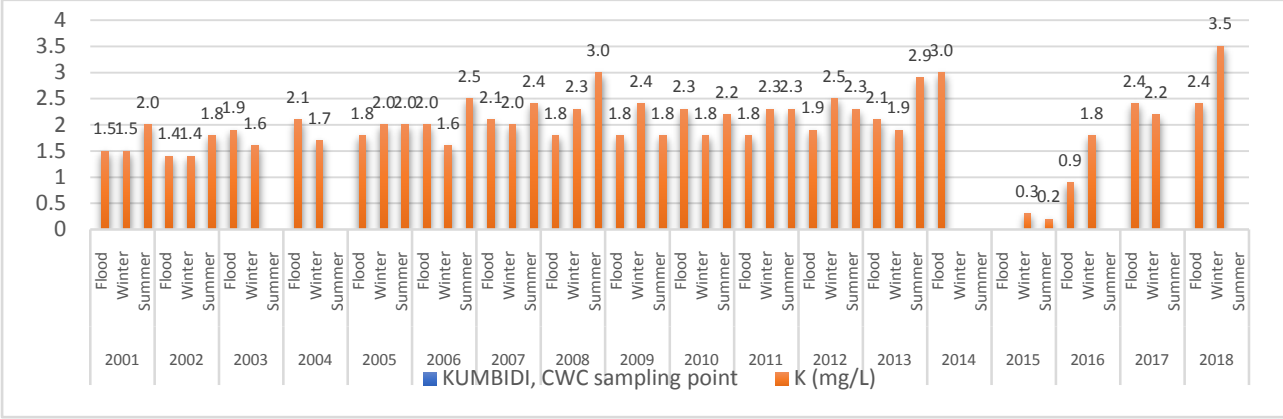
The Potassium value atKumbidi site lies in the range of 0.1 to 5.1 mg/L and the yearly average values for Kumbidi site lies in the range of 1.4 to 2.3 mg/L. The yearly average values of Potassium during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum, minimum and average potassium values during non-monsoon period is higher compared to during monsoon period.

Graph(36):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(37):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

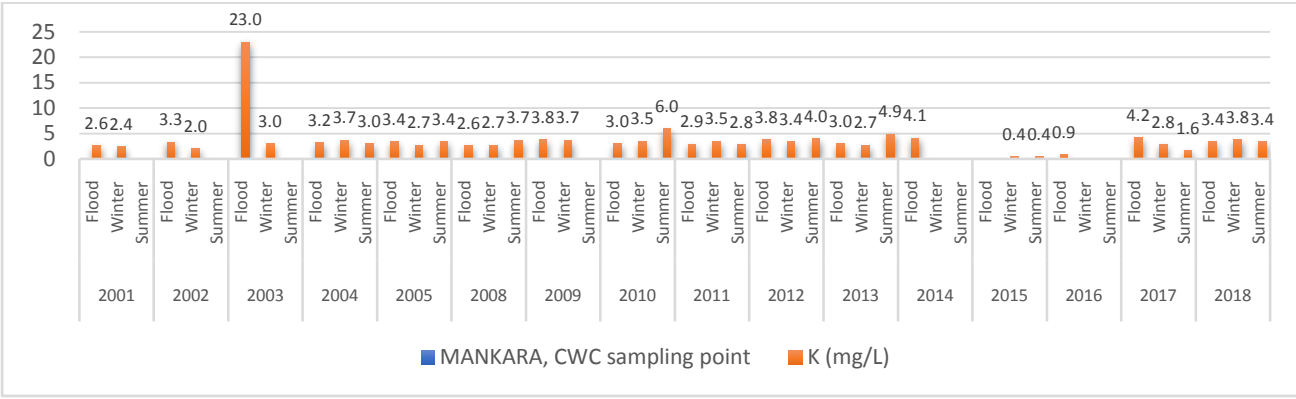


Mankara WQ site:

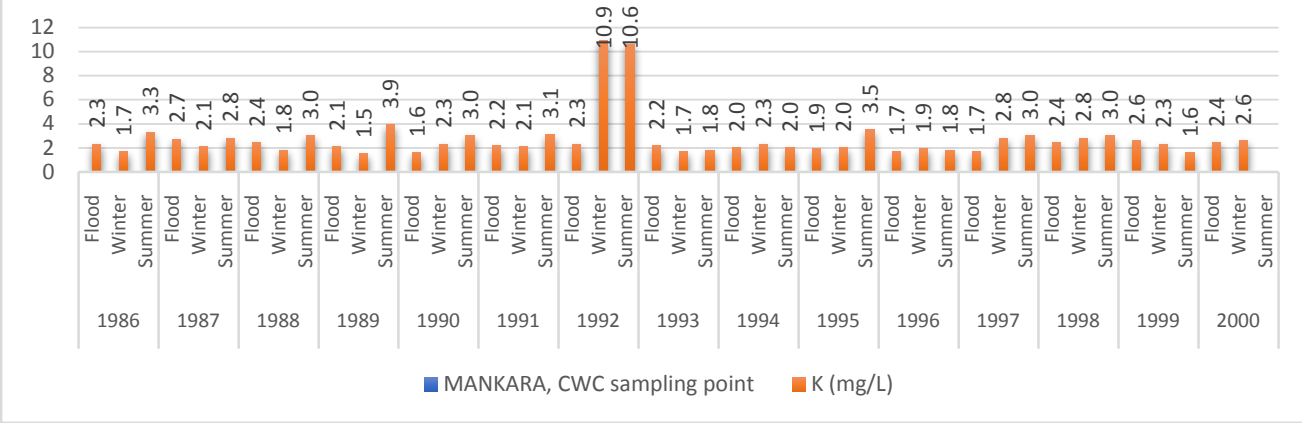
The Potassium values for Mankara sites lies in the range of 0.2 to 7.0 mg/L (except 36mg/L-1992-93, 23mg/L-2003-04) and the yearly Average values for lies in the range of 1.8 to 4.1 mg/L.The yearly Average values of Potassium during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon (Wet season).

The maximum and average potassium values are high during Non-monsoon compared to during monsoon season.

Graph(38):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(39):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



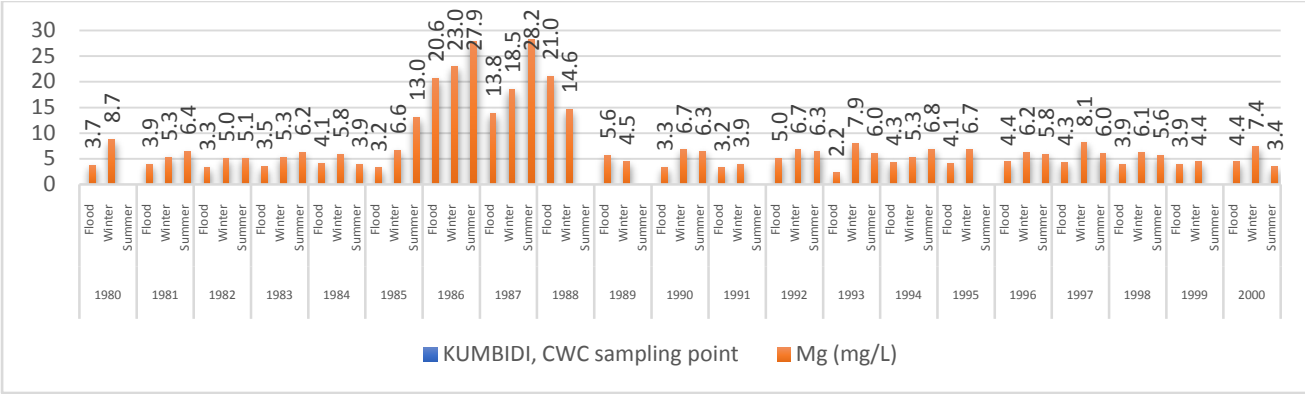
4.12 Magnesium

Kumbidi WQ site:

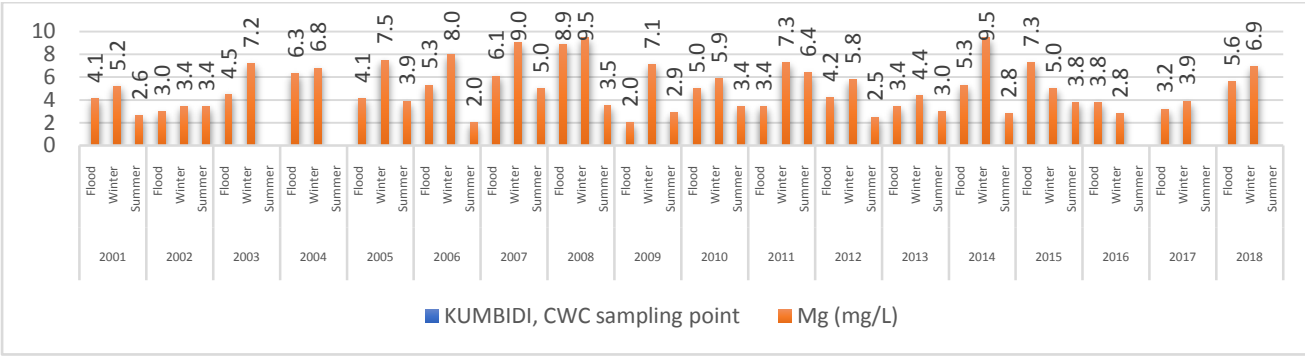
The Magnesium values for Kumbidi sites lies in the range of 0.9 to 18.4 mg/L (except for 1987-88(50.5mg/L), 1986-87(41.3mg/L), 1988-89(27.7 mg/L) and the yearly Average values lies in the range of 3.2 to 9.5 mg/L (except yearly average for 1986(23.8mg/L),1987(20.1mg/L), 1988(17.8mg/L). The yearly Average values of Magnesium during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

During Non-monsoon maximum,minimum and average magnesium values are high compared to during monsoon season. The magnesium values are within the acceptable and tolerance limit for most of the years data except few mentioned above.

Graph(40):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(41):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

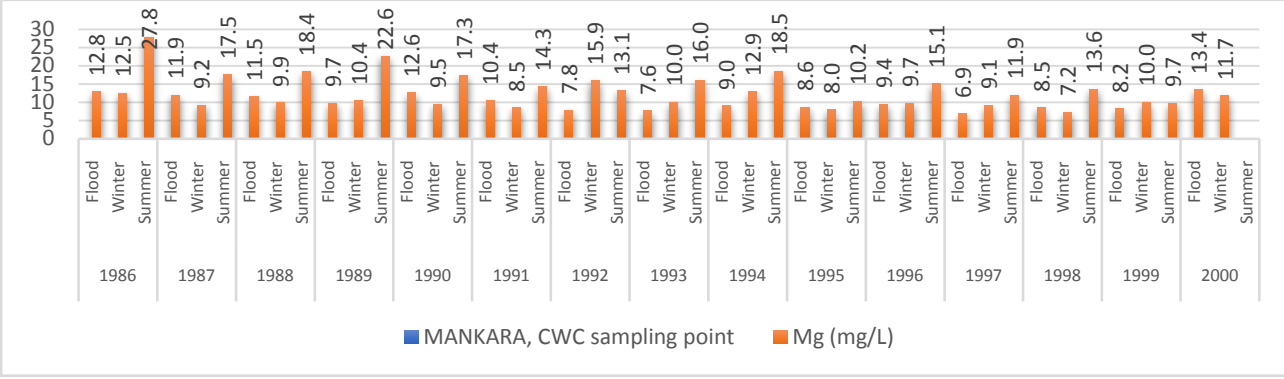


Mankara WQ site:

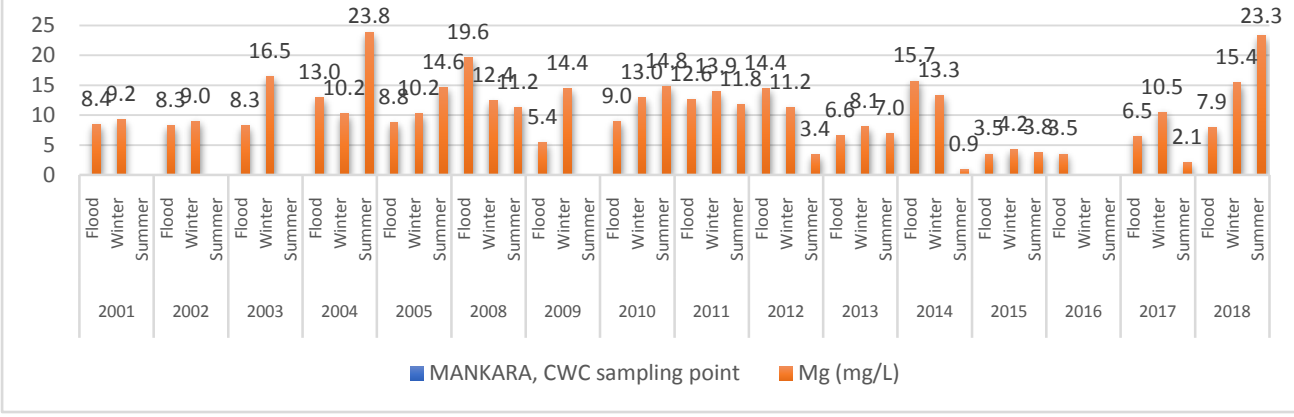
The Magnesium values for Mankara sites lies in the range of 0.9 to 23.5 mg/L (except 31.4 mg/L in 2014-15, 29.4mg/L in 1989-90) and the yearly Average values sites lies in the range of 3.8 to 17.7 mg/L. The yearly Average values of Magnesium during Non-monsoon (dry season) is generally higher when compared to the values during monsoon(Wet season).

During monsoon season the maximum and average values are high compared to the values during non-monsoon period and the minimum value during monsoon is marginallyhigh compared to during non-monsoon. The magnesium values for Mankara WQ site are within the acceptable and tolerance limit except few mentioned above.

Graph(42):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(43):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



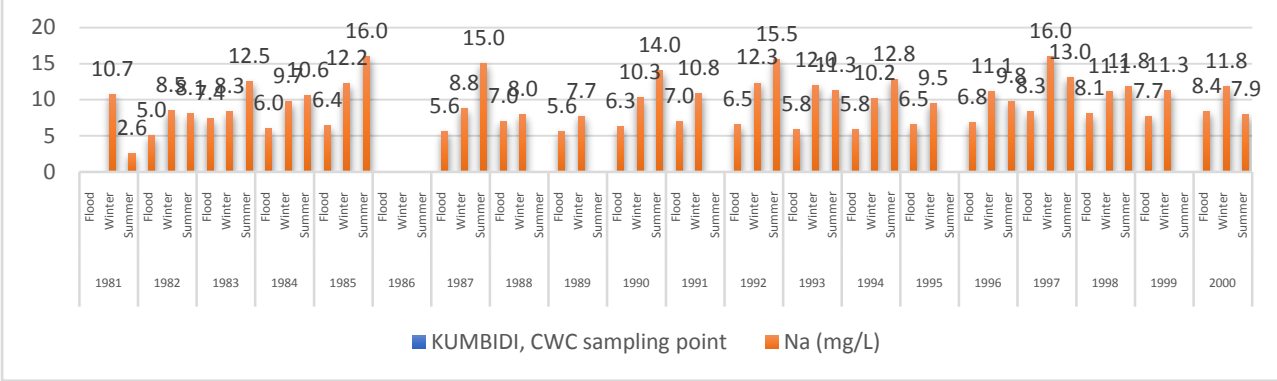
4.13 Sodium

Kumbidi WQ site:

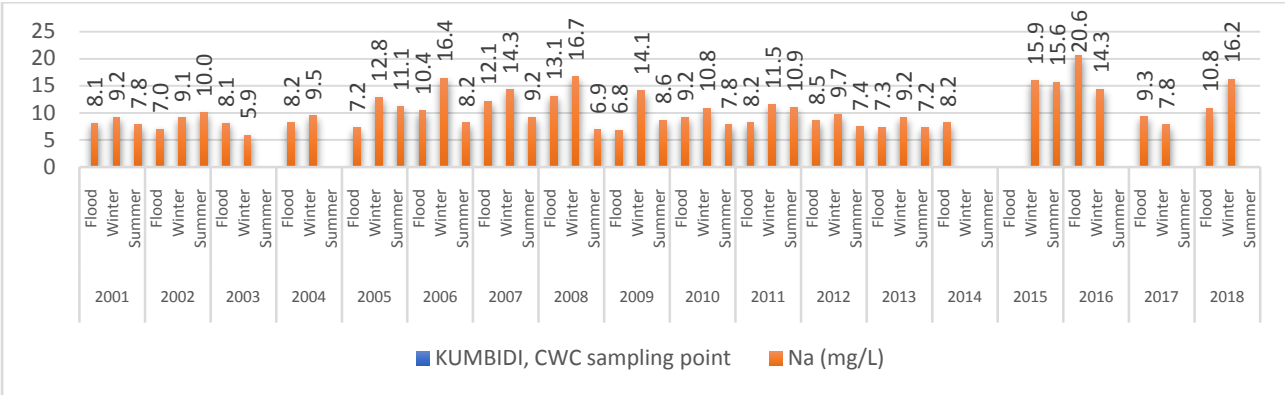
The Sodium values at Kumbidi site lies in the range of 2.5 to 33.2mg/L and the yearly average values at Kumbidi site lies in the range of 6.6 to 17.4 mg/L.The yearly average values of Sodium during Non-monsoon(Dry season) is generally higher compared to the values during monsoon(Wet season) .

The average and minimum values of Sodium during Non-monsoon period is high compared to the values during monsoon season and maximum value during monsoon season is significantly high compared to during Non-monsoon season.

Graph(44):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(45):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



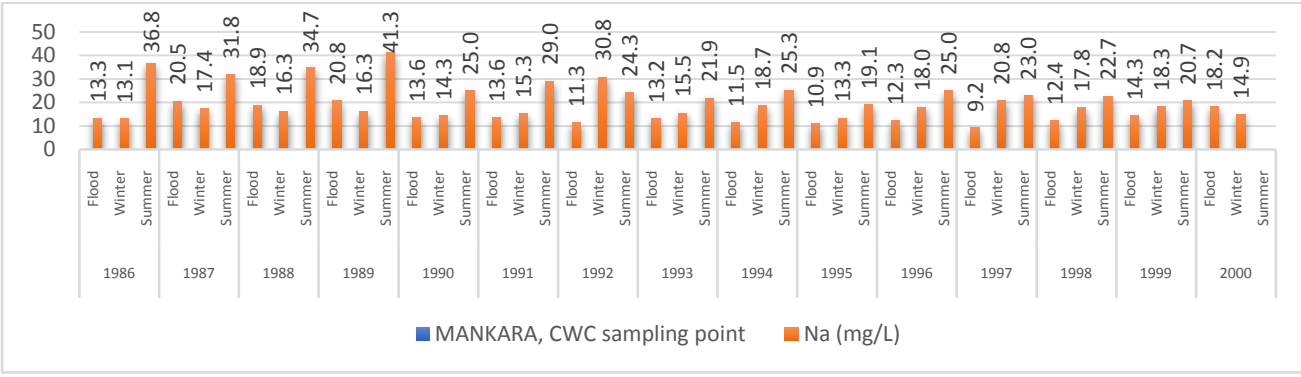
<u>Mankara WQ site:</u>

The Sodium values for Mankara sites lies in the range of 2.0(Yr.1990-91) to 54.1(Yr.1989-90) mg/L the yearly Average values sites lies in the range of 11.5 to 26.1 mg/L.

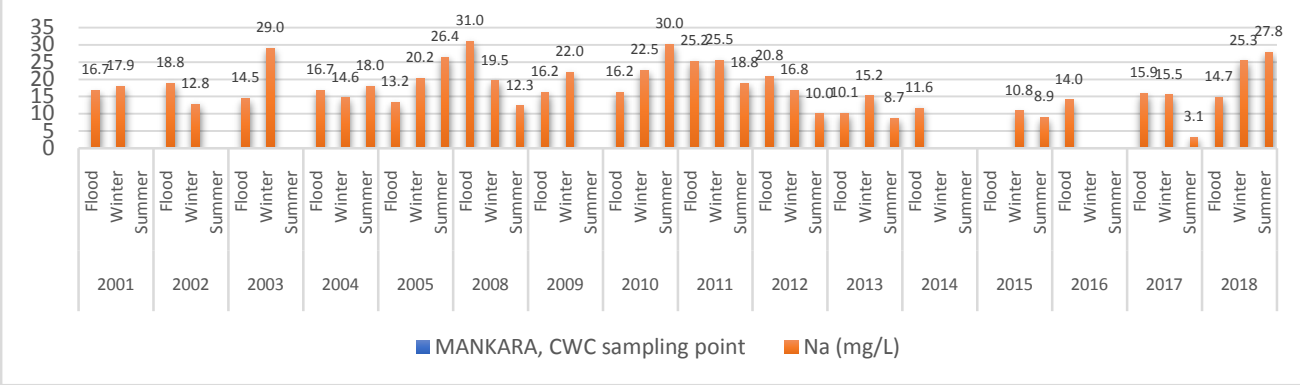
The yearly Average values of Sodium during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum, average and last year average sodium values during Non-monsoon is high compared to during monsoon season except the minimum values which is high during monsoon.

Graph(46):SEASONAL VARIATION :MANKARA site on BHARATAPUZHA River



Graph(47):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River

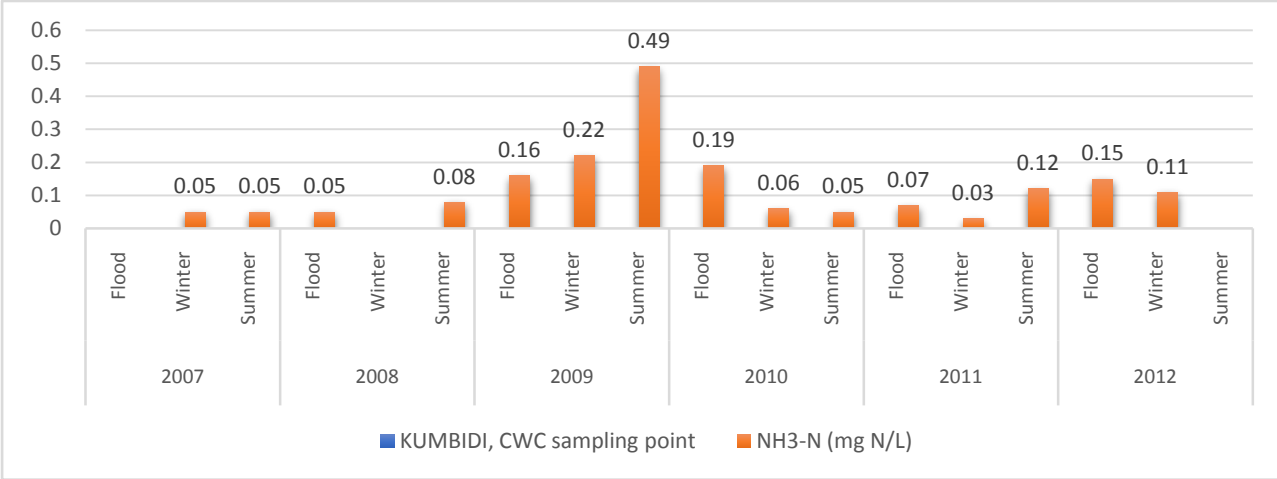


4.14 Nitrogen Ammonia

Kumbidi WQ site:

The Nitrogen Ammonia values at Kumbidi site lies in the range of 0.05 to 0.49 mg/L and the yearly average values lies in the range of 0.05 to 0.29 mg N/L. The yearly average values of Nitrogen Ammonia during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season).The maximum value during non-monsoon is higher compared to values during monsoon season. The average during monsoon is marginally high compared to values during Non-monsoon season and minimum value is same for both the season.

Graph(48):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

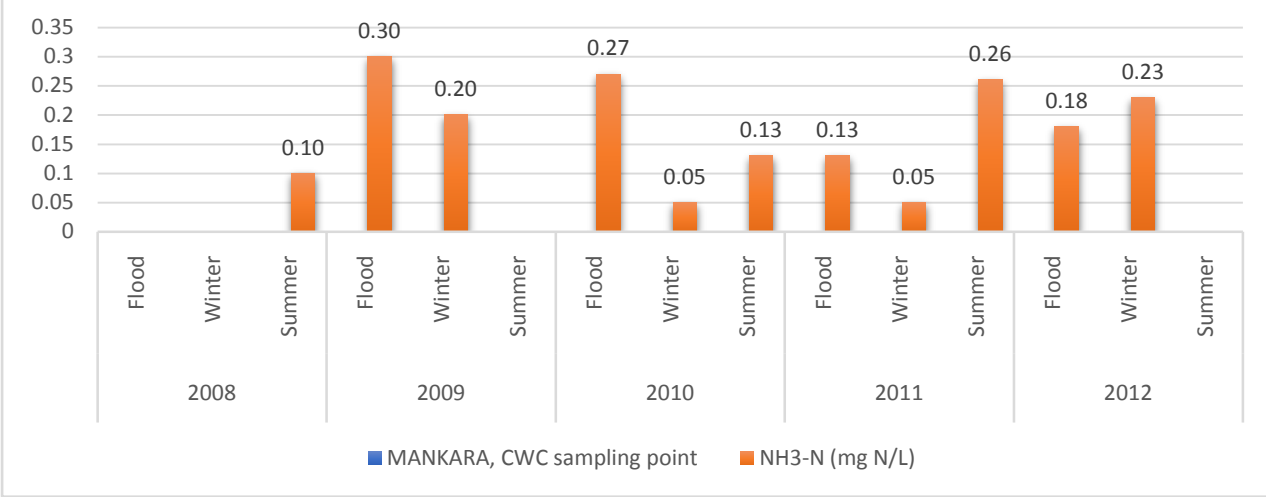


Mankara WQ site:

The Nitrogen Ammonia values at Mankara site lies in the range of 0.05 to 0.47 mg/L and the Nitrogen Ammonia yearly average values lies in the range of 0.1 to 0.25mg N/L. The yearly average values of Nitrogen Ammonia during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season).

The maximum, average and minimum values during Monsoon is high compared to during Non-monsoon season.

Graph(49):SEASONAL VARIATION :MANKARA site on BHARATAPUZHA River



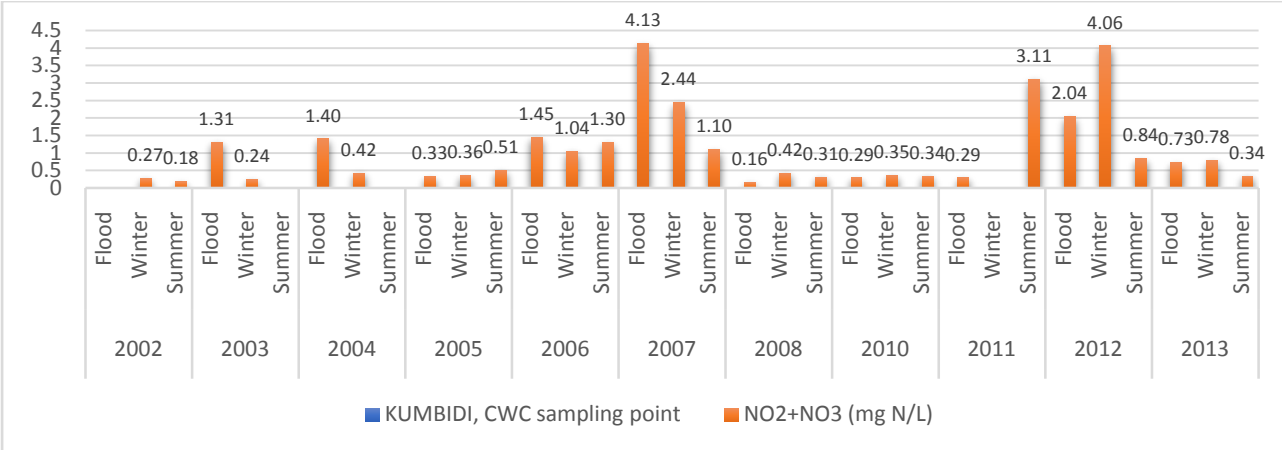
4.15 Nitrogen Total oxydised

Kumbidi WQ site:

The Nitrogen Total oxydised values for Kumbidi sites lies in the range of 0.05 to 6.09 mg N/L. The yearly Average values of Nitrogen Total oxydisedduring Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum and average values during Non-monsoon are high compared to during monsoon season for nitrogen total oxydised and minimum values is high during monsoon season.

Graph(50):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

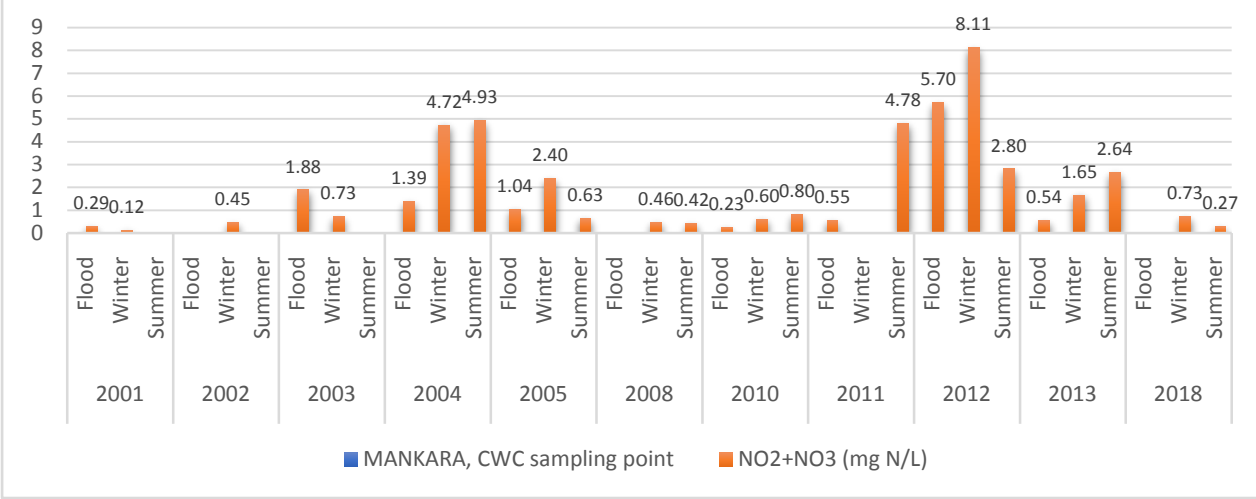


Mankara WQ site:

The Nitrogen Total oxydised values for Mankara sites lies in the range of 0.12 to 13.02 mg N/L. The yearly Average values of Nitrogen Total oxydisedduring Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The average value during Non-monsoon is high compared to during monsoon season and the maximum value during monsoon is marginally high compared to during Non-monsoon season. The minimum value during both monsoon and Non-monsoon remain same.

Graph(51):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



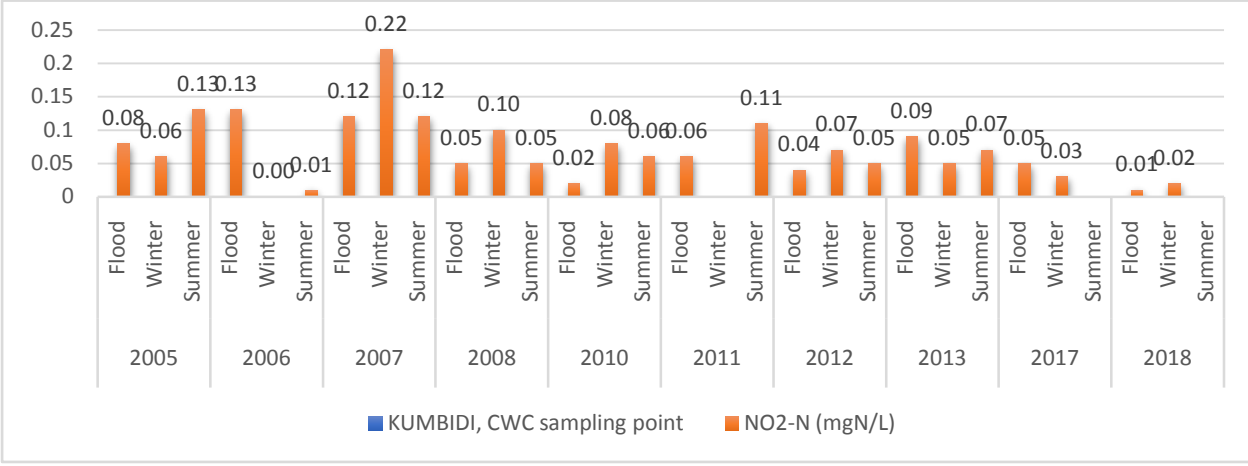
4.16 Nitrogen Nitrite

Kumbidi WQ site:

The Nitrogen Nitrite values for Kumbidi site lie in the range of 0.01 to 0.26mgN/L and the yearly Average values lie in the range of 0.015 to 0.153mg N/L. The yearly Average values of Nitrogen Nitrite during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum and average during Non-monsoon is marginally high compared to during monsoon season.

Graph(52):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

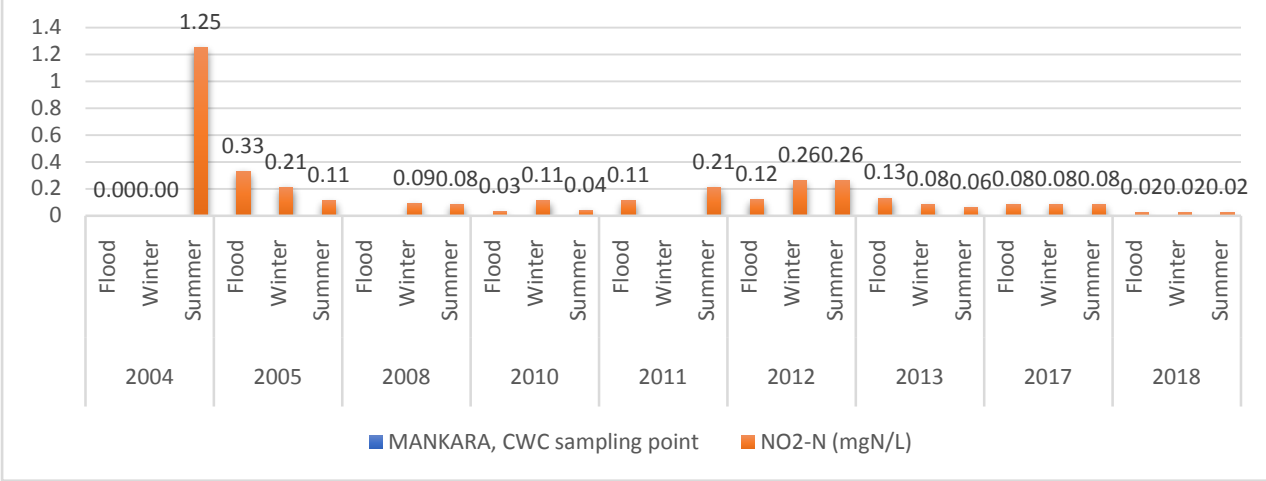


Mankara WQ site:

The Nitrogen Nitrite value for Mankara site lies in the range of 0.01 to 0.45mgN/L and the yearly Average value lies in the range of 0.02 to 0.21mgN/L (Except 1.25 mgN/L Year 2004) . The yearly Average values of Nitrogen Nitrite during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum and average values during Non-monsoon are high compared to during monsoon season and last year average during monsoon/Non-monsoon are same.

Graph(53):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



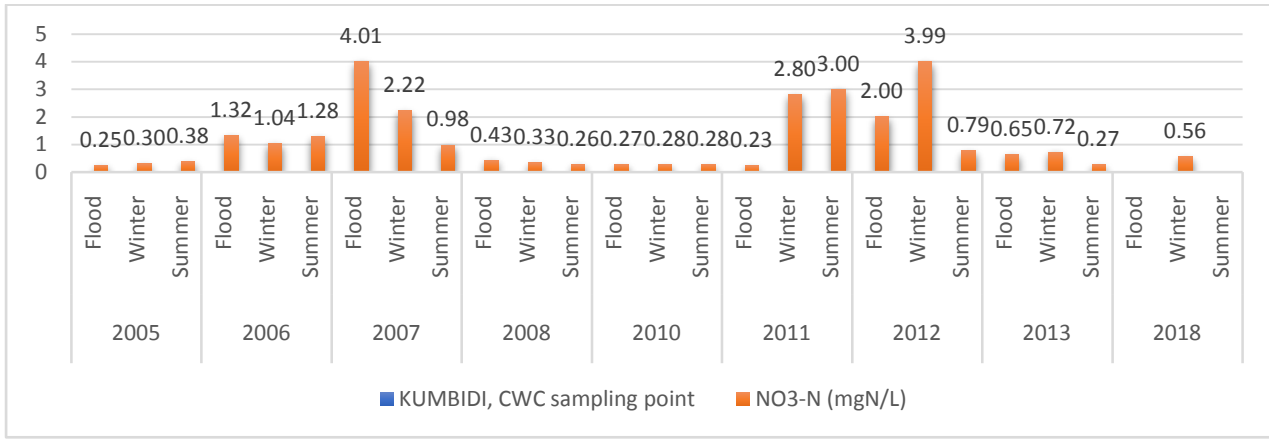
4.17 Nitrogen Nitrate

Kumbidi WQ site:

The Nitrogen Nitrate value for Kumbidi site lies in the range of 0.05 to 6.07 mgN/L and the yearly Average value lies in the range of 0.31 to 2.40mgN/L.The yearly Average values of Nitrogen Nitrate during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum and average value during non-monsoon is high compared to during monsoon season and the minimum value during monsoon is high compared to during Non-monsoon. The nitrogen nitrate values are within the acceptable and tolerance limit.

Graph(54):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

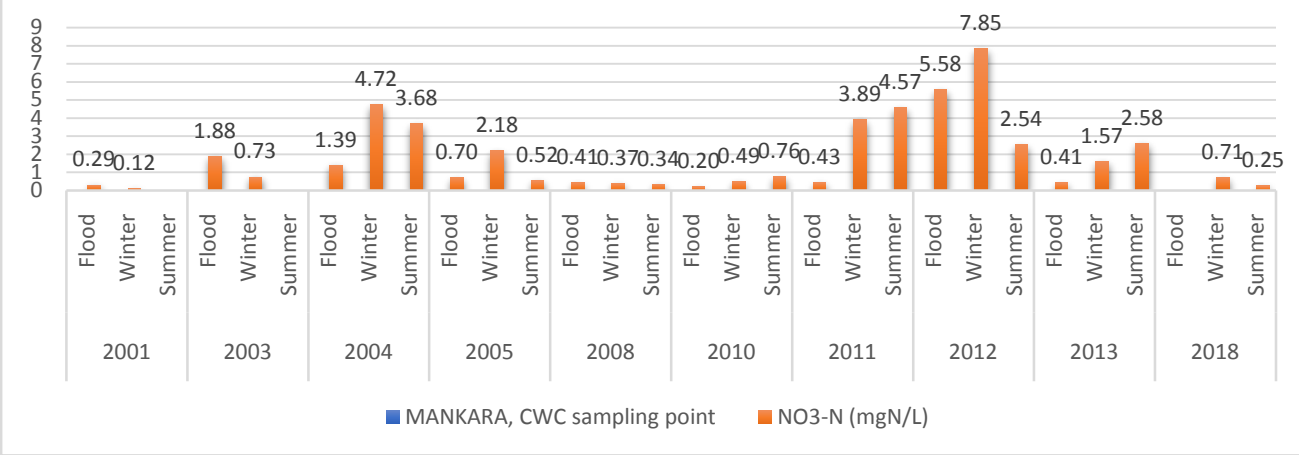


Mankara WQ site:

The Nitrogen Nitrate yearly Average values for Mankara sites lies in the range of 0.12 to 12.8 mgN/L and the yearly Average values for lies in the range of 0.2 to 5.32mgN/L. The yearly Average values of Nitrogen Nitrate during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The average value during Non-monsoon is high compared to during monsoon season. The maximum and minimum values are same during both the season. The nitrate nitrogen values of are within the acceptable and tolerance limit for Mankara site.

Graph(55):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



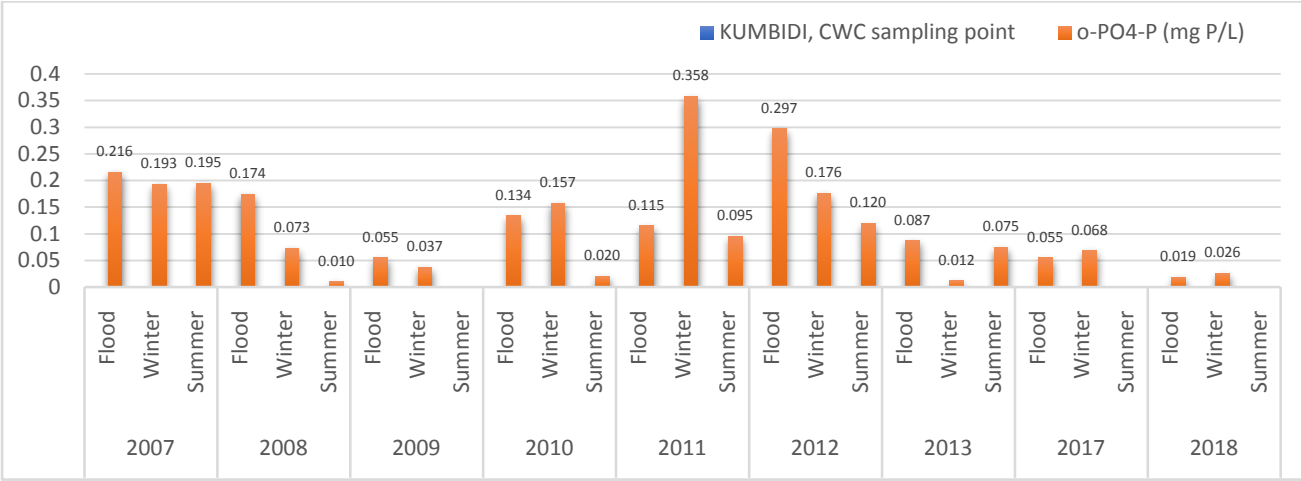
4.18 Ortho phosphate

Kumbidi WQ site:

The ortho phosphate value for Kumbidi site lies in the range of 0.010 to 0.670mg P/L and the yearly Average value lies in the range of 0.023 to 0.189mg P/L. The yearly Average values of ortho phosphate during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season). However, during some of the year, non-monsoon average value is lesser.

The maximum observed and last year average value during Non-monsoon is high compared to during monsoon season. The minimum value observed is same during both the season.

Graph(56):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

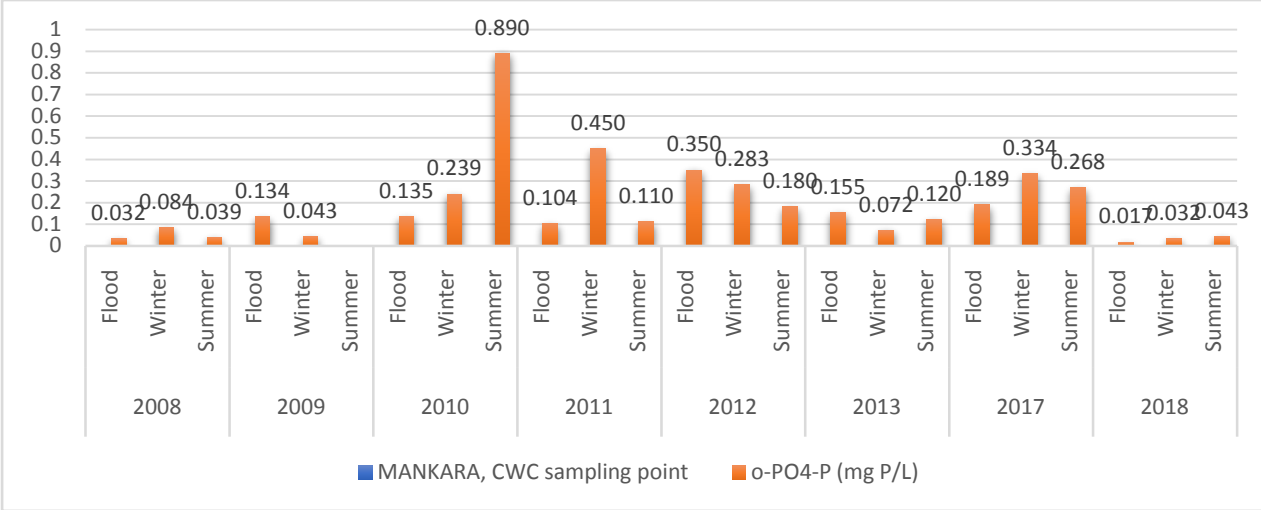


Mankara WQ site:

The ortho phosphate value for Mankara site lies in the range of 0.01 to 0.950mg P/L and the yearly Average value lies in the range of 0.030 to 0.421mg P/L.The yearly Average values of ortho phosphateduring Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum and average value during Non-monsoon season is high compared to during monsoon season. The minimum value during monsoon is marginally high compared to during Non-monsoon season.

Graph(57):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



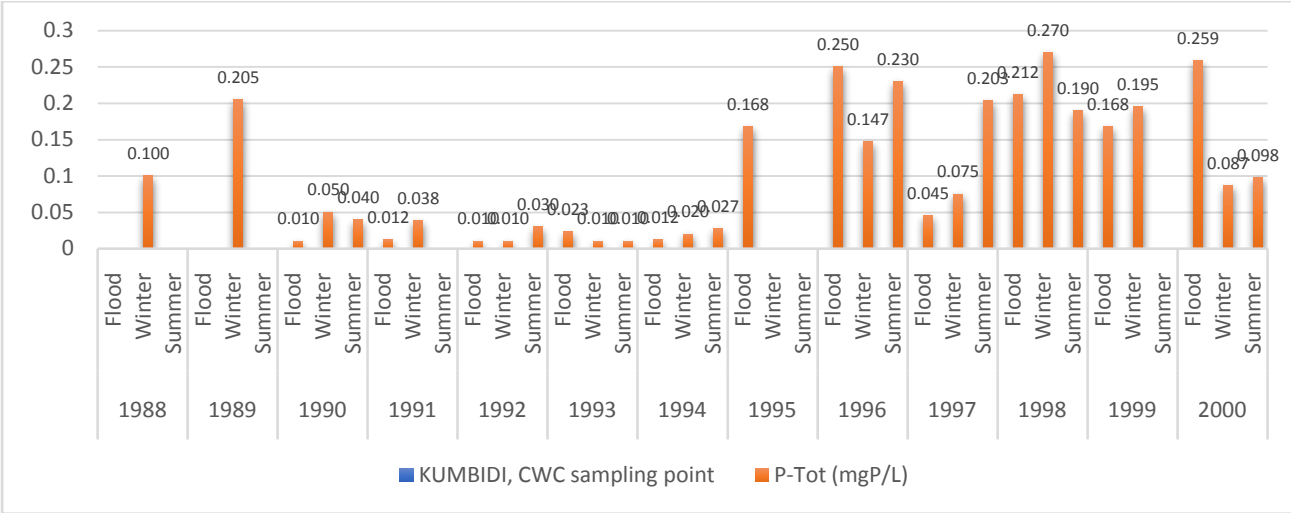
4.19 Phosphate Total

Kumbidi WQ site:

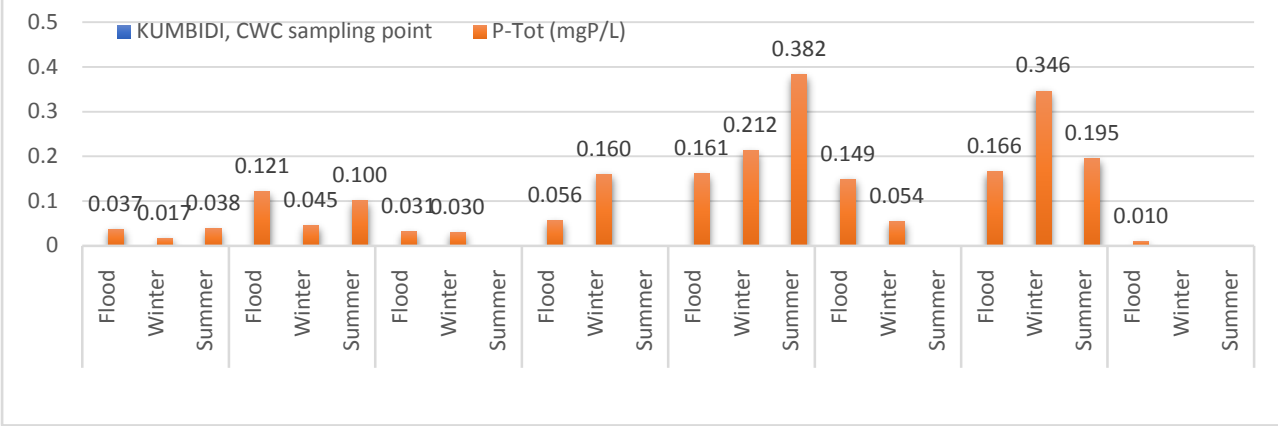
The phosphate value for Kumbidi site lies in the range of 0.01 to 0.726 mgP/L and the yearly Average values lie in the range of 0.033 to 0.251mgP/L. The yearly Average values of Phosphate Totalduring Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum value during non-monsoon is high compared to during monsoon. The Average value during Non-monsoon is high compared to during monsoon. The minimum value observed is same during both the season.

Graph(58):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(59):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

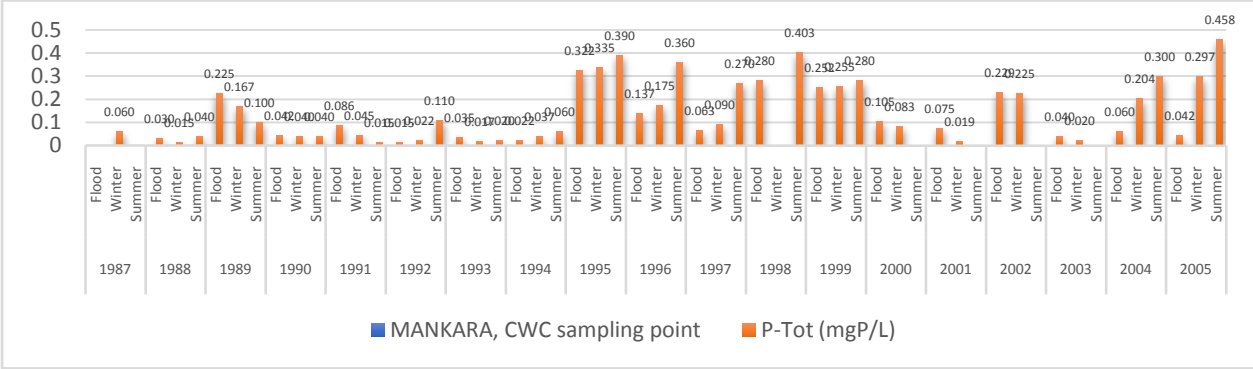


Mankara WQ site:

The phosphate Total value for Mankara site lies in the range of 0.01 to 0.458 mgP/L and the yearly Average value lies in the range of 0.028 to 0.265mgP/L. The yearly Average values of Phosphate Total during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum value during non-monsoon is high compared to value during monsoon.The Average and minimum value during Non-monsoon is high compared to value during monsoon.

Graph(60):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



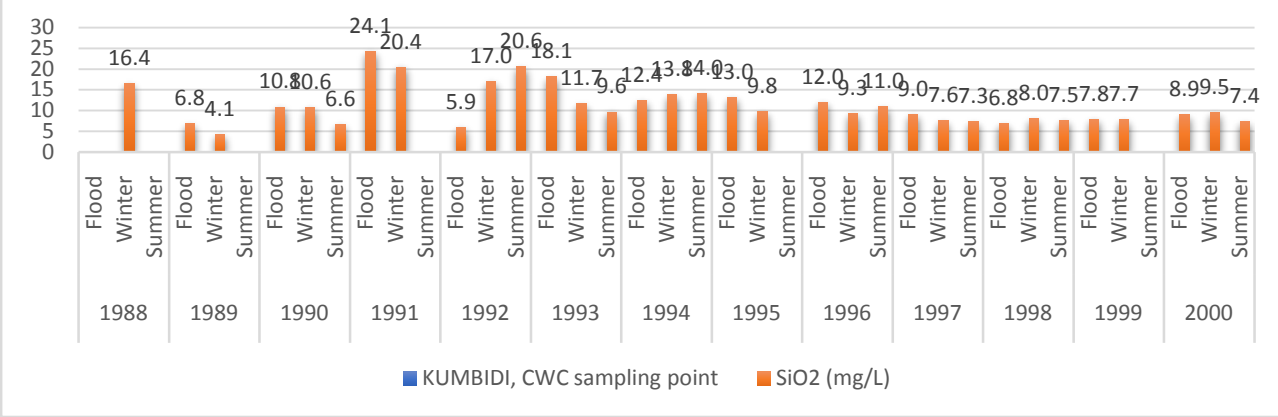
4.20 Silicate

Kumbidi WQ site:

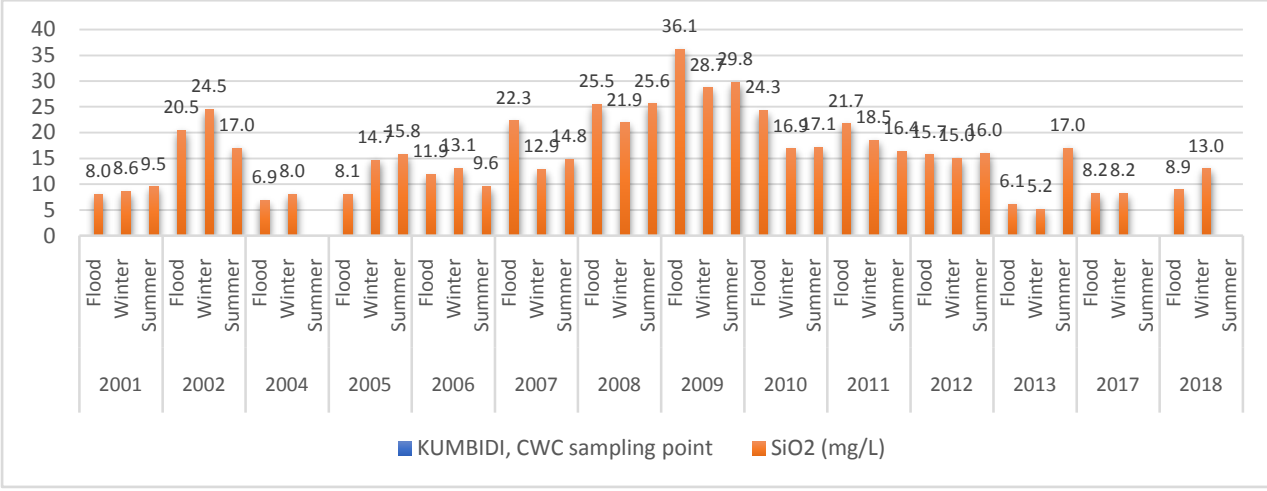
The silicate value for Kumbidi site lies in the range of 1.3 to 42.8 mg/L and the yearly Average values for lies in the range of 5.45 to 31.53 mg/L. The yearly Average values of Silicate during monsoon(Wet season) is generally higher when compared to the values during non-monsoon(Dry season) .

The maximum,minimum and average value during monsoon is high compared to value during Non-monsoon season and the last year average value during Non-monsoon is high compared to value during monsoon season.

Graph(61):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(62):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

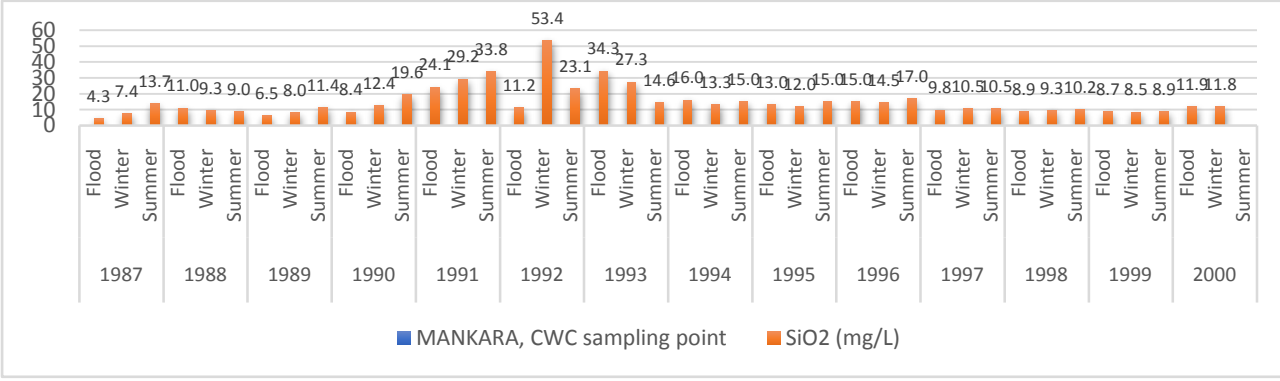


Mankara WQ site:

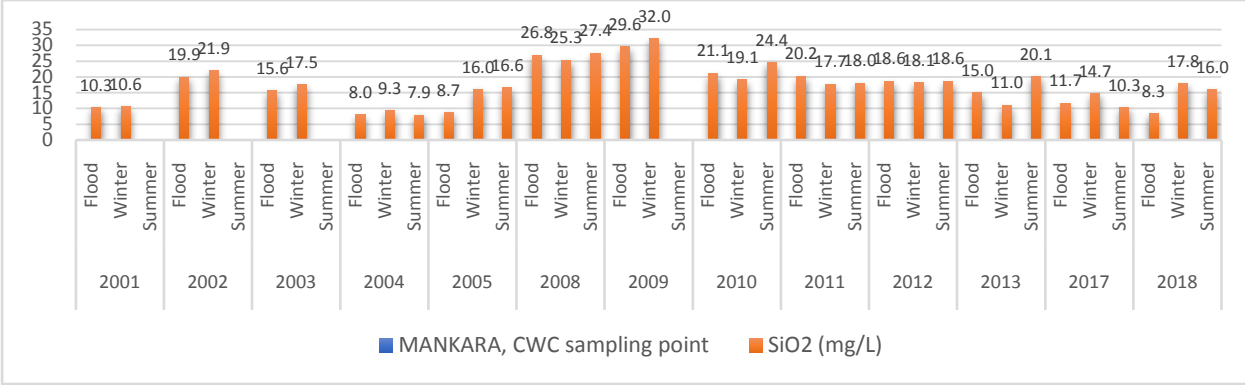
The silicate value for Mankarasite lies in the range of 0.8 to 73.8 mg/L and the yearly Average value lies in the range of 8.5 to 29.2 mg/L. The yearly Average value of Silicate during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum,minimum and average value during Non-monsoon season is high compared to value during monsoon season.

Graph(63):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(64):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



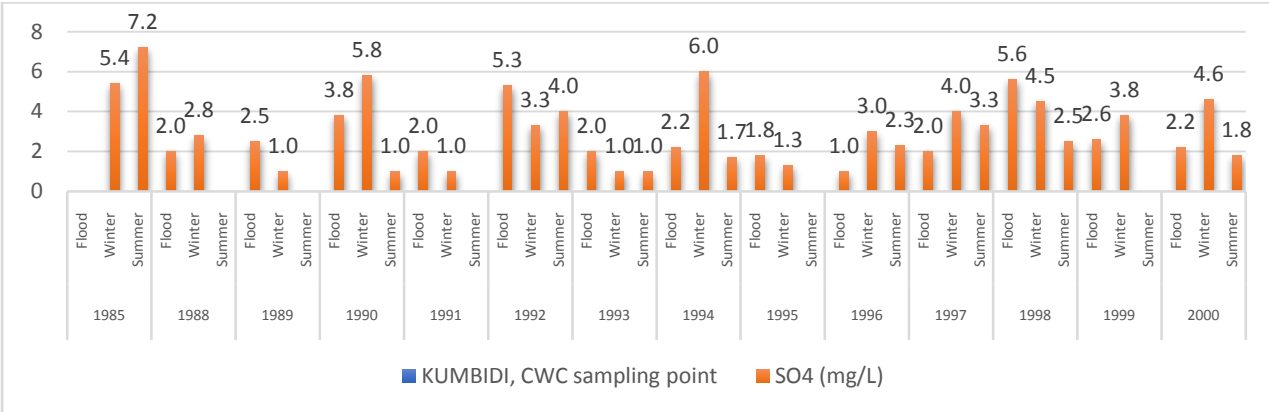
4.21 Sulphate

Kumbidi WQ site:

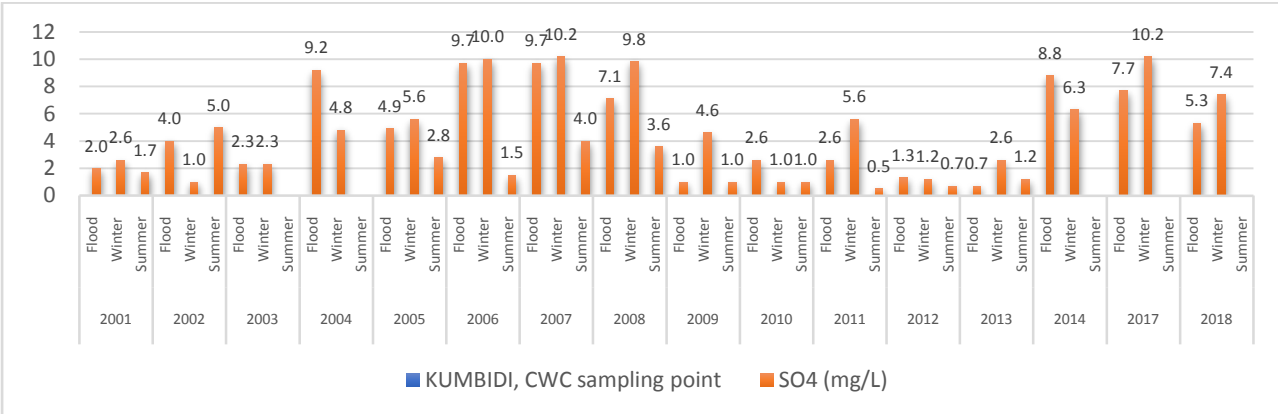
The Sulphate value for Kumbidi site lies in the range of 0.5 to 18 mg/L and the yearly Average value lies in the range of 1.0 to 7.9 mg/L. The yearly Average values of Sulphate during monsoon(Wet season) is generally higher when compared to the values during Non-monsoon(Dry season) except during some of the years.

The average value and minimum value during monsoon is marginally high compared to value during Non-monsoon season and the maximum value is same for both the season.

Graph(65):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(66):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

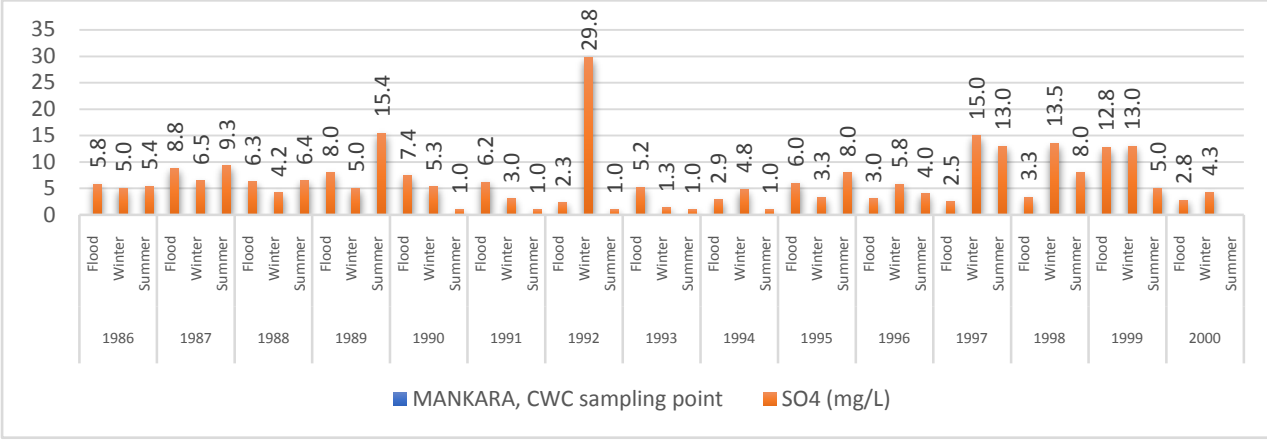


Mankara WQ site:

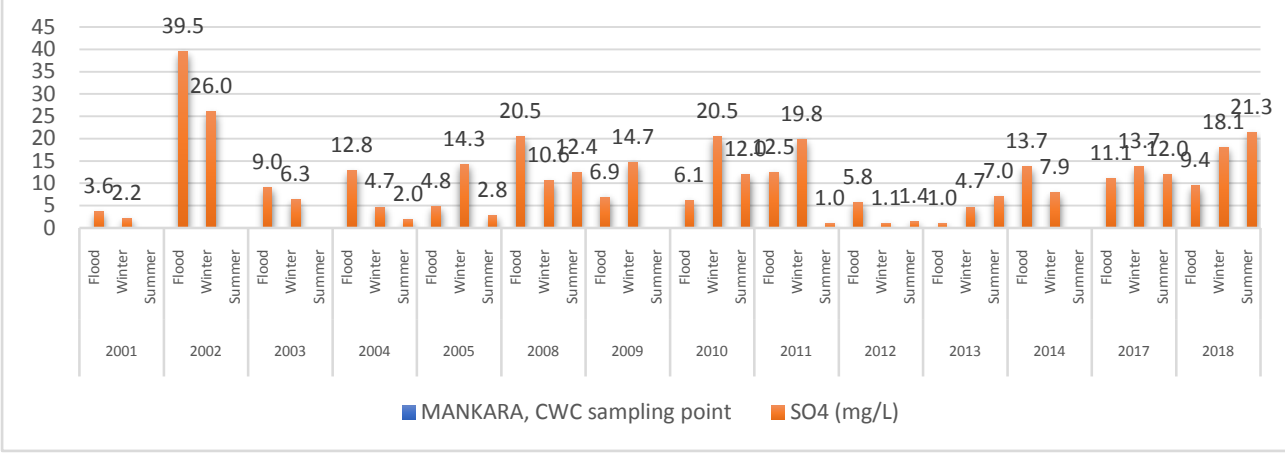
The sulphate value for Mankara site lies in the range of 0.6 to 61 mg/L and the yearly Average value lies in the range of 2.5 to 32.7 mg/L. The yearly Average value of Sulphate during monsoon(Wet season) is generally higher when compared to the values during Non-monsoon(Dry season).

The average value and minimum value during monsoon is high compared to value during Non-monsoon season and the maximum value during monsoon is high compared to value during Non-monsoon. The last year average value during Non-monsoon is high compared to value during monsoon season.

Graph(67):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(68):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



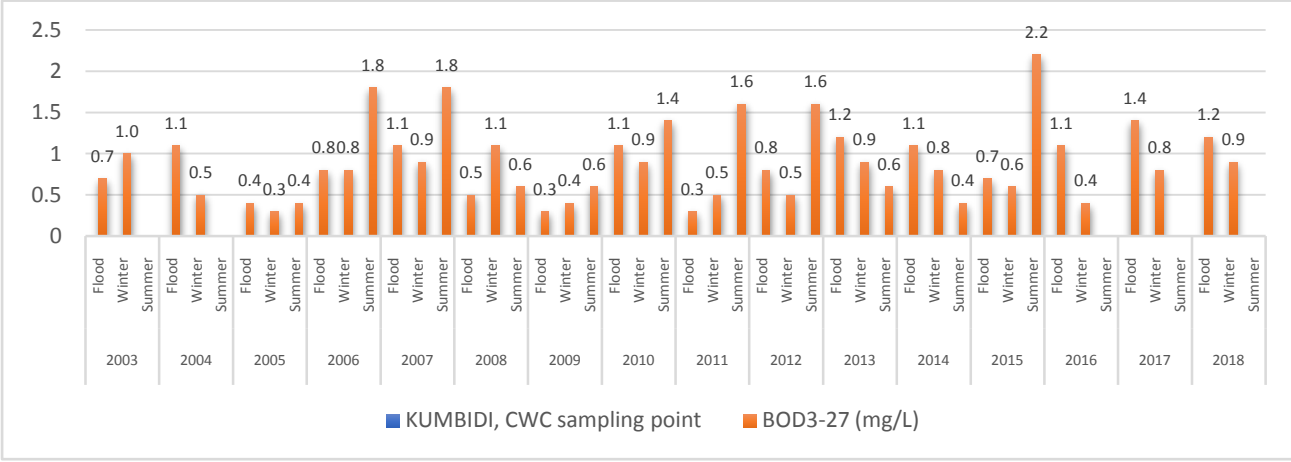
4.22 Biochemical Oxygen Demand

Kumbidi WQ site:

The BOD values for Kumbidi site lie in the range of 0.2 to 2.7 mg/L and the BOD yearly Average value for Kumbidi site lies in the range of 0.36 to 1.27 mg/L.The yearly Average values of BOD during monsoon(Wet season) is generally higher when compared to the values during Non-monsoon(Dry season).

The BOD maximum value during Non-monsoon season is marginally high compared to value during monsoon season and the average value during monsoon is high compared to value during Non-monsoon season. The minimum value is same during both the season.

Graph(69):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

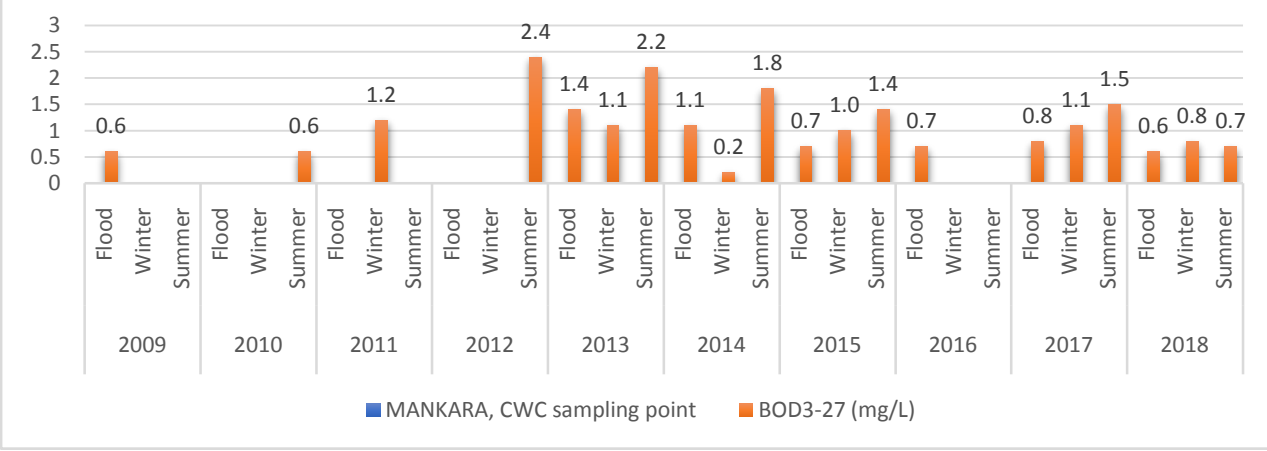


Mankara WQ site:

The BOD value for Mankara site lies in the range of 0.2 to 2.4 mg/L and the BOD yearly Average value for Mankara site lies in the range of 0.6 to 1.6 mg/L.The yearly Average values of BOD during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season).

The maximum and average value during Non-monsoon season is high compared to the value during monsoon season. The minimum value is high during monsoon season compared to value during Non-monsoon season.

Graph(70):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



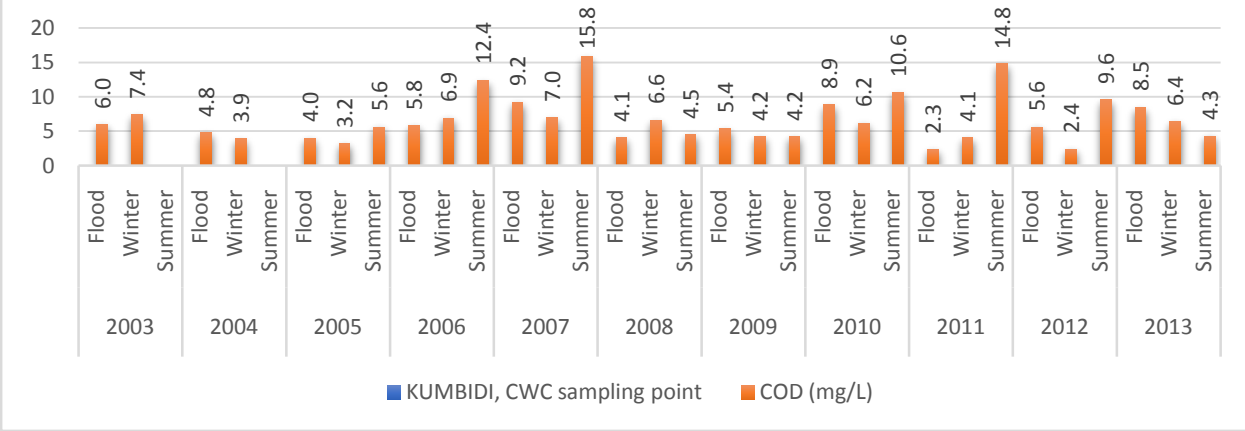
4.23 Chemical Oxygen demand

Kumbidi WQ site:

The COD value for Kumbidi site lies in the range of 1.0 to 15.8 mg/L and the yearly Average values lie in the range of 4.3 to 10.6 mg/L. The minimum average in Flood season and maximum average in the summer season.The yearly Average values of COD during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum and average value during Non-monsoon is high compared to value during monsoon season and the minimum value observed during monsoon is high compared to value during Non-monsoon season.

Graph(71):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

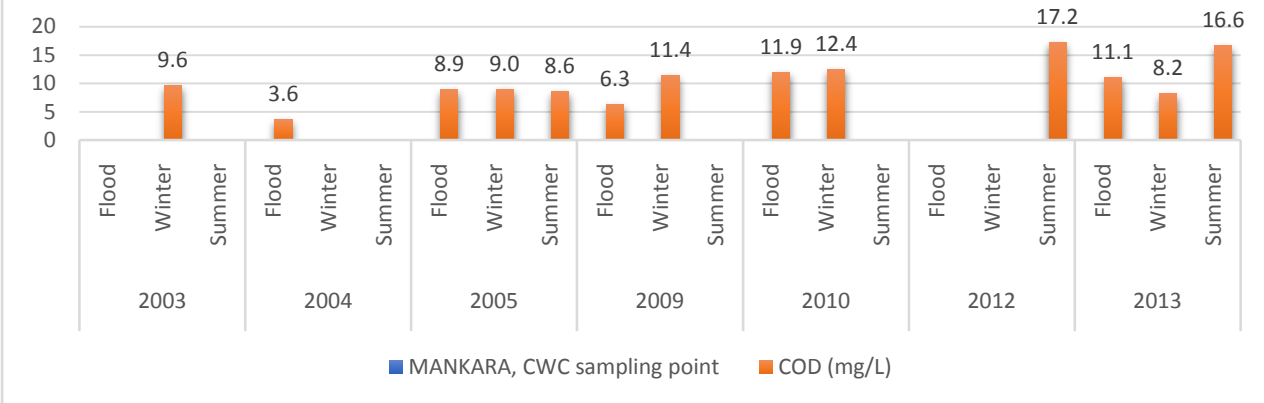


Mankara WQ site:

The COD value for Mankara site lies in the range of 3.6 to 17.2 mg/L and the yearly Average value lies in the range of 8.8 to 11.9 mg/L.The yearly Average values of COD during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum, average and minimum values during Non-monsoon are higher compared to values during monsoon season.

Graph(72):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



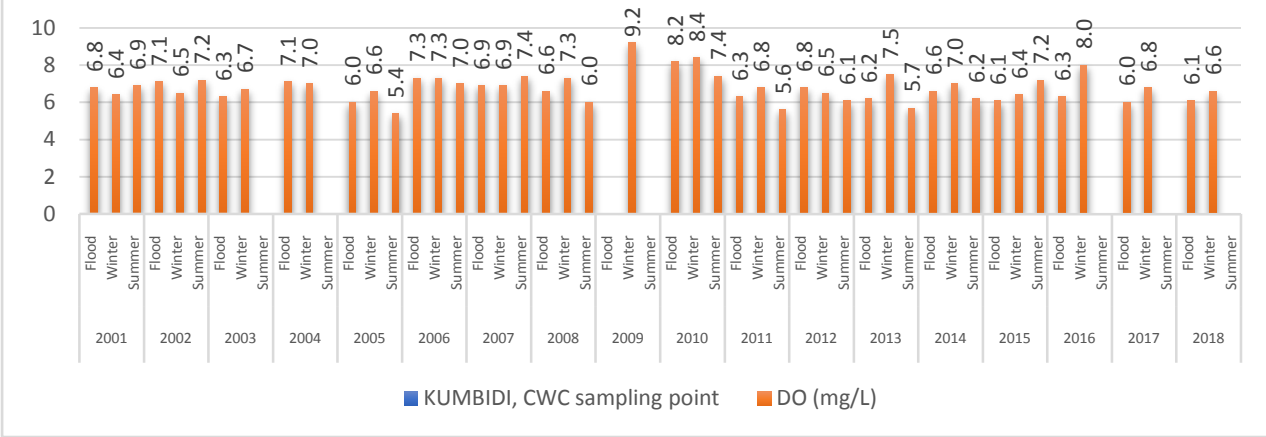
4.24 Dissolved oxygen

Kumbidi WQ site:

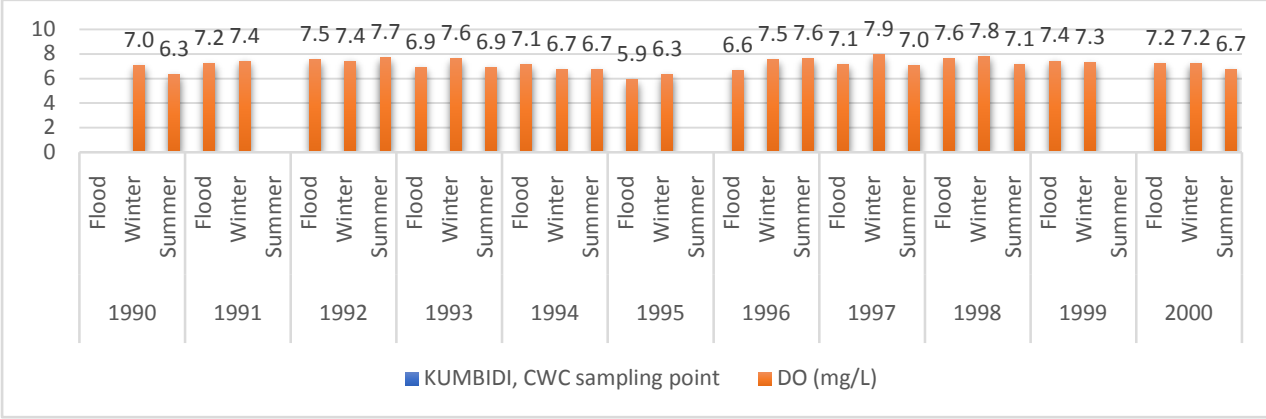
The Dissolved oxygen value for Kumbidi sitegenerally lies in the range of 5.4 to 9.2 mg/L and the yearly Average value lies in the range of 6.0 to 8.0 mg/L. The yearly Average values of DO during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum, minimum and average value during Non-monsoon season is high compared to value during monsoon season.

Graph(73):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(74):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

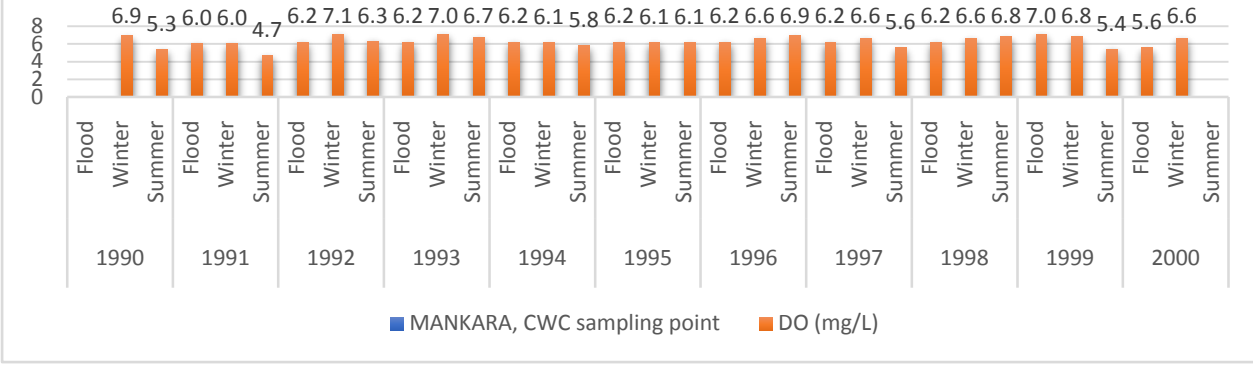


Mankara WQ site:

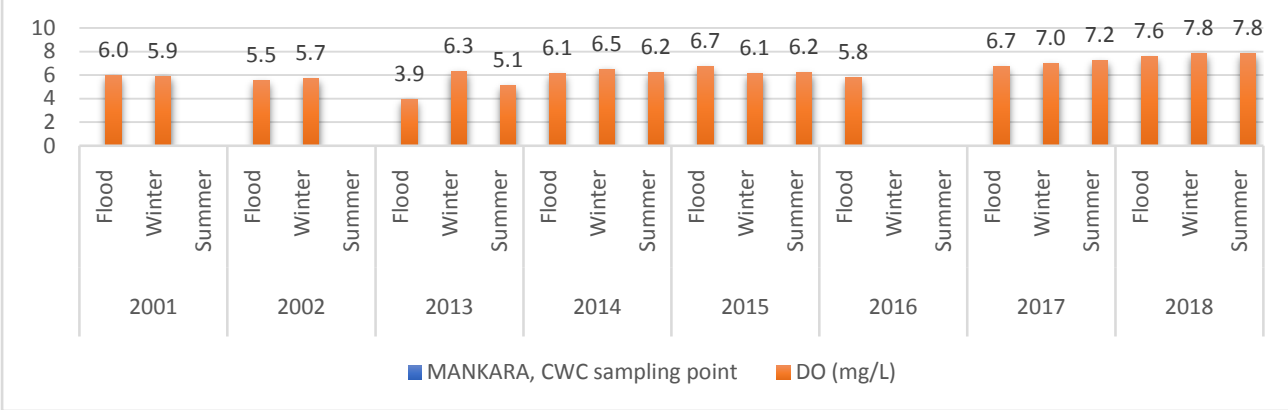
The Dissolved oxygen values for Mankara site lies in the range of 4.0 to 8.5 mg/L and the yearly Average value lies in the range of 5.1 to 7.7 mg/L. The yearly Average values of DO during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum, minimum and average dissolved oxygen during Non-monsoon period is high compared to value during monsoon period.

Graph(75):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(76):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



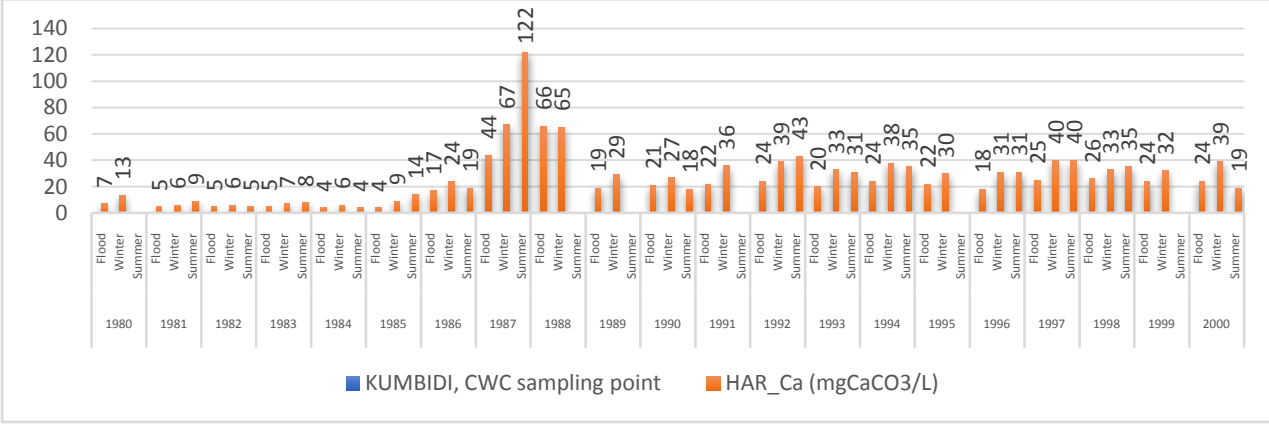
4.25 Calcium hardness

Kumbidi WQ site:

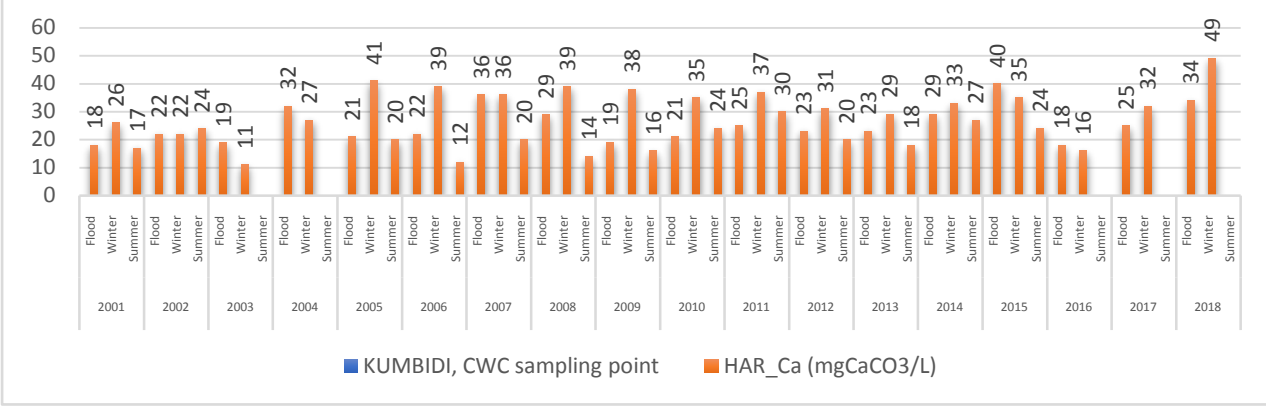
The Calcium hardness value for Kumbidi site lies in the range of 2 to 156 mg CaCO3/L and The Calcium hardness yearly Average value for Kumbidi sites lies in the range of 4.6 to 77.6 mg CaCO3/L. The yearly Average values of Calcium Hardness during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum, minimum and average value during Non-monsoon is high compared to value during monsoon season.

Graph(81):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(82):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

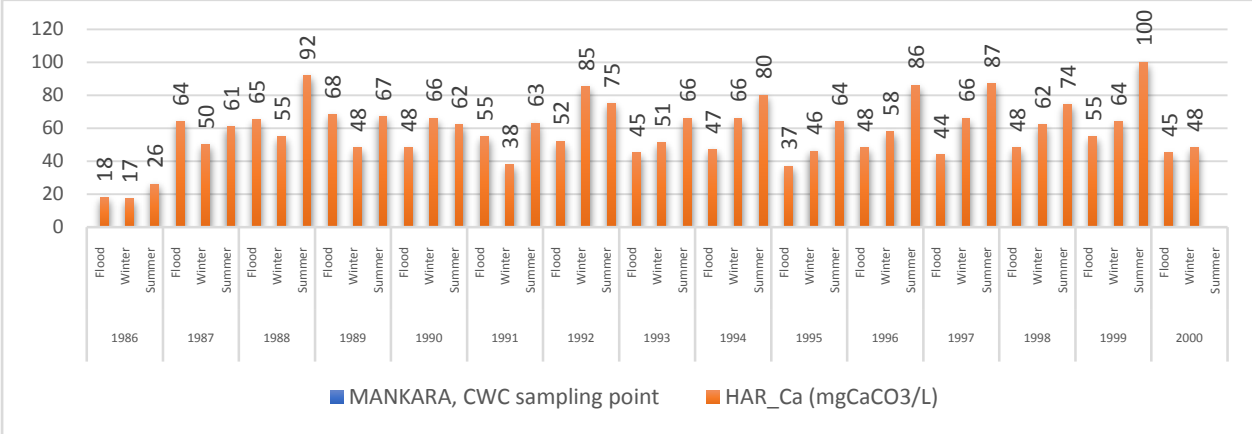


Mankara WQ site:

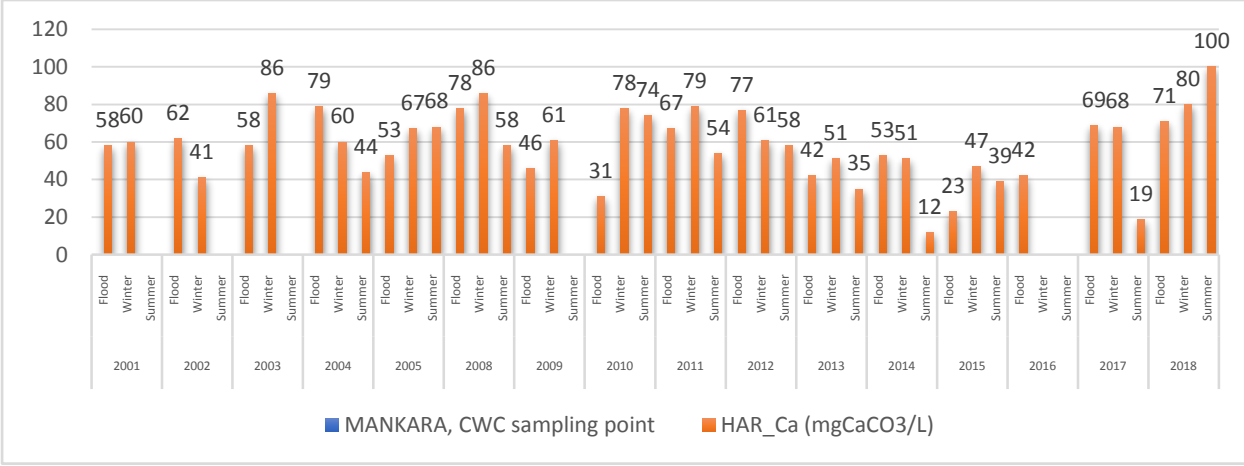
The Calcium hardness values for Mankara site lies in the range of 9 to 128 mg CaCO3/L and the yearly Average values lies in the range of 20.3 to 83.6 mg CaCO3/L. The yearly Average value of Calcium Hardness during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum,minimum and average Calcium Hardness value during Non-monsoon season is high compared to value during monsoon season .

Graph(83):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(84):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



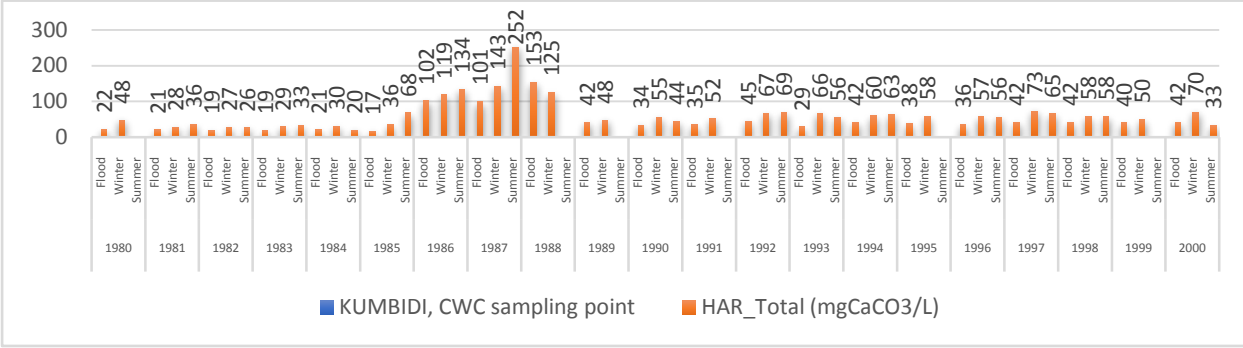
4.26 Total Hardness:

Kumbidi WQ site:

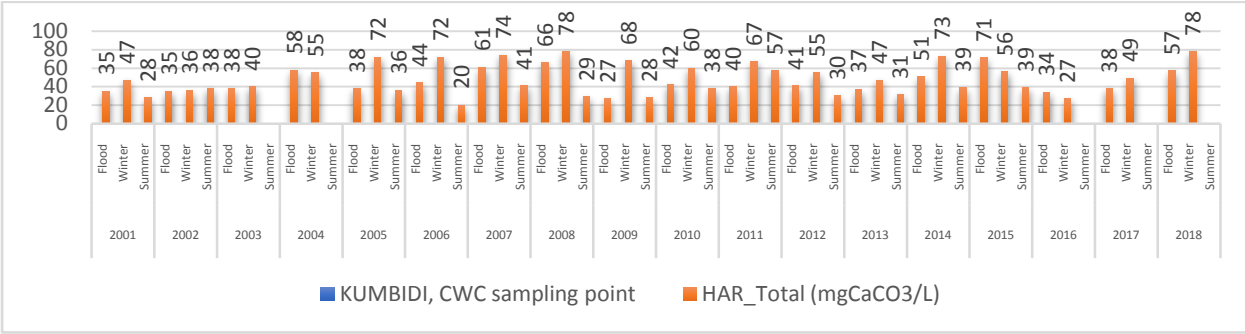
The Total Hardness values for Kumbidi site lies in the range of 14 to 364 mg CaCO3/L and the yearly Average value lies in the range of 24 to 165.3 mg CaCO3/L.The yearly Average values of Total Hardness during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum,minimum and average values during Non-monsoon season are higher compared to the values during monsoon season .

Graph(85):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER



Graph(86):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA RIVER

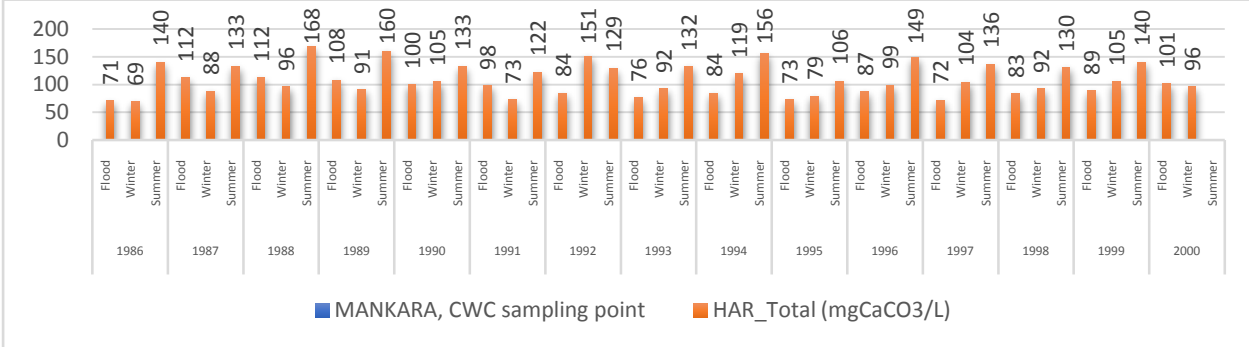


Mankara WQ site

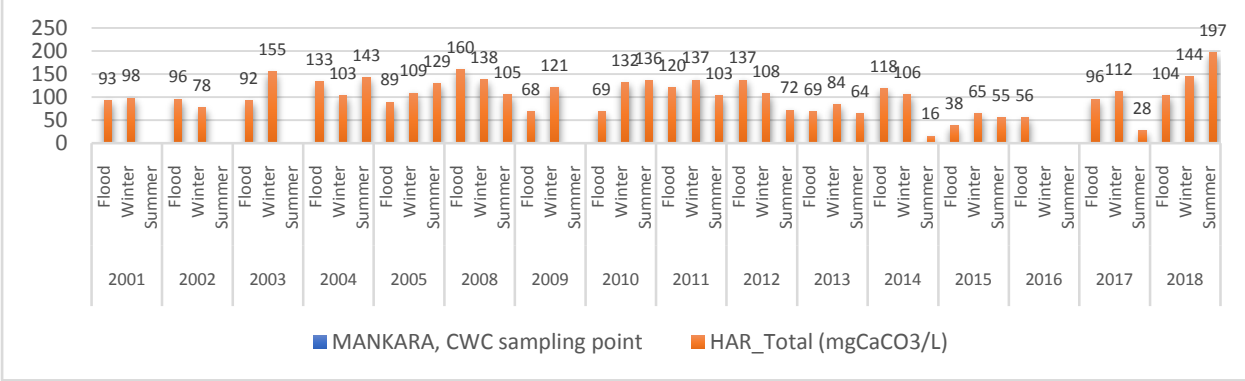
The Total Hardness values for Mankara site lies in the range of 16 to 228 mg CaCO3/L and the yearly Average value lies in the range of 52.6 to 148.3 mg CaCO3/L. The yearly Average values of Total Hardness during Non-monsoon(Dry season) is generally higher when compared to the values during monsoon(Wet season) .

The maximum and average value during Non-monsoon season is high compared to value during monsoon season and the minimum value during monsoon season is high compared to value during Non-monsoon season.

Graph(87):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(88):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River

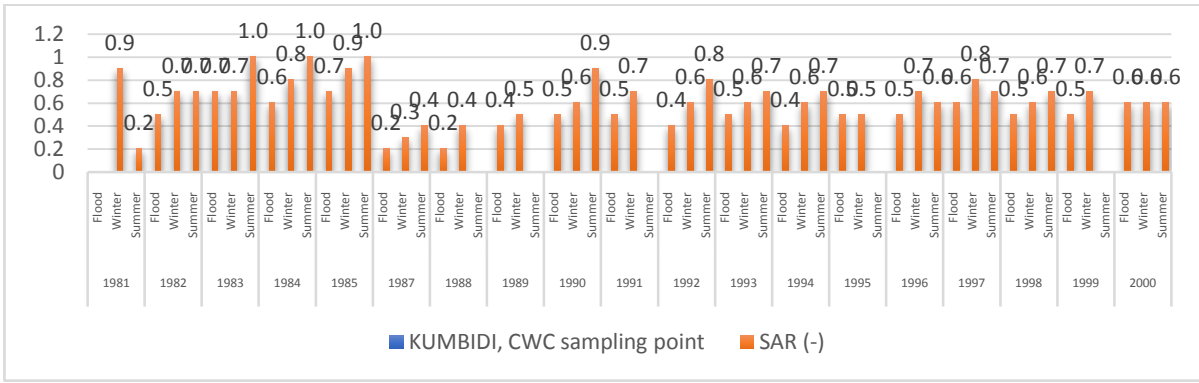


4.27 Sodium Absorption Ratio (SAR)

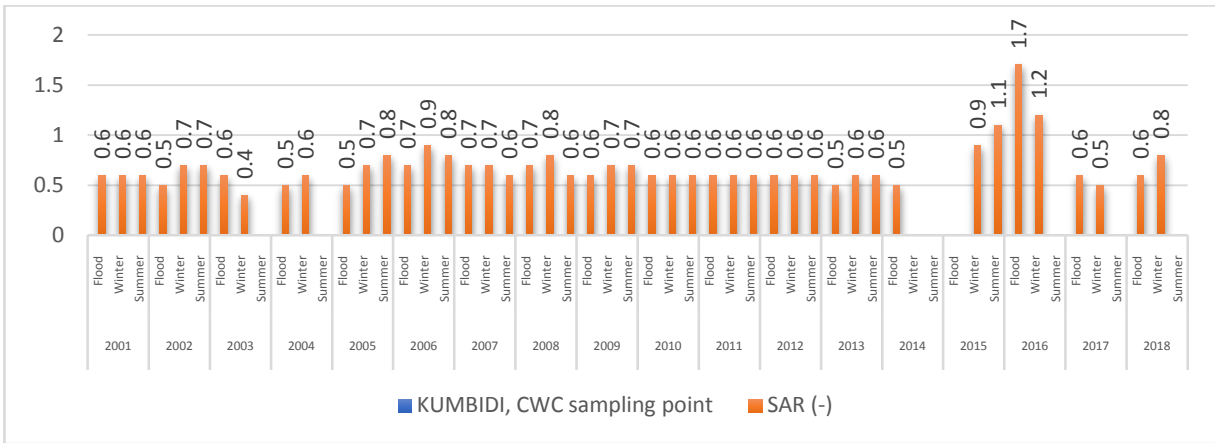
Kumbidi WQ site:

The maximum value of SAR during Monsoon is high compared to value during Non-monsoon and the average value during Non-monsoon is high compared to value during monsoon. The minimum value is same during both the season.

Graph(89):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA River



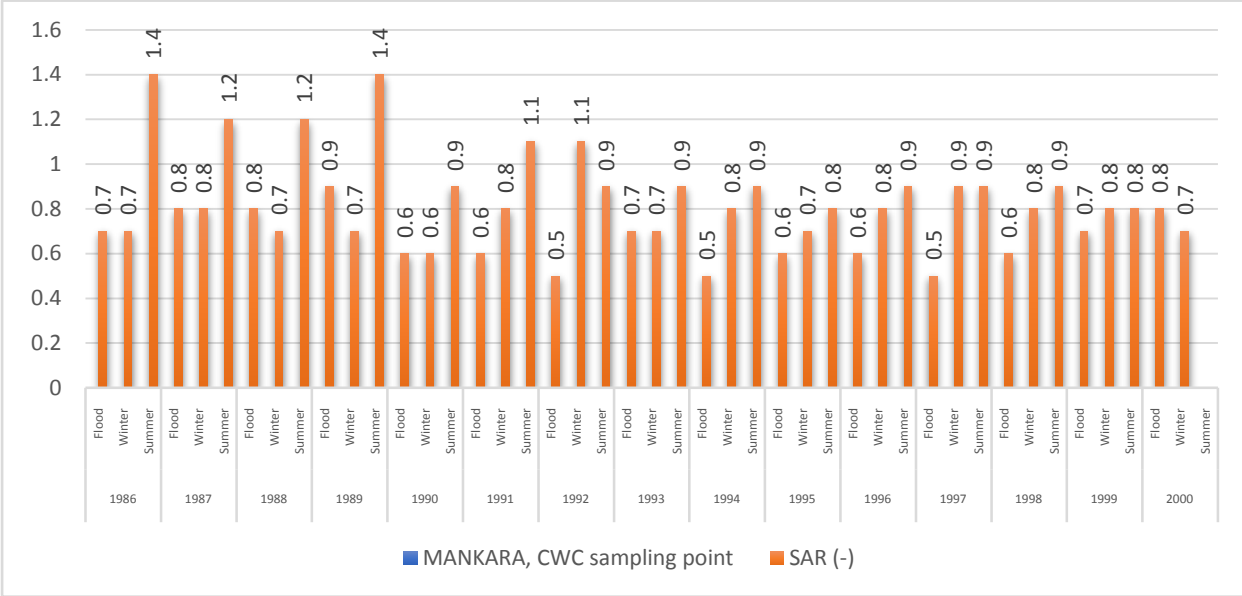
Graph(90):SEASONAL VARIATION : KUMBIDI site on BHARATAPUZHA River



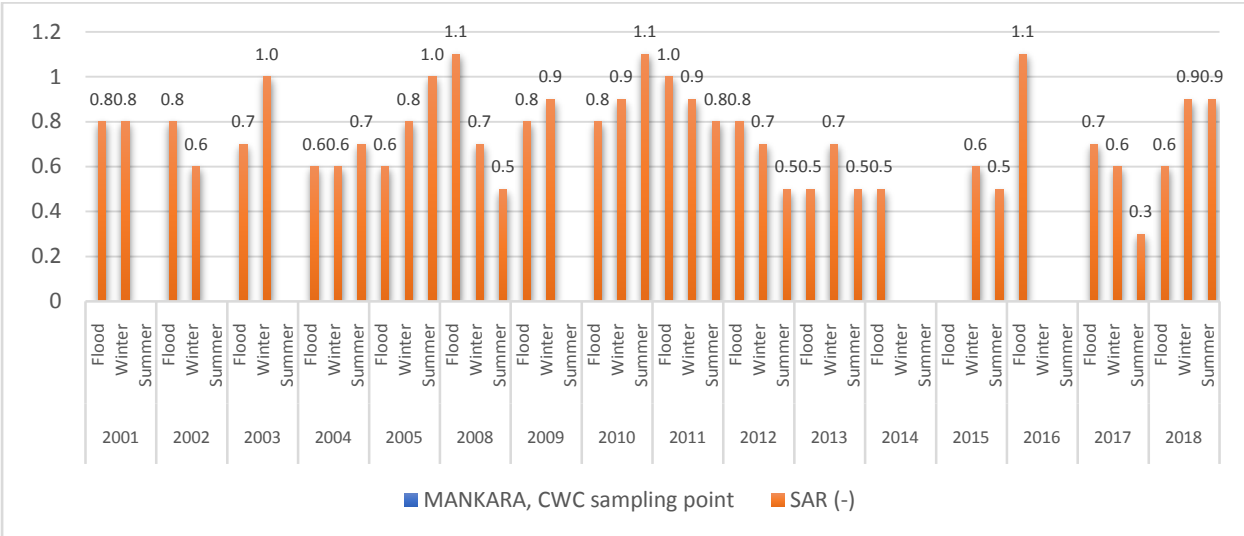
Mankara WQ site:

The maximum and average value of SAR is high during Non-monsoon compared to value during Monsoon and the minimum value is high during monsoon season.

Graph(91):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



Graph(92):SEASONAL VARIATION : MANKARA site on BHARATAPUZHA River



5.0 CONCLUSIONS:

In this report on Bharatapuzha River the Water Quality data of Kumbidi(1980 to 2019) and Mankara(1986 to 2019) under South Western Rivers Division, Central Water Commission, Kochi are taken for discussion. Six WQ data per year are available for discussion at each sampling point.

After detailed study of the data it can be concluded that for Bhratapuzha River during Non-monsoon (Dry Season) period (Nov-May) the Electrical conductivity is high compared to during monsoon(Wet season) period (June-Oct) due to increase in ions concentration . The conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulphate and carbonate compounds. The compounds dissolved into ions are called electrolytes. The more ions present in river water leads to higher conductivity and fewer ions leads to lower conductivity.

It is also observed that the values of WQ parameters of Bhratapuzha River such as pH, TDS,T-Alkalinity, Boron,Calcium,Chloride,Potassium, Magnesium,Sodium, Nitrogen-Ammonia, Nitrogen Total Oxidised, Nitrite nitrogen, Nitrate nitrogen,ortho Phosphate, Total Phosphate,Biochemical oxygen demand, Chemical oxygen demand are higher during the Non-monsoon (Dry Season) compared to during monsoon(Wet) season. The temperature is high during monsoon season compared to during winter season which is a common criteria for a River water body. High Dissolved oxygen in Bharatapuzha River in non-monsoon season may be co-related with low temperature during Non-monsoon (Dry Season during winter).

Only the Silicate and sulphate value in Bhratapuzha river shows similar or marginal difference for both monsoon and non-monsoon season.

The Bharatapuzha river water is suitable for use as Drinking water source after conventional treatment and disinfection, Propagation of Wild life and Fisheries, Irrigation, Industrial Cooling, Controlled Waste disposal.

The water quality of river Bharathapuzha is over all good in nature. The ionic concentration is gradually decreasing from site Mankara (upstream) to site Kumbidi (downstream) which is unusual, as in normal case the water quality is deteriorating from upstream to downstream. It is due to the drainage area of Kumbidi site (5755 sq.km.) which is more than drainage area of site Mankara (2775 sq.km.). As quantum of water is increased at Kumbidi, so, value of all pollution indicating parameters reduces at Kumbidi site.

The values of pH, T-Hardness, Iron, Chloride, Magnesium, Sulphate, Nitrate, Fluoride, T-Alkalinity, Boronof Bharatapuzha river are in the acceptable limits (AS PER INDIAN STANDARD 10500 : 2012 FOR DRINKING WATER).

The river water of this basin is slightly alkaline in nature. The water is free from salinity hazard and classified as C2S1 at (Mankara) and C1S1 at (Kumbidi) by comparing Wilcox Diagram.

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Annexure-1

6.0 ACCEPTABLE LIMITS FOR DRINKING WATER AS PER INDIA STANDARD 10500 : 2012

S. No.	Substance Characteristic	Requirement* (Acceptable Limits)	Undesirable effect outside the desirable limit	Permissible Limit**in absence of alternate source
1.	pH Value	6.5 To 8.5	Beyond this range the water will effect the mucous membrane and/or water supply system	No relaxation
2.	Total Hardness, (as $CaCO_3$) mg/l, Max.	200	Encrustations in water supply structure and adverse effect on domestic use	600
3	Iron (as Fe), mg/l, Max	0. 3	Beyond this limit taste/appearance are affected, has adverse affect on domestic uses and water supply structures, and promotes iron bacteria	No relaxation
4	Chlorides (as Cl), mg/l, Max	250	Beyond this limit taste, corrosion and palatability are affected	1000
5	Total Dissolved Solids, mg/l, Max	500	Beyond this palatability decreases and may cause Gastro intestinal irritation	2000
6	Calcium (as Ca) mg/l, Max.	75	Encrustations in water supply structure and adverse effect on domestic use	200
7	Magnesium (as Mg) mg/l, Max	30	Encrustations in water supply structure and adverse effect on domestic use	100
8	Sulphates (as SO_4), mg/l, Max	200	Beyond this causes Gastro intestinal irritation when magnesium or sodium are present	400
9	Nitrate (as NO_3) mg/l, Max.	45	Beyond this methaemoglobinemia takes place.	No relaxation
10	Fluorides (as F), mg/l, Max	1.0	Fluoride may be kept as low as possible. High fluoride may cause fluorosis	1.5
11	Total Alkalinity mg/l, Max	200	Beyond this limit, taste becomes unpleasant	600
12	Boron mg/l, Max	0.5	-	1.0

7.0 Tolerance and Classification

As per IS: 2296-1982, the tolerance limits of parameters are specified as per classified use of water (Table below) depending on various uses of water. The following classifications have been adopted in India.

Classification	Type of use
Class A	Drinking water source without conventional treatment but after disinfection
Class B	Outdoor bathing
Class C	Drinking water source with conventional treatment followed by disinfection.
Class D	Fish culture and wild life propagation
Class E	Irrigation, industrial cooling or controlled waste disposal

Designated Best Use	Class of water	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	pH between 6.5 and 8.5 ;Dissolved Oxygen : 6mg/l or more Biochemical Oxygen Demand 5 days at 20°C : 2mg/l or less Total Dissolved Solids: 500mg/L ;Calcium : 80.1 mg/L; Chloride : 250 mg/L Fluoride : 1.5mg/L ; Iron : 0.3mg/L; Magnesium : 24.28; Sulphate : 400mg/L Total Hardness : 300mg CaCO3/L ;Total Coliforms Organism : MPN/100ml shall be 50 or less
Outdoor bathing (Organised)	B	pH between 6.5 and 8.5 ;Dissolved Oxygen : 5mg/l or more Biochemical Oxygen Demand 5 days 20°C :3mg/l or less ;Fluoride : 1.5mg/L Total Coliforms Organism : MPN/100ml shall be 500 or less
Drinking water source after conventional treatment and disinfection	C	pH between 6 to 9 ;Dissolved Oxygen : 4mg/l or more ; Iron : 50mg/L; Biochemical Oxygen Demand 5 days 20°C :3mg/l or less ; Sulphate: 400mg/L; Total Dissolved Solids: 1500mg/L; Chloride : 600 mg/L; Fluoride : 1.5mg/L Total Coliforms Organism :MPN/100ml shall be 5000 or less
Propagation of Wild life and Fisheries	D	pH : between 6.5 to 8.5; Dissolved Oxygen : 4mg/l or more Free Ammonia (as N) : 1.2 mg/l or less ;Electrical Conductivity at 25C :1000micro mhos/cm
Irrigation, Industrial Cooling, Controlled Waste disposal	E	pH : between 6.0 to 8.5 ; Electrical Conductivity at 25°C: 2250 micro mhos/cm Sodium absorption Ratio : 26 ; Boron : 2mg/l; Total Dissolved Solids: 2100mg/L Chloride : 600 mg/L; Sulphate : 1000mg/L

8.0 Kumbidi WQ data variation in Monsoon (Wet) and Non-monsoon(Dry) season on Bhratapuzha River:

Parameter	Unit	Analysis of Period 1980-2018						Last Year Average	
		Maximum Observed		Average		Minimum Observed		2018-2019	
		Monsoon	Non-Monsoon	Monsoon	Non-Monsoon	Monsoon	Non-Monsoon	Monsoon	Non-Monsoon
PHYSICAL									
EC_GEN	µmho/cm	324	390	111	160	35	24	154	229
pH_GEN	pH units	8.1	8.3	7.2	7.5	5.6	6.0	7.2	7.7
TDS	mg/L	256	198	77	105	32	26	No data	No data
Temp	deg C	33.5	32.0	28.2	27.6	24.5	23.0	27.7	27.0
CHEMICAL									
ALK-TOT	mgCaCO3/L	141	159	38	55	12	8	54	67
B	mg/L	0.46	0.75	0.07	0.07	0.00	0.00	0.04	0.08
Ca	mg/L	34	62	9	12	1	1	14	20
Cl	mg/L	44.6	44.0	15.8	18.4	7.0	5.2	16.0	25.0
F	mg/L	1.60	2.32	0.26	0.41	0.03	0.05	0.17	0.27
Fe	mg/L	0.3	1.5	0.1	0.2	0.0	0.0	0.2	0.1
K	mg/L	4.1	5.1	1.6	1.8	0.1	0.2	2.4	3.5
Mg	mg/L	36.9	50.5	5.6	7.4	0.5	1.5	5.6	7.0
Na	mg/L	33.2	19.1	7.8	10.9	2.5	2.6	10.8	16.2
NH3-N	mg N/L	0.26	0.49	0.13	0.12	0.02	0.02	No data	No data
NO2+NO3	mg N/L	4.79	6.09	1.33	1.13	0.16	0.05	No data	2.50
NO2-N	mgN/L	0.25	0.26	0.07	0.07	0.00	0.00	0.02	0.03
NO3-N	mgN/L	4.69	6.07	1.19	1.28	0.12	0.05	No data	2.47
o-PO4-P	mg P/L	0.472	0.670	0.128	0.124	0.010	0.010	0.019	0.026
P-Tot	mgP/L	0.726	11.000	0.106	0.240	0.010	0.010	No data	No data
SiO2	mg/L	42.8	39.8	13.2	12.6	1.5	1.3	8.9	13.0
SO4	mg/L	18.0	18.0	3.8	3.5	0.6	0.5	5.3	7.4
BIOLOGICAL									
BOD3-27	mg/L	2.1	2.2	0.9	0.8	0.2	0.2	1.2	0.9
COD	mg/L	14.4	15.8	5.9	6.4	1.5	1.0	No data	No data
DO	mg/L	8.5	9.2	6.8	7.0	3.4	5.4	6.1	6.6
CHEMICAL INDICES									
HAR_Ca	mgCaCO3/L	85	156	22	30	2	3	34	49
HAR_Total	mgCaCO3/L	199	364	46	60	14	15	57	78
SAR	-	3.3	1.4	0.6	0.7	0.2	0.2	0.6	0.8

Annexure-4

9.0 Mankara WQ data variation in Monsoon (Wet) and Non-monsoon(Dry) season on Bhratapuzha River:

Parameter	Unit	Analysis of Period 1980-2018						Last Year Average	
		Maximum Observed		Average		Minimum Observed		2018-2019	
		Monsoon	Non-Monsoon	Monsoon	Non-Monsoon	Monsoon	Non-Monsoon	Monsoon	Non-Monsoon
PHYSICAL									
EC_GEN	µmho/cm	570	900	259	334	21	29	299	415
pH_GEN	pH units	8.6	8.7	7.6	7.8	5.6	6.2	7.3	8.3
TDS	mg/L	399	378	184	211	82	103	No data	No data
Temp	deg C	35.5	33.5	27.7	27.2	21.0	17.5	26.6	27.0
CHEMICAL									
ALK-TOT	mgCaCO3/L	178	231	83	100	20	17	96	127
B	mg/L	1.37	1.12	0.13	0.11	0.01	0.00	0.10	0.15
Ca	mg/L	37	51	21	24	4	5	29	35
Cl	mg/L	70.3	59.2	22.4	26.2	9.0	5.6	24.0	36.3
F	mg/L	2.74	3.81	0.53	0.81	0.05	0.02	0.35	0.47
Fe	mg/L	0.4	1.5	0.1	0.2	0.0	0.0	0.4	0.4
K	mg/L	23.0	36.0	2.7	3.0	0.4	0.2	3.4	3.7
Mg	mg/L	31.4	29.4	9.6	11.9	1.0	0.0	7.9	18.0
Na	mg/L	39.5	54.1	15.3	20.1	4.7	2.0	14.7	26.1
NH3-N	mg N/L	0.47	0.26	0.21	0.14	0.03	0.00	No data	No data
NO2+NO3	mg N/L	13.02	12.99	1.59	2.34	0.12	0.12	No data	1.57
NO2-N	mgN/L	0.53	1.25	0.09	0.14	0.00	0.00	0.03	0.06
NO3-N	mgN/L	12.80	12.80	1.43	2.31	0.12	0.12	No data	1.51
o-PO4-P	mg P/L	0.414	0.890	0.155	0.211	0.013	0.010	0.017	0.036
P-Tot	mgP/L	0.450	37.000	0.131	0.561	0.005	0.010	No data	No data
SiO2	mg/L	36.0	73.8	14.4	16.5	0.8	1.5	8.4	17.2
SO4	mg/L	61.0	48.0	8.0	8.3	0.6	1.0	9.4	19.2
BIOLOGICAL/BACTERIOLOGICAL									
BOD3-27	mg/L	2.1	2.4	0.9	1.1	0.4	0.2	0.6	0.8
COD	mg/L	16.2	17.2	8.4	11.1	2.6	7.2	No data	No data
DO	mg/L	8.2	8.5	6.1	6.4	3.1	3.8	7.7	7.8
CHEMICAL INDICES									
HAR_Ca	mgCaCO3/L	92	128	52	60	9	12	71	87
HAR_Total	mgCaCO3/L	211	228	92	109	20	16	104	162
SAR	-	1.7	1.8	0.7	0.8	0.3	0.1	0.6	0.9

Yearly Minimum and Maximum (WQ parameter) for Kumbidi Site

Year	EC_GEN (µmho/cm)		pH_GEN		TDS (mg/L)		Temp (deg C)		ALK-TOT (mgCaCO3/L)		B (mg/L)		Ca (mg/L)		Cl (mg/L)		F (mg/L)		Fe (mg/L)		K (mg/L)		Mg (mg/L)		Na (mg/L)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1980-1981	103	295	7.6	7.8	68	198			65	159			3	6	15.0	31.1							3.7	9.2		
1981-1982	57	179	6.6	7.9	38	120			61	115			2	4	9.9	44.6					0.9	3.0	2.2	7.2	2.6	15.0
1982-1983	84	153	6.5	7.9	32	145			47	129			1	3	13.2	24.0					1.0	2.3	2.4	6.1	3.7	9.3
1983-1984	68	232	6.2	7.2	50	174			29	141			1	5	16.0	44.0					0.8	2.4	2.2	9.0	2.9	14.2
1984-1985	62	158	6.6	7.0	36	116			41	83			1	2	10.0	15.0					1.2	2.6	2.4	8.3	4.3	12.8
1985-1986	87	200	6.6	8.2	64	132			37	88			1	6	9.0	26.0					0.4	2.2	2.7	16.3	5.5	16.0
1986-1987	50	186	6.8	7.6	26	110			9	71			5	14	15.0	23.0							7.5	41.3		
1987-1988	74	280	6.7	8.1			24.5	31.0	19	76	0.03	0.04	9	62	13.0	31.0					0.8	3.5	6.1	50.5	3.0	19.1
1988-1989	88	231	7.1	8.1			25.5	32.0	27	73	0.02	0.08	13	37	19.0	29.0					1.2	2.3	3.9	27.7	5.3	11.3
1989-1990	81	177	6.7	8.2			26.0	29.5	10	66	0.02	0.07	6	14	14.0	21.3					0.8	3.5	2.4	6.8	4.6	10.4
1990-1991	84	242	7.1	8.1			24.5	30.0	24	64	0.01	0.75	5	14	7.0	21.0					0.8	2.0	1.9	9.7	4.0	14.0
1991-1992	55	188	7.3	7.7			23.0	29.0	18	61	0.01	0.01	6	21	10.0	30.0					0.8	2.0	0.5	6.8	5.0	12.0
1992-1993	93	270	6.9	7.7			24.5	30.0	32	86			8	21	11.0	23.0					0.8	2.3	3.4	9.2	5.0	19.0
1993-1994	45	200	7.0	7.9			25.5	32.0	14	66	0.01	0.10	4	15	10.0	19.0					0.4	2.0	1.0	9.2	3.0	16.0
1994-1995	72	260	6.8	8.1			26.0	28.5	20	68	0.01	0.06	6	18	11.0	21.0					0.8	2.3	1.5	9.2	2.5	15.0
1995-1996	49	170	7.2	7.8			26.0	33.5	18	46	0.01	0.03	6	14	10.0	20.0					0.8	2.0	1.0	9.2	3.7	11.0
1996-1997	77	230	7.2	7.8			26.0	30.0	8	30	0.01	0.04	6	16	11.0	19.0					1.2	2.2	3.4	8.7	5.5	12.0
1997-1998	109	390	7.1	8.3			27.5	31.5	21	68	0.02	0.04	10	25	14.0	33.0					1.2	5.1	3.4	11.2	6.0	19.0
1998-1999	87	270	7.1	8.1			25.0	30.0	16	52	0.02	0.03	6	14	13.0	23.0					1.2	2.7	1.9	7.3	5.3	12.9
1999-2000	129	188	7.2	7.9			24.5	29.5	24	48	0.01	0.03	9	14	16.0	20.0					1.2	2.0	2.9	4.9	5.8	12.0
2000-2001	63	260	7.4	8.1			24.5	30.0	22	86	0.01	0.05	6	22	12.1	21.3					0.8	2.8	1.9	10.2	5.3	14.4
2001-2002	65	146	7.2	8.1			25.5	31.0	22	52	0.02	0.08	6	12	10.8	15.0					1.3	2.4	1.9	6.8	6.6	10.2
2002-2003	79	156	7.1	7.8	57	126	26.0	30.0	28	38	0.01	0.03	6	12	10.0	21.0	0.14	0.24			1.2	1.8	1.5	5.3	6.0	10.0
2003-2004	55	134	7.1	7.4	36	106	25.0	28.5	23	49	0.01	0.03	3	10	8.0	13.0	0.08	0.24			1.2	2.0	2.4	11.4	5.0	11.0
2004-2005	113	144	7.3	7.6	77	131	25.0	28.0	38	56	0.04	0.29	10	14	13.0	17.0	0.06	0.62			1.7	2.6	5.8	7.8	5.9	10.0
2005-2006	78	232	7.0	7.9	53	187	24.5	30.0	19	62	0.02	0.13	6	18	9.9	22.4	0.14	0.32			1.1	2.4	2.4	8.3	5.8	14.5
2006-2007	74	179	6.9	7.9	56	145	26.0	29.0	20	66	0.00	0.07	5	16	12.8	19.2	0.05	0.79			1.4	2.5	2.0	9.7	7.3	18.0
2007-2008	126	226	7.3	7.8	106	192	27.0	29.5	34	67	0.00	0.03	8	15	14.3	22.7	0.19	0.39	0.0	0.7	1.5	2.4	5.0	10.5	9.2	16.6
2008-2009	98	324	7.3	8.1	79	256	26.5	30.0	26	93	0.07	0.46	6	18	9.9	36.2	0.05	0.31	0.0	0.1	0.8	3.3	3.4	18.4	6.5	23.2
2009-2010	63	215	7.2	7.7	39	134	27.0	32.0	18	67	0.00	0.75	6	15	8.5	19.9	0.08	0.26	0.0	0.1	1.5	2.4	0.9	7.3	4.6	15.0
2010-2011	109	180	6.5	7.7	68	114	26.0	32.0	33	60	0.02	0.28	6	14	11.4	21.4	0.05	0.22	0.0	0.6	1.8	3.0	3.4	6.9	7.5	12.0
2011-2012	111	210	6.3	7.3	78	153	26.0	29.0	32	66	0.03	0.35	8	16	12.8	20.6	0.03	2.32	0.0	1.5	1.4	2.4	2.9	8.8	7.8	12.0
2012-2013	86	150	6.5	7.2	56	99	27.0	30.5	26	47	0.06	0.17	8	13	12.0	15.6	0.06	1.19	0.1	0.2	1.6	2.5	2.5	6.2	7.3	10.0
2013-2014	80	170	6.7	7.2	52	120	24.5	29.0	25	62	0.02	0.10	6	17	9.9	15.0	0.12	1.60	0.0	0.1	1.5	3.0	2.9	5.8	6.4	10.9
2014-2015	65	223	6.7	7.2			26.0	29.0					10	14	5.2	26.1			0.0	0.0	2.0	4.1	2.4	10.4	7.0	9.7
2015-2016	24	309	6.0	7.1			27.0	30.0					9	17	7.8	33.5			0.0	0.0	0.2	0.3	3.8	9.5	15.2	16.6
2016-2017	38	100	5.6	7.1			27.0	28.0	12	40			3	11	15.1	23.5					0.1	2.4	2.8	5.7	14.1	33.2
2017-2018	91	105	6.5	7.2	61	69	28.0	29.0	32	36	0.02	0.28	9	13	8.7	20.9	0.30	0.71	0.0	0.1	2.0	3.0	2.7	4.0	6.3	14.2
2018-2019	140	229	6.9	7.7			27.0	28.0	46	67	0.03	0.08	10	20	11.1	25.0	0.15	0.27	0.1	0.3	2.3	3.5	5.2	6.9	8.0	16.2

Yearly Minimum and Maximum (WQ parameter) for Kumbidi Site

Year	NH3-N (mg N/L)		NO2+NO3(mg N/L)		NO2-N (mgN/L)		NO3-N (mgN/L)		o-PO4-P (mg P/L)		P-Tot Q-(mgP/L)		SiO2 (mg/L)		SO4 (mg/L)		BOD3-27 (mg/L)		COD (mg/L)		DO (mg/L)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1985-1986															4.0	7.2						
1988-1989											0.100	0.100	2.3	39.8	2.0	3.4						
1989-1990											0.100	0.310	1.3	8.9	1.0	3.8						
1990-1991											0.010	0.090	2.8	15.2	1.0	18.0					6.3	7.3
1991-1992											0.010	0.100	14.4	33.4	1.0	4.0					6.6	8.0
1992-1993											0.010	0.030	1.5	30.0	1.0	9.0					6.7	8.5
1993-1994											0.010	0.030	7.6	25.1	1.0	4.3					5.8	8.2
1994-1995											0.010	0.040	9.0	18.0	1.0	12.5					5.9	7.6
1995-1996											0.100	11.000	8.0	15.0	1.0	2.0					4.2	7.2
1996-1997											0.120	0.300	8.0	13.0	1.0	5.0					6.4	7.9
1997-1998											0.020	0.220	6.2	10.3	1.0	7.0					5.3	8.5
1998-1999											0.120	0.300	5.9	8.7	2.0	10.0					6.8	8.0
1999-2000											0.100	0.280	7.1	8.4	1.0	6.0					6.4	8.4
2000-2001											0.073	0.726	5.3	11.7	1.0	8.4					6.5	8.2
2001-2002			No data available								0.010	0.066	6.8	9.9	1.4	3.6					5.7	7.4
2002-2003			0.18	0.27							0.030	0.287	10.2	25.6	1.0	13.0	No data available				5.9	7.4
2003-2004			0.24	1.31							0.013	0.040			1.0	5.0	0.4	1.4	4.8	10.0	5.6	6.9
2004-2005			0.36	2.97							0.028	0.270	4.2	10.3	2.8	18.0	0.4	1.6	2.2	6.0	6.4	7.6
2005-2006			0.05	0.67	0.00	0.13	0.05	0.55			0.023	0.397	6.3	16.7	2.8	8.4	0.2	0.6	1.6	5.6	3.9	7.6
2006-2007			0.26	2.73	0.00	0.25	0.26	2.73			0.031	0.200	9.6	14.4	1.5	10.8	0.4	1.8	2.8	12.4	6.8	7.6
2007-2008	0.05	0.05	1.10	4.79	0.05	0.26	0.98	4.69	0.034	0.390	0.093	0.353	12.1	24.6	2.4	17.0	0.4	1.8	3.3	15.8	6.4	7.4
2008-2009	0.05	0.08	0.16	0.42	0.05	0.10	0.12	0.86	0.010	0.472	0.010	0.010	17.6	27.4	3.0	15.0	0.2	1.6	1.5	11.4	5.8	7.8
2009-2010	0.10	0.49					0.12	0.12	0.010	0.090			27.4	42.8	1.0	6.2	0.2	0.6	1.8	9.6	9.2	9.2
2010-2011	0.05	0.26	0.16	0.54	0.01	0.08	0.14	0.53	0.020	0.210			15.2	27.4	1.0	4.8	0.2	1.6	2.0	12.6	7.4	8.4
2011-2012	0.01	0.14	0.17	3.11	0.03	0.11	0.14	3.49	0.025	0.670			16.4	23.0	0.5	9.0	0.2	1.6	1.6	14.8	5.6	6.8
2012-2013	0.09	0.17	0.84	6.09	0.02	0.12	0.79	6.07	0.095	0.380			13.4	17.0	0.7	1.9	0.2	1.6	1.0	9.6	6.1	7.2
2013-2014			0.34	1.37	0.05	0.11	0.27	1.27	0.012	0.140			4.8	17.0	0.6	4.3	0.6	2.0	4.3	14.4	3.4	8.2
2014-2015															4.0	17.0	0.2	1.6			6.0	7.0
2015-2016																	0.2	2.2			5.8	7.2
2016-2017																	0.2	2.0			3.8	8.2
2017-2018					0.03	0.06			0.026	0.080			7.3	8.7	7.5	10.2	0.8	1.6			4.6	7.3
2018-2019			0.58	0.58	0.01	0.02	0.56	0.56	0.017	0.026			6.9	13.0	3.7	7.6	0.7	1.6			4.6	7.2

Yearly Minimum and Maximum (WQ parameter) for Kumbidi Site

Year	HAR_Ca (mgCaCO3/L)		HAR_Total (mgCaCO3/L)		Na% (%)		RSC(-)		SAR(-)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1980-1981	7	16	22	53			0.6	1.2		
1981-1982	4	9	15	36	13	55	0.7	1.2	0.2	1.4
1982-1983	3	8	15	33	32	48	0.5	1.5	0.4	0.8
1983-1984	2	12	14	49	26	64	0.4	1.6	0.3	1.5
1984-1985	3	6	15	40	23	52	0.1	1.0	0.3	1.1
1985-1986	3	16	15	83	34	53	0.0	0.9	0.6	1.2
1986-1987	13	34	44	204			0.0	0.1		
1987-1988	23	156	55	364	8	15	0.0	0.0	0.2	0.4
1988-1989	32	93	48	199	7	26	0.0	0.0	0.2	0.6
1989-1990	16	36	36	58	20	28	0.0	0.0	0.3	0.6
1990-1991	12	36	28	76	23	40	0.0	0.0	0.3	0.9
1991-1992	14	52	16	66	24	47	0.0	0.0	0.4	0.8
1992-1993	20	52	40	90	19	34	0.0	0.0	0.3	0.9
1993-1994	10	38	14	70	21	35	0.0	0.0	0.3	0.9
1994-1995	16	46	22	84	10	40	0.0	0.0	0.2	0.9
1995-1996	14	36	18	60	23	31	0.0	0.0	0.4	0.7
1996-1997	16	40	34	74	23	34	0.0	0.0	0.4	0.7
1997-1998	24	62	40	108	22	35	0.0	0.0	0.4	0.9
1998-1999	16	36	32	66	26	31	0.0	0.0	0.4	0.7
1999-2000	22	34	34	52	26	34	0.0	0.0	0.4	0.7
2000-2001	14	56	22	98	24	34	0.0	0.0	0.5	0.7
2001-2002	14	30	22	56	27	37	0.0	0.2	0.5	0.7
2002-2003	14	30	30	40	27	37	0.0	0.0	0.5	0.7
2003-2004	8	24	20	61	19	34	0.0	0.2	0.4	0.7
2004-2005	24	36	48	62	17	28	0.0	0.0	0.3	0.6
2005-2006	16	44	28	78	26	38	0.0	0.0	0.5	0.8
2006-2007	12	40	20	80	28	43	0.0	0.0	0.6	1.0
2007-2008	20	38	41	78	25	32	0.0	0.0	0.5	0.8
2008-2009	14	46	29	123	29	32	0.0	0.0	0.5	0.9
2009-2010	16	38	20	69	29	38	0.0	0.1	0.4	0.8
2010-2011	16	36	36	65	27	32	0.0	0.0	0.5	0.7
2011-2012	20	40	32	77	25	33	0.0	0.0	0.6	0.6
2012-2013	20	32	30	56	26	34	0.0	0.0	0.5	0.7
2013-2014	14	42	26	66	26	35	0.0	0.0	0.5	0.6
2014-2015	25	35	38	79	24	27			0.5	0.5
2015-2016	24	43	39	79	36	46			0.9	1.1
2016-2017	8	27	20	43	40	79	0.0	0.2	0.9	3.3
2017-2018	21	32	33	49	25	39	0.0	0.0	0.5	0.9
2018-2019	25	49	46	78	22	34	0.0	0.0	0.5	0.8

11.0 Yearly Minimum and Maximum (WQ parameter) for Mankara Site

	EC_GEN (µmho/cm)		pH_GEN		TDS (mg/L)		Temp (deg C)		ALK-TOT (mgCaCO3/L)		B (mg/L)		Ca (mg/L)		Cl (mg/L)		F (mg/L)		Fe (mg/L)		K (mg/L)		Mg (mg/L)		Na (mg/L)	
Year	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
1986-1987	127	506	6.9	8.1	86	322			49	218			4	11	11.0	30.0					1.4	3.6	6.1	27.9	7.8	40.0
1987-1988	222	485	7.2	8.0			23.5	30.5	81	192			12	33	11.0	40.0					1.6	4.3	6.3	23.3	11.0	35.4
1988-1989	190	575	7.3	8.2			23.5	31.0	79	231	0.02	0.38	19	38	13.0	33.0					1.2	3.5	6.3	19.7	10.8	37.0
1989-1990	185	601	7.7	8.1			25.5	31.5	69	209	0.02	0.17	14	29	16.0	40.0					1.2	5.5	5.1	29.4	10.1	54.1
1990-1991	159	506	7.3	8.4			26.0	30.5	54	142	0.02	0.42	18	39	13.0	35.0					0.4	3.5	2.4	25.3	2.0	47.0
1991-1992	129	462	7.5	8.1			25.5	31.0	36	148	0.04	0.04	6	34	9.0	36.0					1.2	3.9	5.3	15.1	6.0	30.0
1992-1993	184	900	7.3	8.1			23.5	33.5	72	188			18	51	17.0	36.0					1.2	36.0	7.3	24.3	9.0	52.0
1993-1994	150	450	7.2	8.5			24.5	35.5	42	156	0.03	0.22	14	35	17.0	26.0					1.6	3.1	3.4	21.4	10.0	23.9
1994-1995	162	440	7.3	8.6			17.5	23.5	46	130	0.01	0.05	15	32	15.0	30.0					1.6	3.1	6.3	18.5	10.4	30.4
1995-1996	87	330	7.7	8.1			26.0	30.0	28	80	0.01	0.05	9	26	11.0	25.0					1.2	3.5	3.9	11.7	5.8	19.1
1996-1997	165	430	7.3	8.3			24.0	30.0	25	48	0.02	0.04	17	37	16.0	37.0					1.2	2.3	6.8	17.0	11.0	26.0
1997-1998	184	650	7.6	8.3			25.0	30.0	20	96	0.01	0.05	11	41	12.8	48.0					1.2	5.1	4.4	12.1	5.1	28.0
1998-1999	240	530	7.4	8.4			26.0	32.0	52	110	0.02	0.04	16	32	20.0	50.0					2.0	4.3	0.0	14.6	8.5	23.9
1999-2000	173	490	7.5	8.3			26.0	31.0	48	120	0.02	0.03	16	40	18.0	31.0					1.6	3.5	4.4	14.6	7.8	23.0
2000-2001	190	360	6.9	8.6			25.5	30.5	56	110	0.01	0.40	9	29	16.0	33.0					2.0	3.1	6.8	22.7	12.6	20.2
2001-2002	172	478	7.6	8.4			26.5	30.0	58	100	0.03	0.08	17	32	17.8	32.7					1.6	3.5	5.8	12.6	14.0	22.8
2002-2003	159	369	7.1	8.4	120	145	25.5	30.5	64	116	0.01	0.05	15	30	16.0	32.0	0.10	0.44			1.8	5.2	5.8	12.1	11.6	30.0
2003-2004	250	434	7.3	7.6	145	308	25.0	28.0	68	158	0.04	0.34	23	34	25.0	36.0	0.43	0.73			3.0	23.0	8.3	16.5	14.5	29.0
2004-2005	230	357	7.2	7.7	155	288	23.5	29.0	66	118	0.24	1.12	18	37	17.0	32.6	0.31	0.83			2.9	4.0	8.7	23.8	7.9	24.2
2005-2006	123	390	7.3	8.1	82	276	24.0	30.5	45	151	0.01	0.47	12	35	14.9	44.6	0.21	0.43			2.0	5.9	4.9	14.6	8.4	26.4
2006-2007																										
2007-2008																										
2008-2009	250	470	7.3	8.3	202	378	25.5	30.5	80	160	0.03	0.18	19	50	16.3	43.3	0.05	0.42	0.0	0.1	2.1	3.7	10.7	19.6	12.3	31.0
2009-2010	130	464	7.2	8.1	85	316	21.5	27.5	39	146	0.00	1.37	13	30	14.2	34.1	0.11	0.24	0.0	0.1	2.2	5.7	2.5	18.1	10.0	25.0
2010-2011	223	461	7.1	8.3	141	321	25.5	31.0	65	160	0.13	0.34	10	39	18.5	47.5	0.05	0.67	0.1	0.5	2.2	6.0	7.3	16.6	13.8	30.0
2011-2012	270	570	7.0	8.4	198	399	26.5	30.5	93	146	0.25	0.66	22	38	26.2	70.3	0.04	3.30	0.0	1.5	1.2	5.8	10.2	17.0	17.0	39.5
2012-2013	169	435	6.8	7.6	115	320	26.0	29.5	64	143	0.08	0.26	19	34	13.5	34.1	0.31	3.81	0.1	0.2	1.8	5.0	3.4	18.0	10.0	24.0
2013-2014	139	259	6.9	7.4	103	181	25.5	30.5	50	89	0.02	0.17	14	21	11.3	21.3	0.57	2.74	0.0	0.2	1.9	4.9	5.0	9.3	8.5	15.4
2014-2015	78	650	7.1	7.8			26.5	31.0					5	32	11.3	33.0			0.0	0.0	2.0	7.0	0.9	31.4	4.7	18.5
2015-2016	29	385	6.2	7.5			26.5	30.0					5	28	10.4	24.8			0.0	0.0	0.2	0.6	1.9	6.7	8.2	13.4
2016-2017	21	180	5.6	7.0			26.8	29.5	31	37			8	31	13.0	32.6					0.4	1.8	0.9	7.6	8.0	20.0
2017-2018	223	298	6.7	8.1	128	188	20.0	29.3	17	109	0.09	0.36	8	30	5.6	31.7	0.34	0.78	0.1	0.1	1.6	5.0	2.1	13.8	3.1	20.6
2018-2019	278	554	7.3	8.7			25.0	29.0	88	166	0.06	0.21	25	40	13.2	59.2	0.02	0.76	0.2	0.6	2.5	5.0	5.8	23.3	6.9	43.6

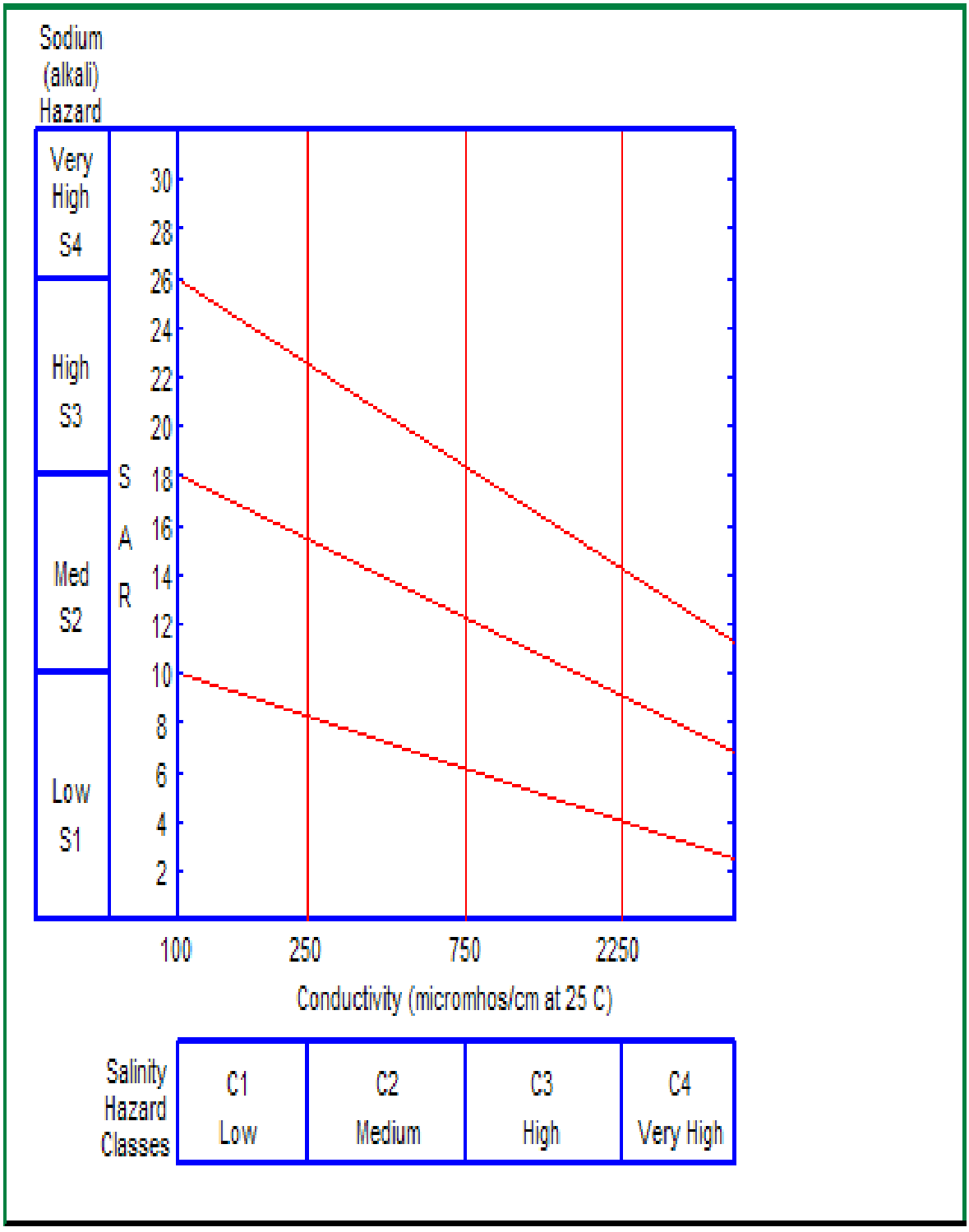
Yearly Minimum and Maximum (WQ parameter) for Mankara Site

	NH3-N (mg N/L)		NO2+NO3(mg N/L)		NO2-N (mgN/L)		NO3-N (mgN/L)		o-PO4-P (mg P/L)		P-Tot Q-(mgP/L)		SiO2 (mg/L)		SO4 (mg/L)		BOD3-27 (mg/L)		COD (mg/L)		DO (mg/L)	
Year	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
1986-1987															3.6	8.0						
1987-1988											0.060	0.060	3.4	19.0	3.2	14.0						
1988-1989											0.010	0.080	1.9	16.2	2.8	8.4						
1989-1990											0.100	0.300	2.0	13.2	3.2	27.2						
1990-1991											0.010	0.100	0.8	25.6	1.0	30.0					5.2	7.1
1991-1992											0.010	0.360	16.0	44.6	1.0	9.0					3.8	7.0
1992-1993											0.010	0.160	5.9	73.8	1.0	48.0					5.3	7.4
1993-1994											0.010	0.080	14.0	44.6	1.0	11.0					5.0	7.8
1994-1995											0.010	0.060	11.0	18.0	1.0	6.7					5.1	7.2
1995-1996											0.220	0.450	10.0	17.0	2.0	11.0					4.8	7.3
1996-1997											0.080	0.370	12.0	19.0	2.0	9.0					4.7	7.2
1997-1998											0.030	0.290	7.4	12.4	1.0	22.0					5.2	7.6
1998-1999											0.230	37.000	8.0	11.1	2.0	26.0					4.0	7.6
1999-2000											0.200	0.300	6.7	10.4	4.0	32.0					5.4	7.5
2000-2001											0.080	0.114	11.3	12.8	2.1	7.6					3.9	7.1
2001-2002			0.12	0.29	0.00	0.00	0.12	0.29			0.013	0.099	8.8	13.9	1.0	6.2					5.1	7.2
2002-2003			0.45	0.45							0.110	0.345	12.0	28.3	25.0	61.0					5.0	6.0
2003-2004			0.73	1.88	0.00	0.00	0.73	1.88			0.020	0.040	15.6	17.5	6.3	9.0			9.6	9.6		
2004-2005			0.90	4.93	0.00	1.25	0.90	4.72			0.040	0.350	6.9	9.8	1.0	29.0			3.2	4.0		
2005-2006			0.12	3.78	0.00	0.53	0.12	3.35			0.005	0.458	7.0	17.7	1.5	24.0			8.2	9.6		
2006-2007																						
2007-2008																						
2008-2009	0.10	0.10	0.42	0.46	0.08	0.09	0.34	0.41	0.025	0.144			22.8	27.8	5.2	20.5						
2009-2010	0.19	0.31							0.010	0.284			28.8	33.2	1.0	28.4	0.6	0.6	2.6	12.6		
2010-2011	0.05	0.47	0.15	0.80	0.02	0.19	0.12	0.76	0.053	0.890			16.0	26.0	1.0	40.0	0.6	0.6	10.4	13.4		
2011-2012	0.00	0.28	0.21	4.78	0.01	0.21	0.20	4.57	0.020	0.670			15.0	22.0	1.0	28.3	1.2	1.2				
2012-2013	0.11	0.26	0.90	13.02	0.06	0.34	0.82	12.80	0.108	0.458			14.8	22.7	1.0	12.0	2.4	2.4	17.2	17.2	4.5	4.5
2013-2014			0.47	2.64	0.06	0.19	0.38	2.58	0.072	0.175			10.0	20.1	0.6	7.2	0.4	2.2	2.8	16.6	3.1	6.6
2014-2015															4.6	29.0	0.2	1.8			4.8	7.0
2015-2016																	0.6	1.4			5.8	7.2
2016-2017																	0.4	1.2			4.0	6.8
2017-2018					0.07	0.09			0.143	0.421			10.3	14.8	9.1	15.4	0.7	1.5			6.1	7.6
2018-2019			0.27	0.86	0.01	0.04	0.25	0.82	0.013	0.043			8.0	19.9	4.2	21.3	0.5	0.9			7.1	8.5

Yearly Minimum and Maximum (WQ parameter) for Mankara Site

	HAR_Ca (mgCaCO3/L)		HAR_Total (mgCaCO3/L)		Na%(%)		RSC(-)		SAR(-)	
Year	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
1986-1987	9	28	34	142	23	38	0.0	0.8	0.6	1.5
1987-1988	29	82	73	146	20	37	0.0	1.3	0.5	1.4
1988-1989	48	95	78	176	17	33	0.0	0.0	0.5	1.2
1989-1990	35	73	61	181	25	39	0.0	0.0	0.6	1.7
1990-1991	44	98	54	150	3	43	0.0	0.0	0.1	1.8
1991-1992	14	86	46	136	19	37	0.0	0.0	0.4	1.2
1992-1993	44	128	74	228	20	32	0.0	0.3	0.5	1.5
1993-1994	34	88	48	176	23	32	0.0	0.0	0.5	0.9
1994-1995	38	80	64	156	18	37	0.0	0.0	0.5	1.3
1995-1996	22	64	38	106	23	30	0.0	0.0	0.4	0.8
1996-1997	42	92	80	163	21	30	0.0	0.0	0.5	1.0
1997-1998	28	102	51	140	17	33	0.0	0.0	0.3	1.1
1998-1999	40	80	60	140	20	42	0.0	0.0	0.4	1.2
1999-2000	40	100	58	150	22	32	0.0	0.0	0.4	0.9
2000-2001	22	72	70	116	23	31	0.0	0.0	0.6	0.8
2001-2002	42	80	76	121	27	29	0.0	0.0	0.7	0.9
2002-2003	38	76	64	116	19	35	0.0	0.0	0.5	1.2
2003-2004	58	86	92	155	21	29	0.0	0.1	0.7	1.0
2004-2005	44	92	98	157	14	27	0.0	0.0	0.3	0.9
2005-2006	30	88	60	143	21	30	0.0	0.2	0.5	1.0
2006-2007										
2007-2008										
2008-2009	48	124	93	183	20	29	0.0	0.0	0.5	1.1
2009-2010	32	74	42	149	26	34	0.0	0.1	0.7	1.0
2010-2011	25	98	68	167	25	36	0.0	0.2	0.7	1.1
2011-2012	54	96	103	151	26	35	0.0	0.0	0.7	1.4
2012-2013	48	84	72	153	22	26	0.0	0.1	0.5	0.8
2013-2014	34	52	58	90	20	29	0.0	0.0	0.5	0.8
2014-2015	12	80	16	211	16	20			0.3	0.6
2015-2016	12	70	20	86	25	29			0.5	0.6
2016-2017	20	78	28	82	23	59	0.0	0.2	0.5	1.7
2017-2018	19	76	28	118	18	29	0.0	0.1	0.3	0.8
2018-2019	64	100	103	197	12	34	0.0	0.0	0.3	1.4

Wilcox Diagram



CAUVERY & SOUTHERN RIVERS ORGANISATION

CENTRAL WATER COMMISSION

KOCHI

ESTABLISHMENT OF CORRELATION AMONG WATER QUALITY PARAMETERS AT PAZHAYAR RIVER

By

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Senior Research Assistant

WFRWQL

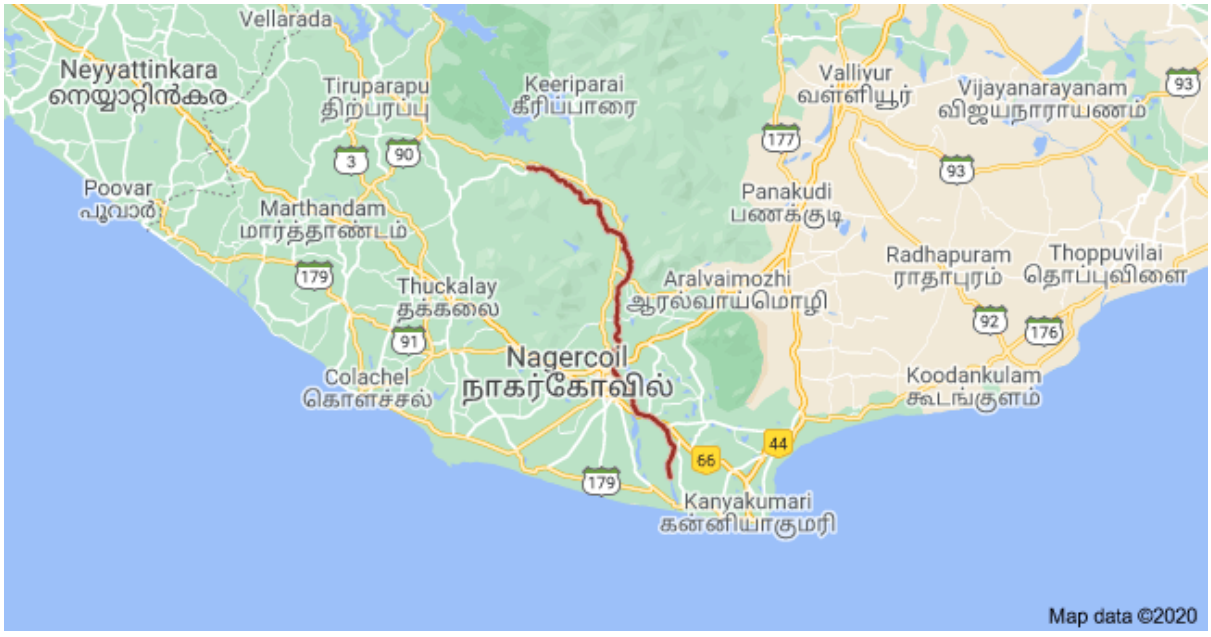
Table of contents

1.0 INTRODUCTION

Pazhayar River is originating from Kanyakumari district of Tamilnadu state. It originates from mahendragiri hills at an altitude of 1300m. The length of the river is 40 km and with a drainage area of 397 sq.kms and is taken away through channels of irrigation. The river is benefited by both South west and North east monsoons.

Central water Commission has started water quality monitoring station on pazhayar river at site Ashramam from December 2002 under SWR subdivision Trivandrum.

1.1 Flowing Path of River Pazhayar



2.0 Site description and sample collection

Central water Commission is monitoring water quality at site Ashramam since 02.12.2002 at the right bank of pazhayar river. Surface water samples were collected from river pazhayar at site Ashramam which lies at longitude 77°27'32". This site is designated as baseline station. So, water quality is monitored six times in a year. Water samples from the site were collected in one litre polythene bottles for analysis of physicochemical parameters and in sterile glass bottles for DO & BOD analysis and transported to the laboratory in ice-boxes, processed within 1-4 hrs and stored at 4-5°C for further analysis.

3.0 study Area

Present work deals with the assessment of physico-chemical parameters of water samples of pazhayar River at ashramam sampling station during 2018-19 in pre-monsoon, monsoon and post monsoon seasons. statistical studies have been carried out by calculating correlation co-efficient among different pairs of water quality parameters and t-test is applied for checking the significance.

The water samples were collected in one litre polythene bottles which were thoroughly washed twice with the water to be analysed. The physico-chemical parameters like pH, EC, Total Hardness, Calcium, Magnesium, Total Alkalinity, Chloride, Fluoride, Sulphate, Sodium, Potassium, DO and BOD were analysed and estimated as per APHA test methods.

The task of monitoring the quality of water is facilitated if one can find some corelation among these water quality parameters. When such corelation exists then by measuring a few important water quality parameters one can easily calculate the remaining parameters and the Quality of water can be easily and quickly assessed. Corelation indicate the association between two variables. The corelation coefficient shows strong linear relationship between two parameters. If the corelation coefficient is +/- 0.8 and above implies a strong relationship, corelation coefficient between +/-0.5 to +/-0.8 is sufficient degree of corelation and corelation coefficient less than +/-0.5 is a weak corelation. If the corelation is positive both the parameters are moving in same direction and negative corelation implies that one parameter increases, the other parameter decreases.

3.1 Water quality data sheet for the period:2018-2019

S.No	parameters	01/06/2018	01/08/2018	01/10/2018	01/12/2018
1	pH_GEN (pH units)	7.0	6.9	6.5	7.0
2	EC_GEN (µmho/cm)	144	163	144	183
3	ALK-TOT (mgCaCO3/L)	40	42	41	52
4	B (mg/L)	0.11	0.04	0.06	0.08
5	Ca (mg/L)	8.0	12.0	11.0	15.0
6	Cl (mg/L)	11.5	19.4	20.0	21.7
7	F (mg/L)	0.19	0.22	0.22	0.20
8	Fe (mg/L)	0.2	0.2	0.2	0.4
9	HCO3 (mg/L)	49	51	50	64
10	K (mg/L)	2.6	3.7	4.2	3.3
11	Mg (mg/L)	4.2	3.2	4.4	4.0
12	Na (mg/L)	8.7	12.7	13.3	16.2
13	NO2-N (mgN/L)	0.02	0.01	0.02	0.02
14	o-PO4-P (mg P/L)	0.069	0.060	0.085	0.064
15	SO4 (mg/L)	7.5	8.2	5.8	9.6
16	CO3 (mg/L)	0.0	0.0	0.0	0.0

3.2 Test Methods used for the analysis

Sl. No	Parameter	Test Method used (APHA 23rd Edition)
1	pH_GEN	Electrometric Method
2	EC_GEN	Laboratory Method
3	Total Alkalinity	Acid-Base Titration
4	Boron(B)	Curcumin Method
5	Calcium (Ca)	EDTA Titrimetric Method
6	Chloride (Cl)	Argentometric Method
7	Fluoride (F)	Ion selective electrode Method
8	Iron (Fe)	Phenanthroline Method
9	Bicarbonate (HCO3)	Calculation Method from pH &Alkalinity
10	Potassium (K)	Flame Emission Photometry
11	Magnesium (Mg)	Calculation Method
12	Sodium (Na)	Flame Emission Photometry
13	Nitrite (NO2-N)	Sulphanilamide Spectrophotometric Method
14	Ortho phosphate (o-PO4-P)	Ascorbic Acid Spectrophotometric Method
15	Sulphate (SO4)	Turbidimetry

4.0 Methodology

Correlation formula

In the formula below,

- **x** and **y** are two vectors of length **n**
- m_x and m_y corresponds to the means of x and y, respectively.

Pearson correlation formula

$$r = \frac{\sum (x - m_x)(y - m_y)}{\sqrt{\sum (x - m_x)^2 \sum (y - m_y)^2}}$$

m_x and m_y are the means of x and y variables.

The p-value (significance level) of the correlation can be determined :

1. by using the correlation coefficient table for the degrees of freedom : $df = n - 2$, where n is the number of observation in x and y variables.
2. or by calculating the **t value** as follow:

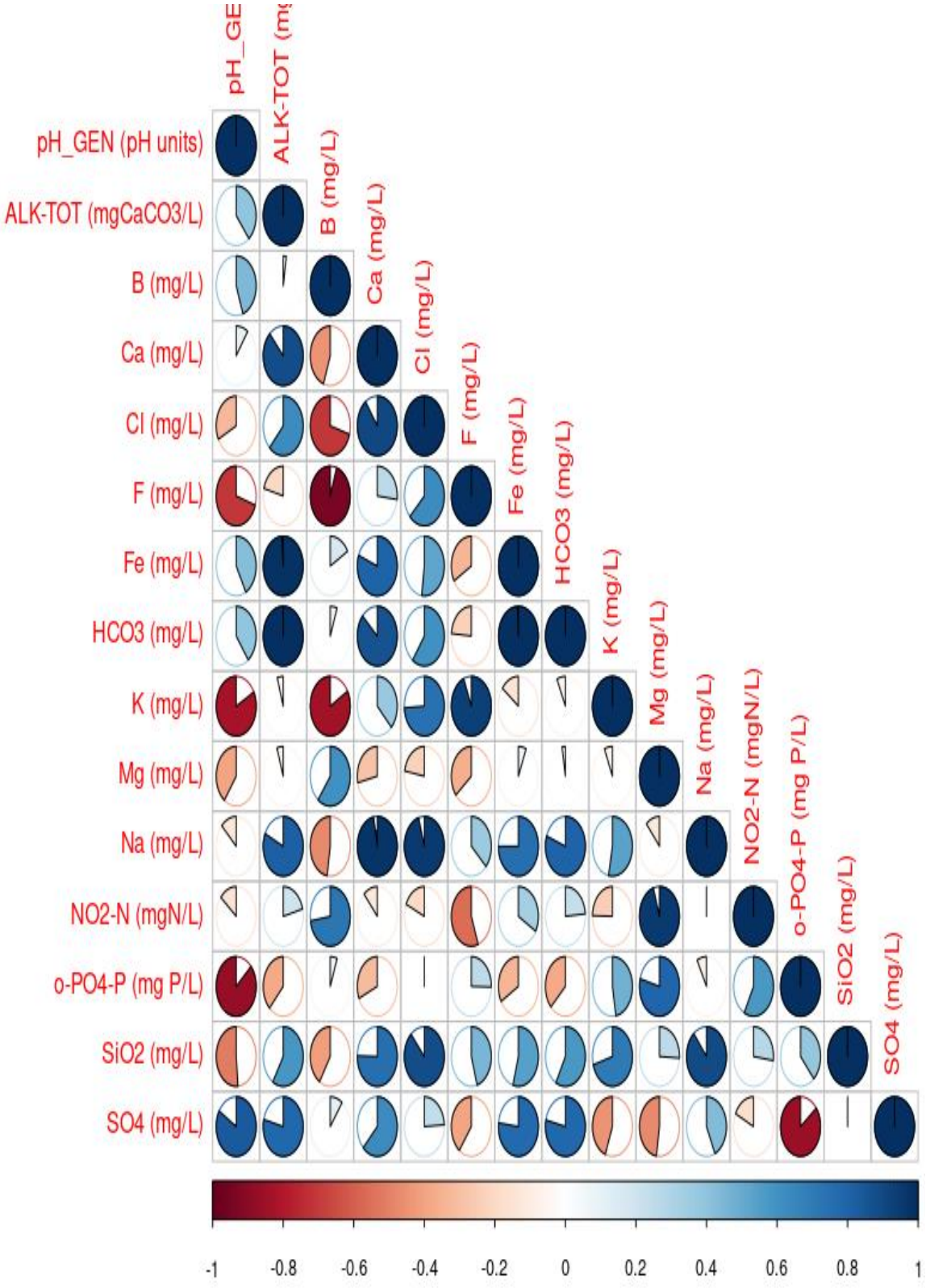
$$t = \frac{r}{\sqrt{1 - r^2}} \sqrt{n - 2}$$

5.0 Results and Discussions:

The current analysis focused on the establishment of corelation among water quality parameters. The datasets are first arranged and transposed to parameters levels, then converted to a matrix of values. The matrix is then applied with the **cor** function of the **stats** package in R programming language. Later the correlation values are plotted in Pie charts according to the R^2 .

The correlations generated here are using the Pearson method. This method seems efficient, particularly when sample size is low. The generated correlations were visualized using a corrplot. corrplot function offers flexible ways to visualize correlation matrix, lower and upper bound of confidence interval matrix. The colour code denotes negative(red) and positive(blue) correlations, whereas the size of the circles shows the intensity of correlations. The results suggest that Ca and Alk-tot are positively correlated, whereas the Alk-tot is fully related with Fe and HCo3. The same way calcium and chlorine are positively correlated with Na. The pH is negatively correlated with F, K and o-PO4. Another prominent relation observed are F and K which is very close to one. The same is shown with NO2 and Mg. The rest of the values seem less relevant. Here the correlation data for preview, a detailed table is attached with the docs.

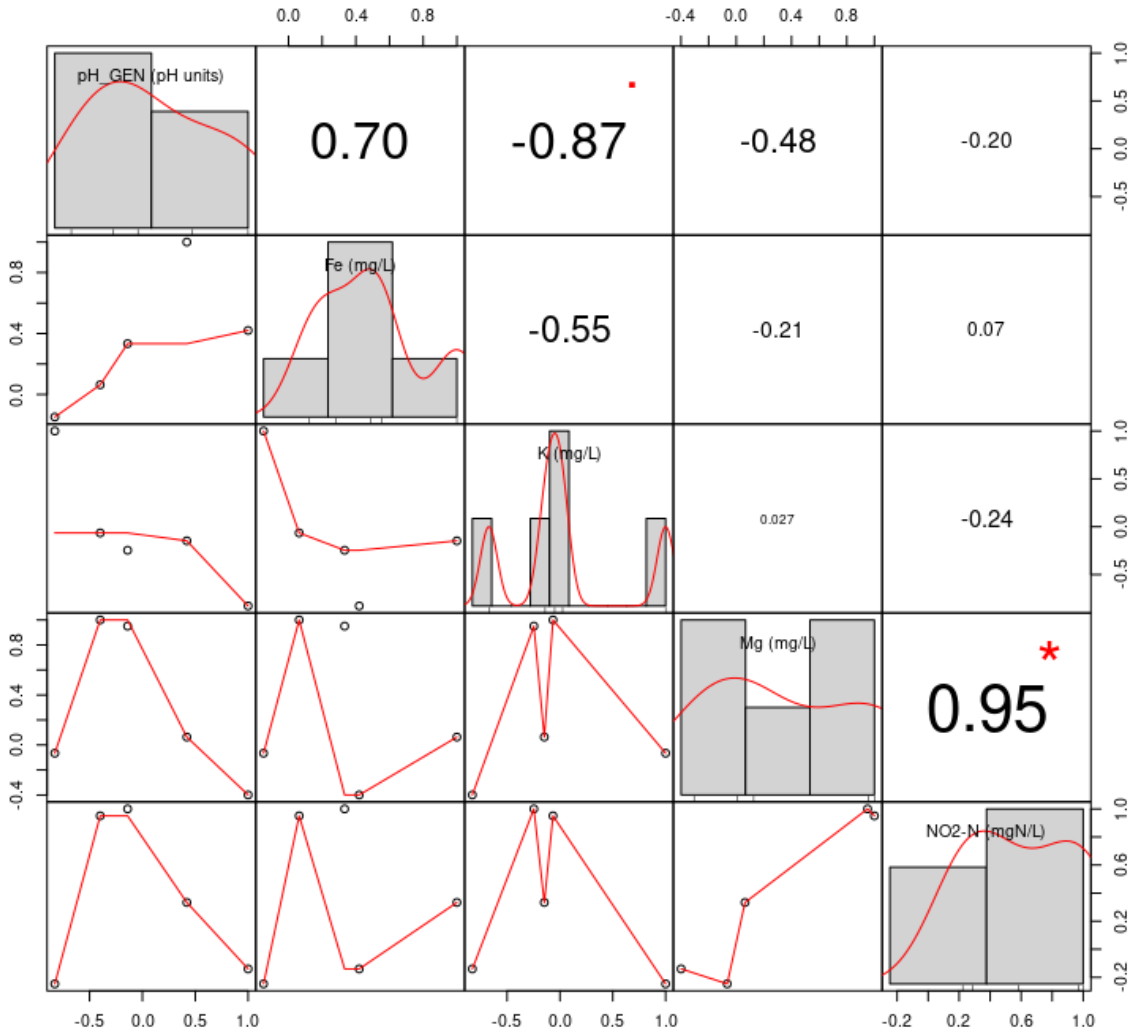
5.1 Corelation plot among different water quality parameters



5.2 Corelation matrix of different water quality parameters

	pH_GEN (pH units)	ALK-TOT (mgCaCO3/L)	B (mg/L)	Ca (mg/L)	Cl (mg/L)	F (mg/L)	Fe (mg/L)	HCO3 (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/L)	NO2-N (mgN/L)	o-PO4-P (mg P/L)	SiO2 (mg/L)	SO4 (mg/L)
pH_GEN (pH units)	1.00000000	0.39034649	0.44548927	0.09701425	-0.32391829	-0.7001400	0.42008403	0.39738585	-0.82884867	-0.39932615	-0.129235089	-0.140028008	-0.86802224	-0.514495755	0.837604362
ALK-TOT (mgCaCO3/L)	0.39034649	1.00000000	0.02509523	0.88259602	0.62008220	-0.2098217	0.98915957	0.99951145	-0.04879164	-0.05128809	0.819733617	0.209821727	-0.37981686	0.587378479	0.788343799
B (mg/L)	0.44548927	0.02509523	1.00000000	-0.44469878	-0.70458495	-0.9488475	0.16744367	0.05543870	-0.83419811	0.60484476	-0.474457663	0.725589244	0.05596895	-0.410151556	0.100689586
Ca (mg/L)	0.09701425	0.88259602	-0.44469878	1.00000000	0.90054182	0.2694301	0.80829038	0.86838584	0.37591737	-0.28538708	0.970347753	-0.115470054	-0.31578947	0.754247233	0.624924703
Cl (mg/L)	-0.32391829	0.62008220	-0.70458495	0.90054182	1.00000000	0.6291032	0.52139679	0.60020551	0.74113056	-0.22198760	0.954451670	-0.183590418	0.00401669	0.884415594	0.241018829
F (mg/L)	-0.70014004	-0.20982173	-0.94884747	0.26943013	0.62910316	1.0000000	-0.33333333	-0.23649188	0.93720088	-0.35911041	0.368809441	-0.555555556	0.25322380	0.453609212	-0.397372811
Fe (mg/L)	0.42008403	0.98915957	0.16744367	0.80829038	0.52139679	-0.3333333	1.00000000	0.99326592	-0.14797909	0.06337243	0.750212375	0.333333333	-0.33425542	0.544331054	0.770129606
HCO3 (mg/L)	0.39738585	0.99951145	0.05543870	0.86838584	0.60020551	-0.2364919	0.99326592	1.00000000	-0.06999171	-0.02697672	0.806427423	0.236491885	-0.37081024	0.579284446	0.785900845
K (mg/L)	-0.82884867	-0.04879164	-0.83419811	0.37591737	0.74113056	0.9372009	-0.14797909	-0.06999171	1.00000000	-0.06564456	0.531118480	-0.246631812	0.47214502	0.704809109	-0.441802062
Mg (mg/L)	-0.39932615	-0.05128809	0.60484476	-0.28538708	-0.22198760	-0.3591104	0.06337243	-0.02697672	-0.06564456	1.00000000	-0.113897445	0.950586376	0.79145809	0.258716842	-0.475347141
Na (mg/L)	-0.12923509	0.81973362	-0.47445766	0.97034775	0.95445167	0.3688094	0.75021238	0.80642742	0.53111848	-0.11389745	1.000000000	0.005397211	-0.07823004	0.890174529	0.430630200
NO2-N (mgN/L)	-0.14002801	0.20982173	0.72558924	-0.11547005	-0.18359042	-0.5555556	0.33333333	0.23649188	-0.24663181	0.95058638	0.005397211	1.000000000	0.57735027	0.272165527	-0.179345251
o-PO4-P (mg P/L)	-0.86802224	-0.37981686	0.05596895	-0.31578947	0.00401669	0.2532238	-0.33425542	-0.37081024	0.47214502	0.79145809	-0.078230044	0.577350269	1.00000000	0.384566846	-0.856891214
SiO2 (mg/L)	-0.51449576	0.58737848	-0.41015156	0.75424723	0.88441559	0.4536092	0.54433105	0.57928445	0.70480911	0.25871684	0.890174529	0.272165527	0.38456685	1.000000000	0.008613811
SO4 (mg/L)	0.83760436	0.78834380	0.10068959	0.62492470	0.24101883	-0.3973728	0.77012961	0.78590085	-0.44180206	-0.47534714	0.430630200	-0.179345251	-0.85689121	0.008613811	1.000000000

5.3 Corelation chart of water quality parameters



From the above data, it is found that parameters such as pH, Fe, K, NO2 and Mg, which are again plotted as charted correlations are getting good insights.
In the last analysis, the NO2 and Mg are the most correlated parameters with an R2 0.95, and the pH and K are most negatively correlated.

6.0 Conclusion

The corelation co efficient is bound between -1 and 1 and tells the linear relationship between two parameters. A co-efficient close to 1 means a strong and positive association between the two parameter and A co-efficient close to -1 means a strong and negative association between those two parameters. A co-efficient close to 0 means there is no linear relation between the two parameters.

1. Association does not mean necessarily a casual relation between two parameters as a third parameter influences the behaviour of that two parameters.
2. Even if there is a casual relationship between the two parameters, the corelation co-efficient does not tell which parameter is the cause and which parameter is the effect.
3. If the corelation co-efficient is close to 0, does not necessarily mean that there is no relation between those parameters as there might be another relationship like quadratic or exponential.

A Report on Seasonal variation of physio-chemical parameters and Water Quality Scenario of Periyar River Basin for the Water Year (2018-19)

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TABLE OF CONTENTS

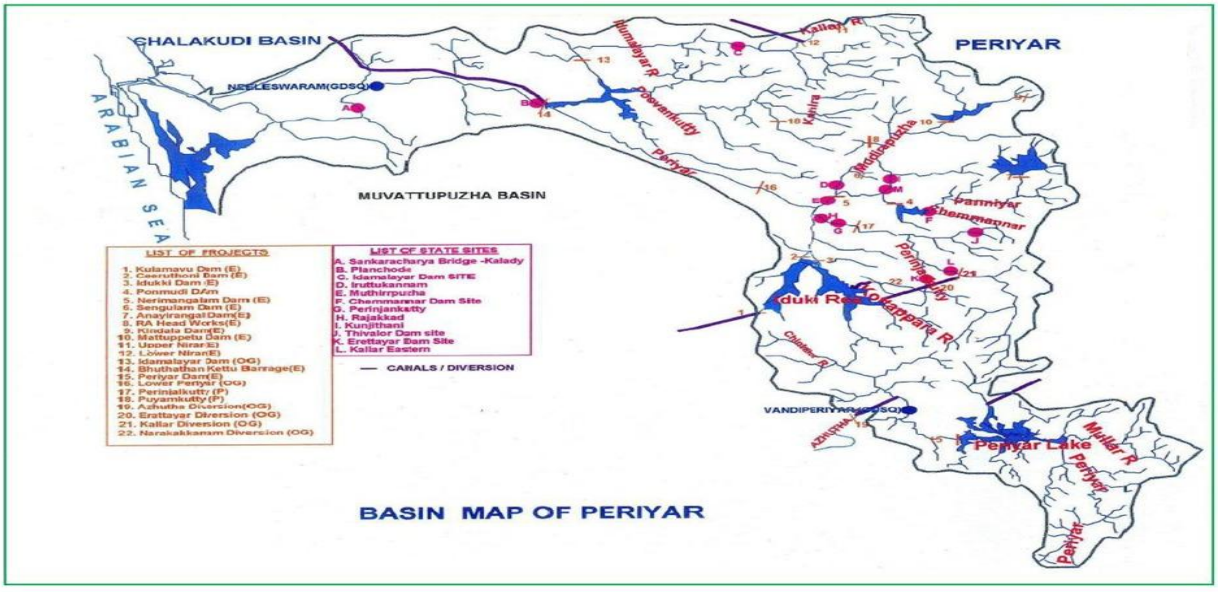
1.0: INTRODUTION:

Water is one of the most indispensable resources on the planet, without which life is not possible. It acts as an internal and external medium for several organisms. Out of its several forms of availability, surface water is highly valued for its significant role in the existence of human beings, flora and fauna in the region. It's usage for different purposes, namely for drinking, irrigation, industrial and others, mainly depends on its intrinsic quality of water resources available in the region. For this, Monitoring is a pre-requisite. Secondly a large amount of agricultural, municipal and industrial wastewater discharges are finally entering the river systems, resulting in the decrease of water quality. Hence it is necessary to manage the water quality and predict the impact of contaminants on them.

CWC is one of the central agency which monitors the quality of surface water in India. It has a wide network of water quality monitoring sites all over the country covering all major river basins The water quality monitoring network consists of field laboratories called the level-I laboratories located at field Hydrological Observation sites on various rivers of India for monitoring of 6 in situ parameters, Level-II laboratories for the analysis of 25 physio-chemical plus bacteriological parameters and Level-III laboratories for the analysis of 41 parameters including heavy metals / toxic parameters and pesticides.

2.0: Study Area:

The Periyar River, one of the longest rivers in Kerala, originates in the Sivagiri peak of Western Ghats. The total length of river is about 300kms and drains an area of 5,389 square kilometers. The Periyar basin lies between latitudes 9°15'30"N and 10°21'00"N and longitudes 76°08'38"E and 77°24'32"E.On its course to Arabian Sea at Cochin, the river is enriched with water from minor tributaries like Muthayar, Perunthuraiar, Chinnar, Cheruthony, Kattapanayar, and Edamalayar at different junctures and branches out into two at Alwaye. The Chalakudy River joins the upper branch at Munambam Lake and the other branch further split into small channels.



3.0: Methodology

3.1 Sampling Location:

The SWRD, Kochi of Central Water Commission is monitoring the water quality of Periyar River through three water quality stations. Two are on the main river Periyar at **Neeleswaram** and **Vandiperiyar**. The third is on its tributary Chalakudy at **Arangaly.** The detail of stations and sampling location is given in Table1 and fig-2.

S.No	Site Name	District	River	Latitude	Longitude	Station Type	Start of WQ Monitoring
1	Vandiperiyar	Idukki	Periyar	9°34’24"	77°05’26"	Baseline	01/10/2002
2	Neeleswaram	Ernakulam	Periyar	10°11’01"	76°29’44"	Baseline	15/06/1978
3	Arangaly	Thrissur	Chalakudy	10°17’10"	76°19’20"	Baseline	01/08/1978

Table-1: Details of sampling locations.

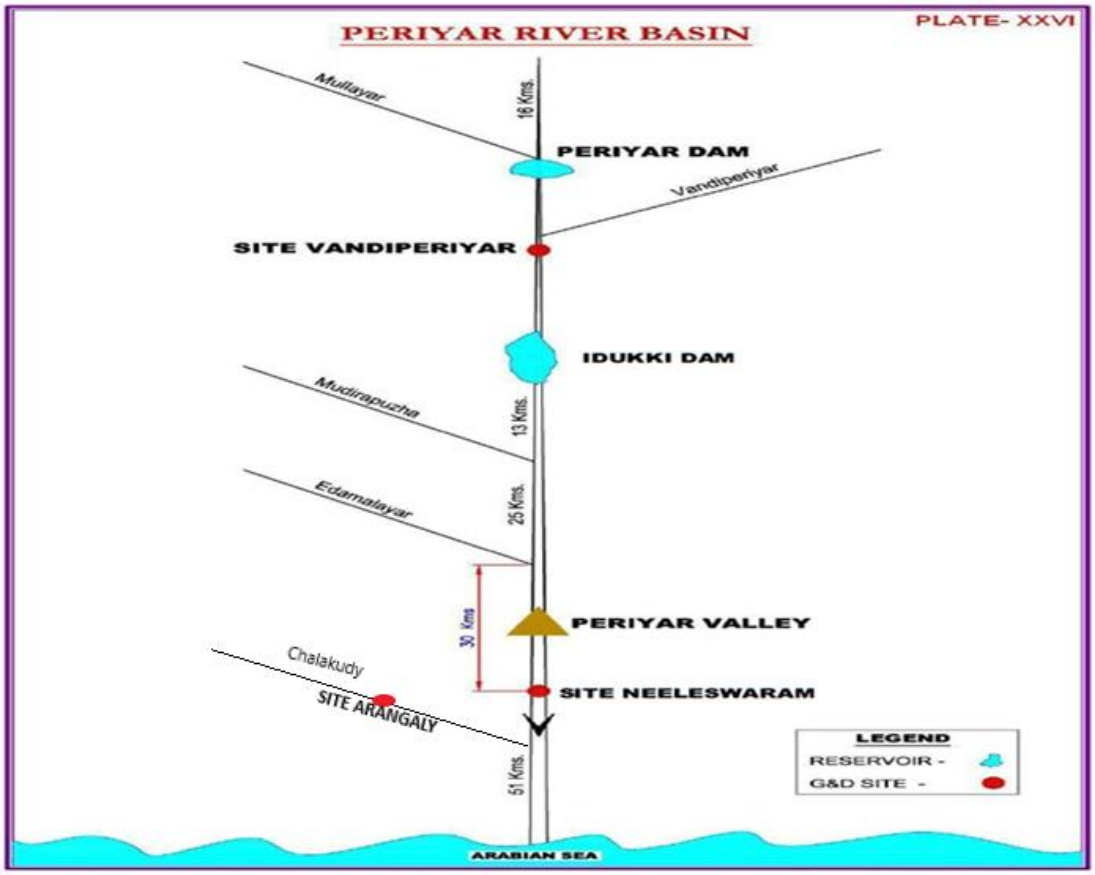


Fig .2 Details of sampling location

3.2 Sampling & Analysis:

The samples are collected as per the standard norms set by the Water Quality Assessment Authority notification (WQAA- June 2005) for the Water Year 2018-19. The collected water samples are preserved and transported to Water Quality Laboratory, SWR Division, Central Water Commission Kochi, for analysis. The samples are analyzed following the methods of APHA, 23rd edition as listed below in Table-2.

S. No.	Water Quality Parameters	Method (APHA-23rd Edition)
1	Electrical Conductivity (EC)	Laboratory Method
2	pH	Electrometric Method
3	Total Hardness (TH)	Complexometric Titration
4	Calcium Hardness (CH)	EDTA Titrimetric Method
5	Calcium (Ca)	EDTA Titrimetric Method
6	Magnesium (Mg)	Calculation Method
7	Sodium (Na)	Flame Emission Photometric Method
8	Potassium (K)	Flame Emission Photometric Method
9	Chloride (Cl)	Argentometric Method
10	Total Alkalinity	Titration Method
11	Bicarbonate (HCO3)	Acid Base Titration
12	Fluoride (F)	Ion sensitive Electrode Method
13	Silicate	Molybdosilicate Method
14	Sulphate (SO4)	Turbidimetric Method
15	Iron (Fe)	Phenanthroline Method
16	Boron (B)	Curcuremin Method
17	Dissolved Oxygen (DO)	Winkler Azide method
18	Biochemical Oxygen Demand(BOD)	5 days BOD Test at 20ºC
19	Sodium Adsorption Ratio (SAR)	Calculation
20	Sodium Percentage (Na %)	Calculation

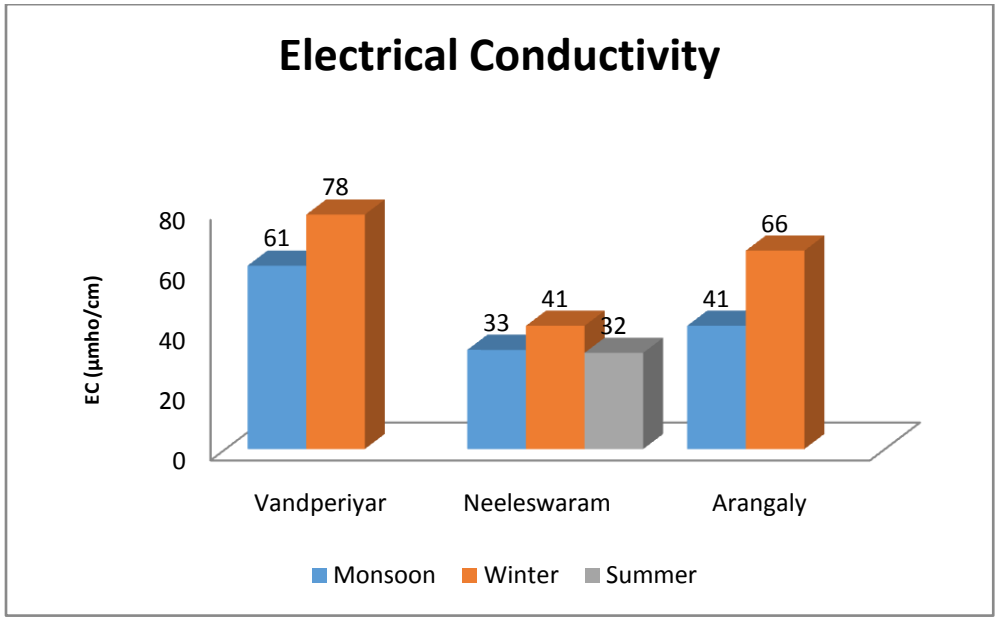
Table-2: Details of Parameters and Methods.

For the present study data has been analyzed for important physio-chemical parameters (Table-2) such as pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) etc. The whole study period was divided into three seasons, monsoon (June-October), winter (November to February, summer (March – May). Parameter wise seasonal averages (table- 5, 6, 7 in Annexure) and Yearly Range (Table-7 in Annexure) are calculated for all the three sites .Summer seasonal data is blank for sites Arangaly and Vandiperiyar as the river is dry during that time. To understand the scenario of water quality for the study year, Annual range and seasonal average values are compared with designated use class of Inland surface water specifications of BIS 2296-1982 (Table-3 in Annexure) .

4 .0: RESULT & DISCUSSION:

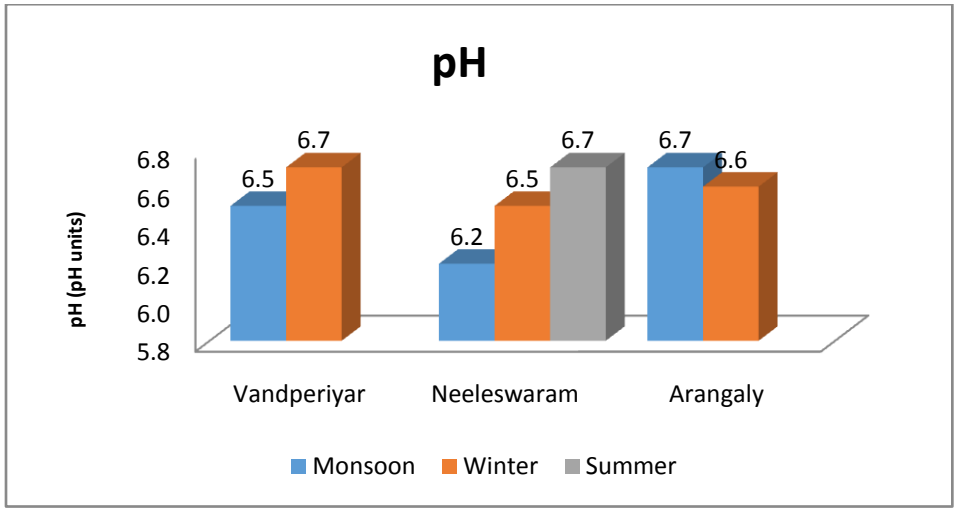
4.1 Electrical Conductivity:

Electrical conductivity (EC) is a measure of the capacity of water to conduct an electric current through it and depends on concentration of ions. Seasonal average of conductivity is maximum during winter season at Vandiperiyar site and minimum value is observed during Summer season at Neeleswaram site. At all the sites ,the conductivity value is lower during monsoon than during winter as there would be dilution effect during monsoon. The Conductivity value of the riverat the sites is found to be between 31 to 78µs/cm (table-7 in Annexure) and is much lower than the maximum permissible limits as prescribed in BIS: 2296-1982 throughout the study year.



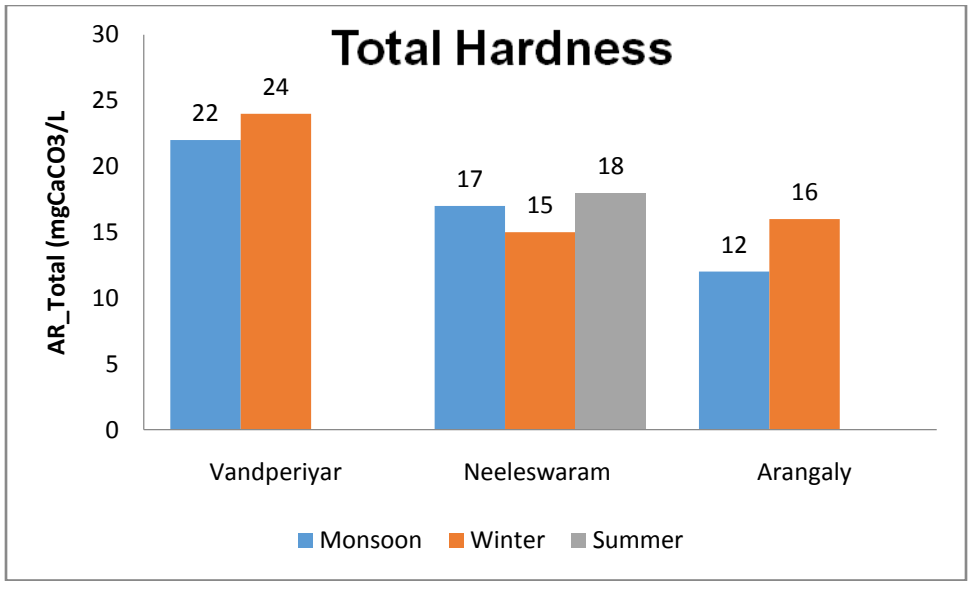
4.2 pH:

Seasonal average of pH is minimum at Neeleswaram site during monsoon season. No specific trend among the sites is observed. The pH of the river at the sites range from 5.9 to 6.9 (Table-7 in Annexure) and is of acidic in nature during all the seasons. In Vandiperiyar and Neeleswaram sites the acidity is increasing more during monsoon.The seasonal minimum value differed considerably with the Annual minimum value (Table-7 in Annexure) due to one low value recorded during monsoon at Neeleswaram & Vandiperiyar sites. The seasonal averages of pH are within the prescribed limit of BIS:2296-2018(6.0-8.5).However, the Annual minimum pH value (Table-7 in Annexure) at Neeleswaram site is below the lower limit of class D&E, and at Vandiperiyar site it is within the prescribed limits of class-D&E as per BIS:2296-1982. At Arangaly site, the pH value is within the permissible limit of class:A,B,C as per BIS:2296-1982 throughout the year.



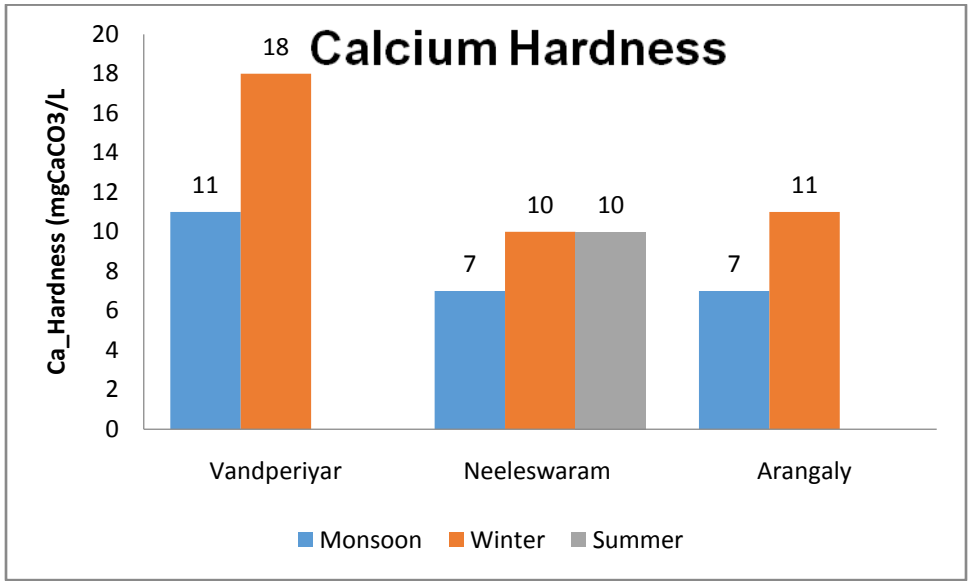
4.3 Total Hardness:

Seasonal average of total hardness is maximum at Vandiperiyar site during winter season while minimum is at Arangaly site during monsoon season. No specific trend is followed among the seasons. The values of Total Hardness at the sites range from 11 to 26 mg/l (Table-7 in Annexure) and well within maximum prescribed limits for class A of BIS: 2296-1982.



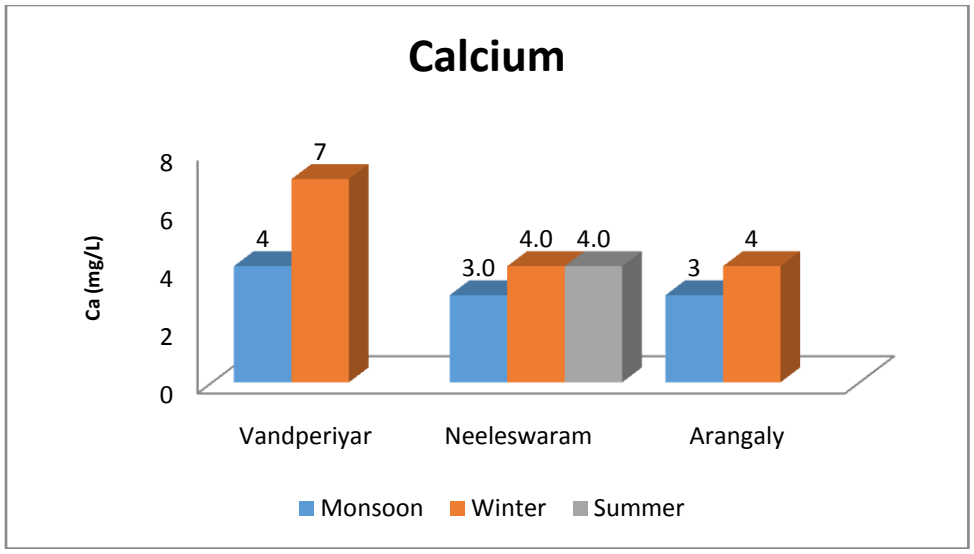
4.4 Calcium Hardness:

Seasonal average of calcium Hardness (CH) for all the sites is Minimum during Monsoon season and maximum during winter season. Lower Monsoon values would be due to dilution effect during monsoon. The values of Calcium Hardness at the sites range from 4 to 18 mg/l (Table-7 in Annexure) and well within the maximum prescribed limit for class A of BIS: 2296-1982.



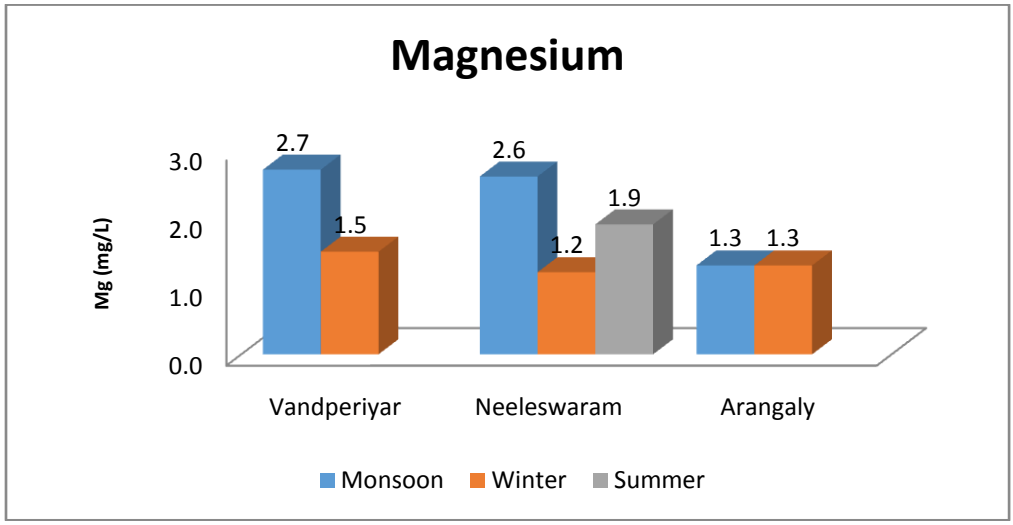
4.5 Calcium:

Seasonal average of calcium is maximum during winter season at Vandiperiyar site and minimum during Monsoon season at Neeleswaram & Arangaly sites. From Monsoon to winter an increasing trend of calcium values is observed as there would be dilution effect during monsoon. The values of Calcium at the sites range from 2.0-7.0 mg/l (table -7 in Annexure). Calcium is not listed in surface water classification of BIS 2296: 1982 .



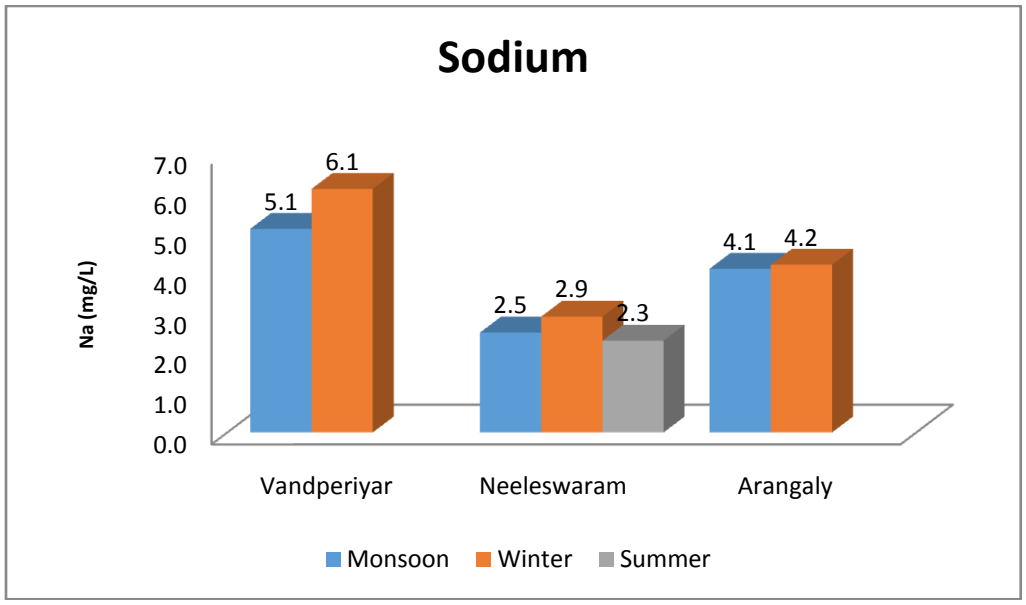
4.6 Magnesium:

Seasonal average of Magnesium is maximum during Monsoon season at Vandiperiyar site and lowest during winter season at Neeleswaram site. From monsoon to winter there is a decrease in Magnesium values for Vandiperiyar and Neeleswaram sites, not much change in seasonal average is observed at the Arangaly site. The values of Magnesium at the sites range from 0.6-3.4 mg/l (table -7 in Annexure). is not listed in surface water classification of BIS 2296: 1982 .



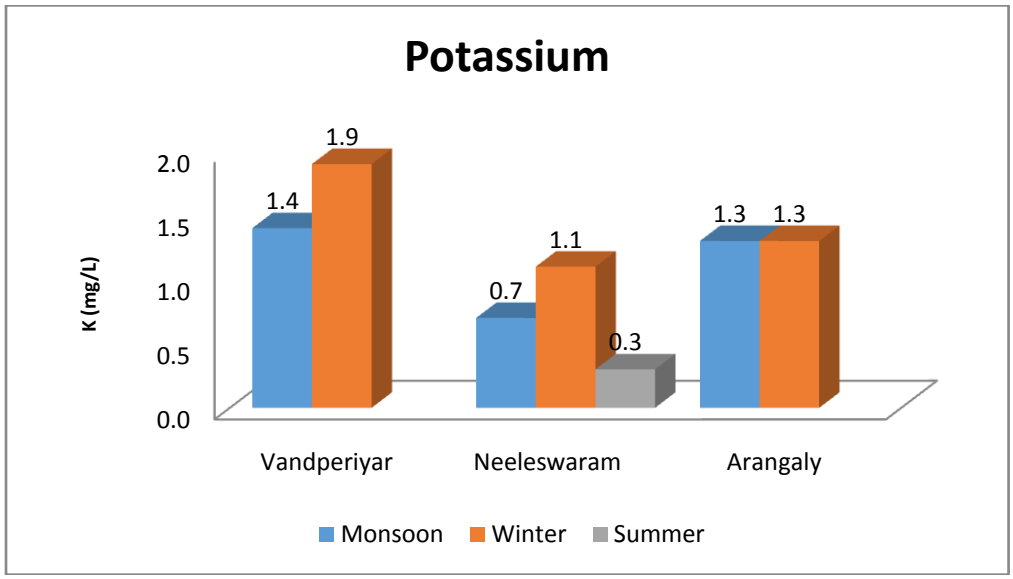
4.7 Sodium:

Seasonal average is maximum during winter season at Vandiperiyar site and lowest during summer season at Neeleswaram site. From Monsoon to winter an increasing trend of sodium values is observed as there would be dilution effect during monsoon. The values of Sodium at the sites range from 1.1 to 7.4 mg/l (Table-7 in Annexure).Sodium parameter is not listed in surface water classification of BIS 2296: 1982 .



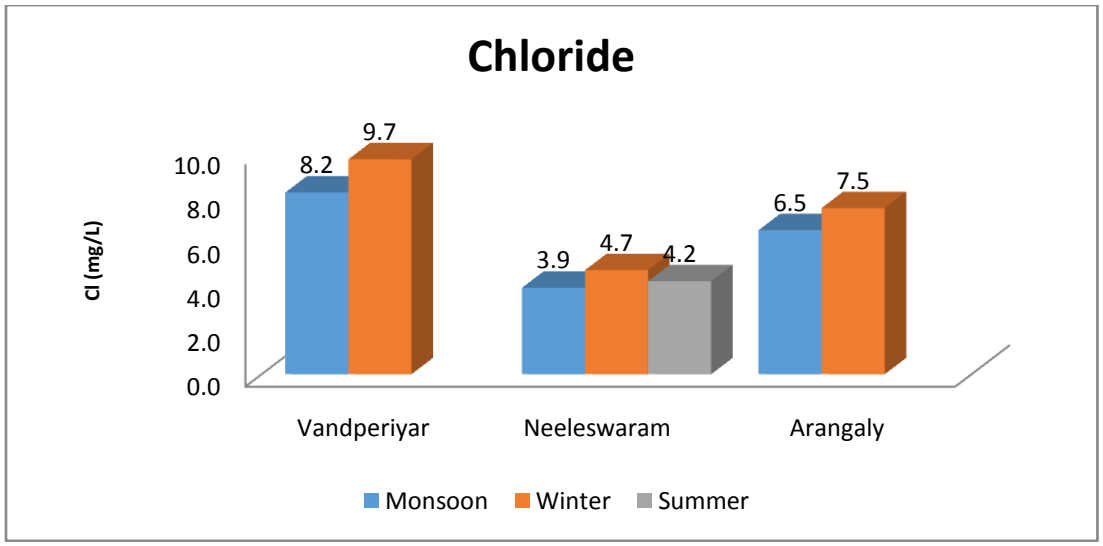
4.8 Potassium:

Seasonal average of Potassium is maximum during winter at Vandiperiyar site and lowest during summer at Neeleswaram site. From monsoon to winter an increase in trend of values is observed for Vandiperiyar and Neeleswaram sites, as there would be dilution effect during monsoon. In Arangaly seasonal averages not changed much. The values of Potassium at the sites range from 0.3-1.9 mg/l (Table-7 in Annexure). Potassium parameter is not listed in surface water classification of BIS 2296: 1982.



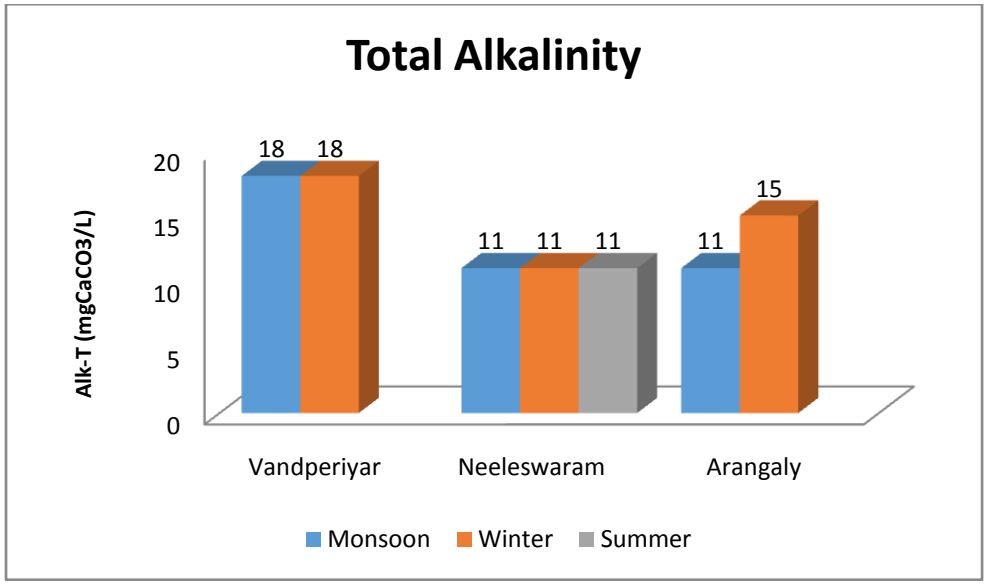
4.9 Chloride:

Seasonal average of chloride is maximum during winter at Vandiperiyar site and minimum during summer at Neeleswaram site. From monsoon to winter an increase in trend of chloride values is observed as there would be dilution effect during monsoon. The values of chloride at the sites range from 1.5-11.7 mg/l (Table-7 in Annexure) and well within the maximum prescribed limit of class A of BIS: 2296-1982.



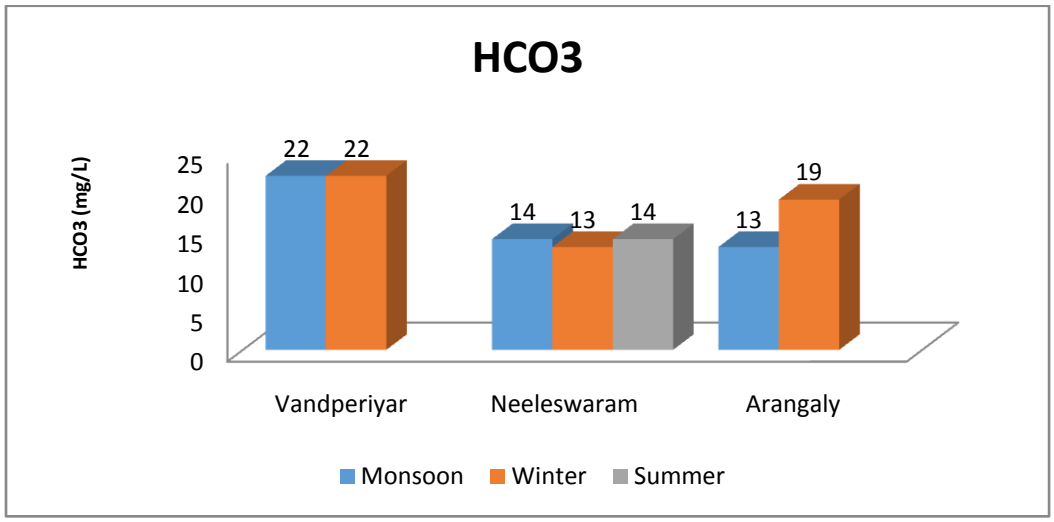
4.10 Total Alkalinity:

Seasonal average of Total Alkalinity not varied much along the seasons for Vandiperiyar and Neeleswaram sites. Low Total Alkalinity values are reported at all the sites indicating a low buffering capacity for river water towards acids. The values of Total Alkalinity at the sites range from 1.5-11.7 mg/l (Table-7 in Annexure). The parameter Total Alkanity is not listed in surface water classification of BIS 2296: 1982.



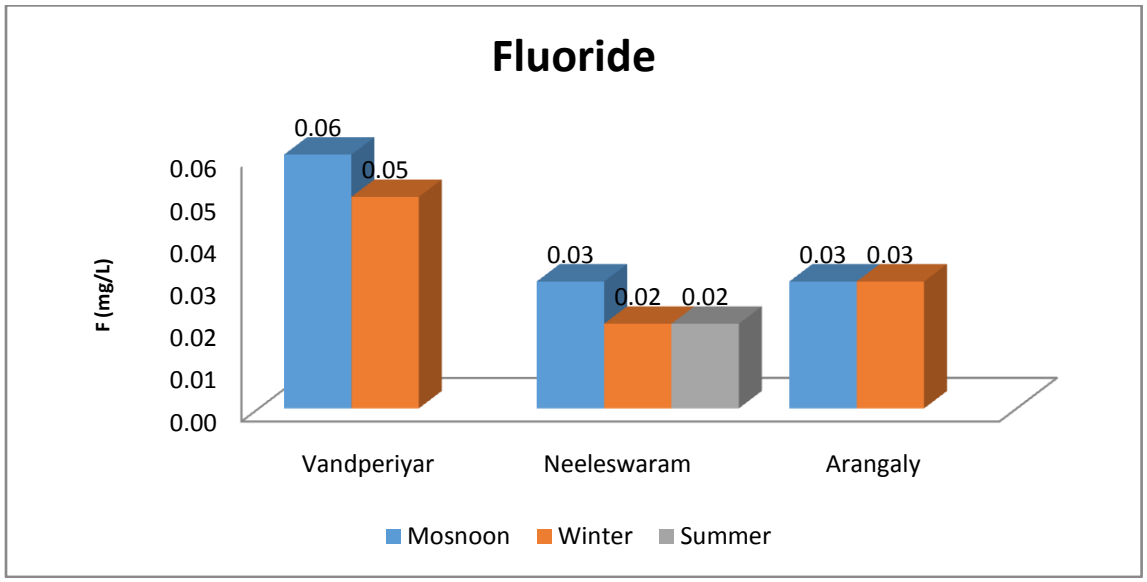
4.11 Bicarbonate:

Seasonal average of Bicarbonate not varied much along the seasons for Neeleswaram and Vandperiyar sites.The values of Bicarbonate at the sites range from 0.3-1.9 mg/l (Table-7 in Annexure). The parameter Bicarbonate is not listed in surface water classification of BIS 2296: 1982.



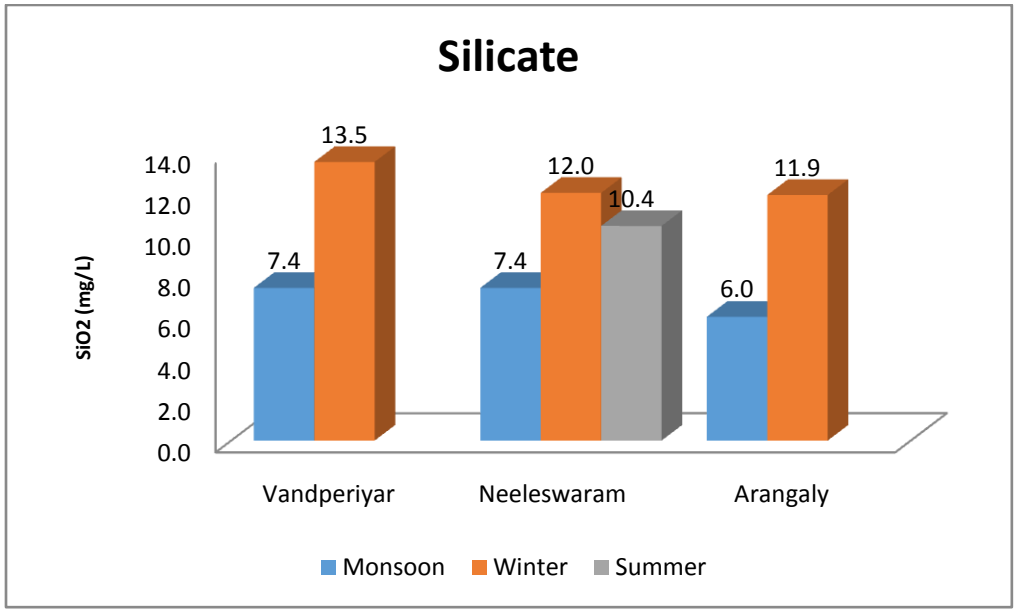
4.12 Fluoride:

During the study ,Seasonal average of Fluoride values showed a decreasing trend from monsoon to winter at Vandiperiyar & Neeleswaram sites.The values of Fluoride at the sites range from range from 0.02 to 0.06 mg/l and is well within the maximum prescribed limit of 1.5 mg/l as per BIS 2296: 1982 throughout the year.



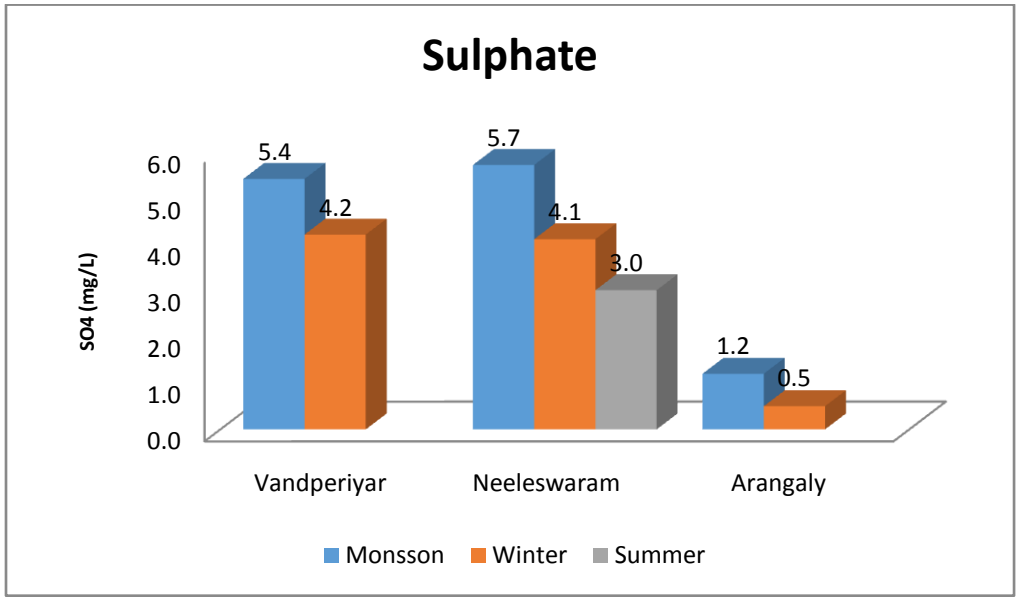
4.13 Silicate:

Seasonal average of silicate is maximum during winter season at Vandiperiyar site and minimum during monsoon sesson at Neeleswaram site. From monsoon to winter an increase in trend of chloride values is observed as there would be dilution effect during monsoon. The values of silicate at the sites range from 4.3 to 13.5 mg/l (Table-7 in Annexure) .The parameter Silicate is not listed in surface water classification of BIS 2296: 1982.



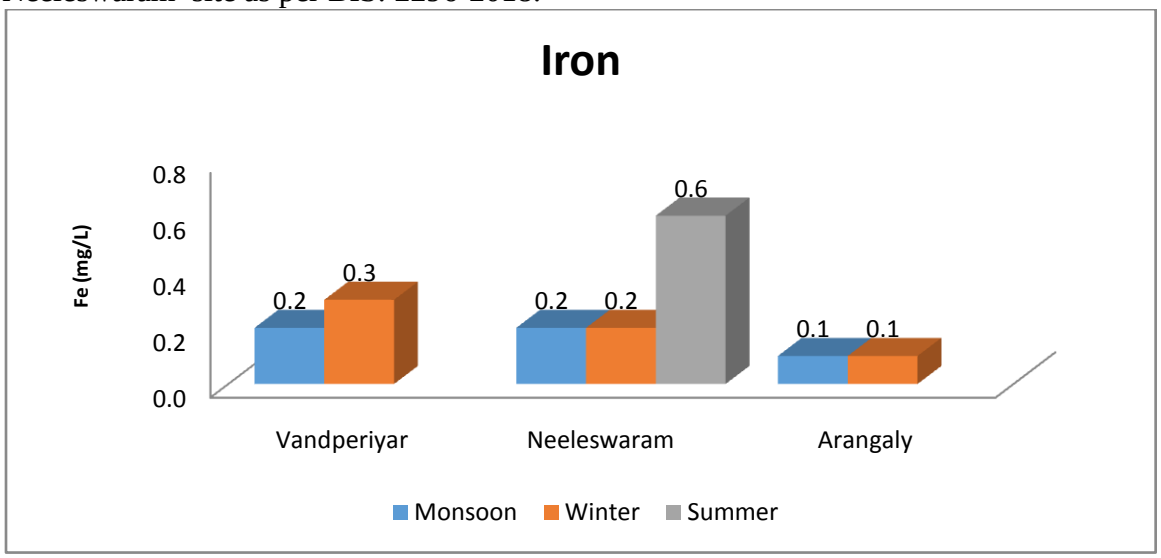
4.14 Sulphate:

Seasonal average of sulphate is maximum during monsoon season at Neeleswaram site and minimum during summer season at Arangaly site. From monsoon to winter an decrease in trend of sulphate values is observed at all the sites.. The values of sulphate at the sites range from 0.3 to11.5 mg/l (Table-7 in Annexure) and well within the maximum prescribed limit for class A of BIS: 2296-1982.



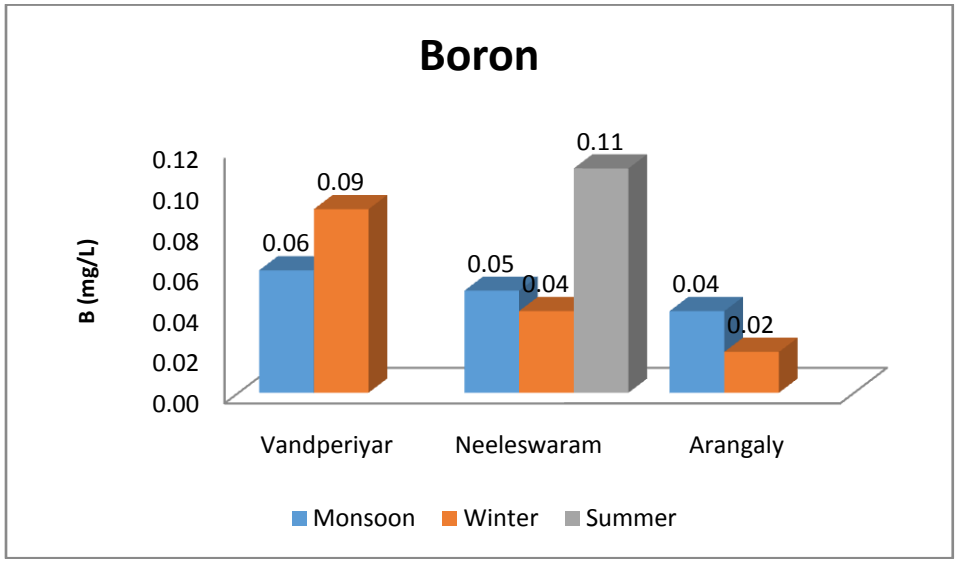
4.15 Iron:

Seasonal average of Iron is maximum during summer season at Neeleswaram site and minimum at Arangaly site. The values of iron at the sites range from 0.1 to 0.6 mg/l (Table-7 in Annexure). River water is of class A at Vandiperiyar & Arangaly sites and is of Class C at Neeleswaram site as per BIS: 2296-2018.



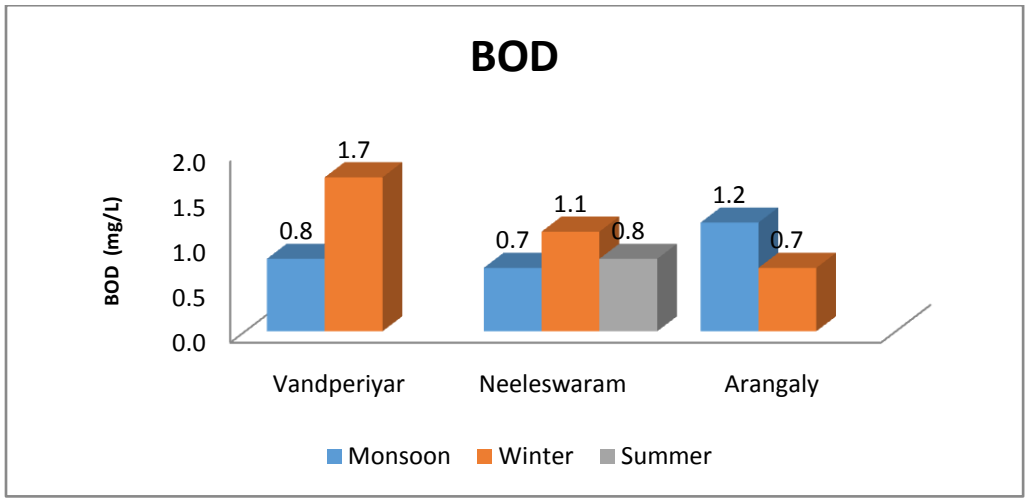
4.16 BORON:

Seasonal average of Boron is maximum during Summer season at Neeleswaram site and minimum during winter season at Arangaly site.. The values of Boron at the sites range from 0.02 to 0.11 mg/l and is well within the maximum limit of 2 mg/l as per the BIS: 2296-1982 throughout the year**.**



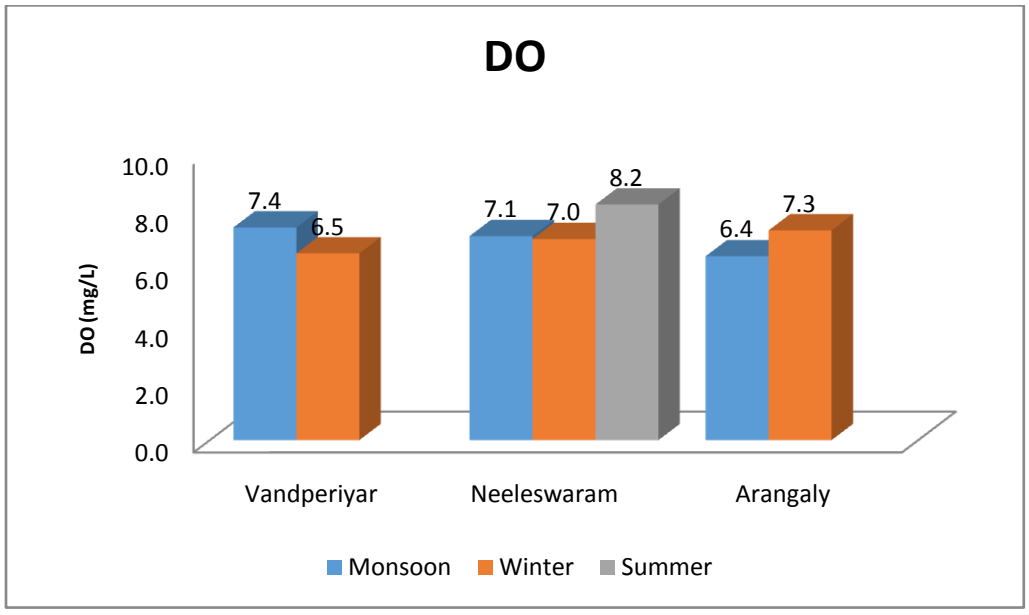
4.17 BOD:

Biochemical oxygen demand is an important parameter for usage conditions of surface waters. It is an approximate measure of the amount of biochemical degradable organic matter present in a water sample. The seasonal average of BOD is minimum during monsoon season at Neeleswaram and maximum is in winter season at Vandiperiyar site. Seasonal averages are in coherence with the Annual range.The values of BOD at the sites range from 0.6 to1.7mg/l (Table-7 in Annexure) and is within the maximum limit of class A as per BIS: 2296-1982 throughout the year.



.4.18 Dissolved Oxygen (DO)

Dissolved oxygen is an important parameter that gives an indication of pollution in water body. It depends upon the water temperature, water agitation, types and number of aquatic plants, light penetration and amount of dissolved or suspended solids. The seasonal average was minimum during Monsoon season at Arangaly site and maximum during summer season at Neeleswaram site.No specific trend is observed. The seasonal minimum differed considerably with the yearly minimum (Table-7 in Annexure) due to one low value recorded during monsoon at Neeleswaram & Arangaly. On an average for all seasons a good amount of DO above the minimum limit of Class A as per BIS:2296-1982is observed at at all the sites. However, the Annual minimum DO value (Table-7 in Annexure) at Neeleswaram is below the minimum limit of class A and at Vandiperiyar sites it is below the minimum limit of class B as per BIS:2296-1982.



5.0 Conclusion:

The ionic concentration is gradually decreasing from upstream (vandiperiyar) to downstream (Neeleswaram) which is unusual when compared with other rivers. The predominant cation is Sodium followed by Calcium, Magnesium and Potassium.. Among the anions Bi-carbonate is the predominant anion followed by Silicate, Chloride and Sulphate. Boron, Fluoride, and Iron are found to be in small quantities

No specific seasonal trend variation among all the sites is observed. Calcium, Sodium ,Potassium ,Chloride and silicate increases during the seasonal changes from monsoon to winter. Magnesium, Fluoride, Sulphate values decreases during the seasonal changes from Monsoon to winter . Seasonal averages of Bicarbonate, Total Alkalinity not changed much.

During the study period it is observed that river is of acidic in nature with low alkalinity. Increase in acidic nature during the monsoon would be due to high Sulphate values observed during the period.

Sodium Adsorption Ratio (SAR) is found to be within the limits and the water is classified as good quality for irrigation purpose

The water sources may be used safely for irrigation purposes but for drinking purposes the river water is falling behind the lower limit of pH considering the samples at the sites Neeleswaram, Vandiperiyar and Arangaly on the river Periyar. .

TABLE-4 INLAND SURFACE WATERS CLASSIFICATION BY THE BUREAU OF INDIAN STANDARDS (BIS: 2296-1982)

Sl No.	Parameters	UNITS	A	B	C	D	E
1	EC	(µs/cm), Max	-	-	-	1000	2250
2	pH	(pH units)	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.0-8.5
3	Total Hardness	as CaCO3, mg/L, Max	300	-	-	-	-
4	Calcium Hardness	as CaCO3, mg/L, Max	200	-	-	-	-
5	Magnesium	as CaCO3, mg/L, Max	100	-	-	-	-
6	Chloride	as Cl, mg/L, Max	250	-	600	-	600
7	Fluoride	as F, mg/L, Max	1.5	1.5	1.5	-	-
8	Sulphate	as SO4, mg/L, Max	400	-	400	-	1000
9	Iron	as Fe, mg/L, Max	0.3	-	50	-	-
10	Boron	as B, mg/L, Max	-	-	-	-	2
11	BOD	mg/L, Max	2	3	3	-	-
12	DO	mg/L, Min	6	5	4	4	-
13	SAR (-)	Max	-	-	-	-	26

A Drinking Water source without conventional treatment but after disinfections
B Outdoor bathing- organized
C Drinking Water source with conventional treatment followed by disinfections
D Propagation of wildlife, fisheries
E Irrigation, industrial cooling and controlled waste disposal

Table: 4 VANDIPERIYAR SEASONAL AVERAGES

	VANDIPERIYAR	**2018-19**		
Sl No.	**PARAMETER**	**MONSOON**	**WINTER**	**SUMMER**
1	EC (µmho/cm)	61	78	
2	pH	6.5	6.7	
3	HAR_Total (mgCaCO3/L)	22	24	
4	HAR_Ca (mgCaCO3/L)	11	18	
5	Ca (mg/L)	4	7	
6	Mg (mg/L)	2.7	1.5	
7	Na (mg/L)	5.1	6.1	
8	K (mg/L)	1.4	1.9	
9	Cl (mg/L)	8.2	9.7	
10	ALK-TOT (mgCaCO3/L)	18	18	
11	HCO3 (mg/L)	22	22	
12	F (mg/L)	0.06	0.05	
13	SiO2 (mg/L)	7.4	13.5	
14	SO4 (mg/L)	5.4	4.2	
15	Fe (mg/L)	0.2	0.3	
16	B (mg/L)	0.06	0.09	
17	BOD3-27 (mg/L)	0.8	1.7	
18	DO (mg/L)	7.4	6.5	
19	SAR (-)	0.5	0.5	

Table: 5 NEELESWARAM SEASONAL AVERAGES

	NEELESWARAM	2018-19		
	PARAMETER	**MONSOON**	**WINTER**	**SUMMER**
1	EC (µmho/cm)	33	41	32
2	pH	6.2	6.5	6.7
3	HAR_Total (mgCaCO3/L)	17	15	18
4	HAR_Ca (mgCaCO3/L)	7	10	10
5	Ca (mg/L)	3	4	4
6	Mg (mg/L)	2.6	1.2	1.9
7	Na (mg/L)	2.5	2.9	2.3
8	K (mg/L)	0.7	1.1	0.3
9	Cl (mg/L)	3.9	4.7	4.2
10	ALK-TOT (mgCaCO3/L)	11	11	11
11	HCO3 (mg/L)	14	13	14
12	F (mg/L)	0.03	0.02	0.02
13	SiO2 (mg/L)	7.4	12.0	10.4
14	SO4 (mg/L)	5.7	4.1	3.0
15	Fe (mg/L)	0.2	0.2	0.6
16	B (mg/L)	0.05	0.04	0.11
17	BOD3-27 (mg/L)	0.7	1.1	0.8
18	DO (mg/L)	7.1	7.0	8.2
19	Na% (%)	23	28	22
20	SAR (-)	0.3	0.3	0.2

Table:6 ARANGALY SEASONAL AVERAGES

	ARANGALY	2018-19		
	PARAMETER	**MONSOON**	**WINTER**	**SUMMER**
1	EC (µmho/cm)	41	66	
2	pH	6.7	6.6	
3	HAR_Total (mgCaCO3/L)	12	16	
4	HAR_Ca (mgCaCO3/L)	7	11	
5	Ca (mg/L)	3	4	
6	Mg (mg/L)	1.3	1.3	
7	Na (mg/L)	4.1	4.2	
8	K (mg/L)	1.3	1.3	
9	Cl (mg/L)	6.5	7.5	
10	ALK-TOT (mgCaCO3/L)	11	15	
11	HCO3 (mg/L)	13	19	
12	F (mg/L)	0.03	0.03	
13	SiO2 (mg/L)	6.0	11.9	
14	SO4 (mg/L)	1.2	0.5	
15	Fe (mg/L)	0.1	0.1	
16	B (mg/L)	0.04	0.02	
17	BOD3-27 (mg/L)	1.2	0.7	
18	DO (mg/L)	6.4	7.3	
19	Na% (%)	38	34	
20	SAR (-)	0.5	0.5	

Table-7 MAXIMUM MINIMUMN VALUES OF PERIYAR RIVER IN 2018-19

Sl No.	Parameters	Vandiperiyar		Neeleswaram		Arangaly		Range of the river
		Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	
1	EC (µmho/cm)	61	78	31	41	33	66	31 - 78
2	pH	6.2	6.8	5.9	6.8	6.5	6.9	5.9 - 6.9
3	HAR_Total (mgCaCO3/L)	18	26	12	25	11	16	11 - 26
4	HAR_Ca (mgCaCO3/L)	8	18	4	11	6	11	4 - 18
5	Ca (mg/L)	3	7	2	4	2	4	2 - 7
6	Mg (mg/L)	1.4	3.4	0.8	3.4	0.6	2.4	0.6 - 3.4
7	Na (mg/L)	3.0	7.4	1.1	4.6	3.0	6.2	1.1 - 7.4
8	K (mg/L)	1.3	1.9	0.3	1.1	1.2	1.4	0.3 - 1.9
9	Cl (mg/L)	5.4	11.7	1.5	7.0	4.8	9.2	1.5 - 11.7
10	ALK-TOT (mgCaCO3/L)	15	20	10	12	10	15	10 - 20
11	HCO3 (mg/L)	19	25	12	15	12	19	12 - 25
12	F (mg/L)	0.05	0.06	0.02	0.04	0.03	0.03	0.02 - 0.06
13	SiO2 (mg/L)	5.5	13.5	5.5	12.6	4.3	11.9	4.3 - 13.5
14	SO4 (mg/L)	1.8	11.5	1.5	10.8	0.3	2.6	0.3 - 11.5
15	Fe (mg/L)	0.1	0.3	0.1	0.6	0.1	0.2	0.1 - 0.6
16	B (mg/L)	0.03	0.09	0.03	0.11	0.02	0.06	0.02 - 0.11
17	BOD3-27 (mg/L)	0.8	1.7	0.6	1.1	0.7	1.5	0.6 - 1.7
18	DO (mg/L)	6.5	9.2	5.2	8.4	4.4	7.6	4.4 - 9.2
19	Na% (%)	21	45	14	39	28	53	14 - 53
20	SAR (-)	0.3	0.8	0.1	0.5	0.3	0.8	0.1 - 0.8

Comparative Study between Ground (Well) Water Quality and River (Ganga) Water Quality in different season at Buxar (GDSQ) site

Abstract: Comparative study of Ground Water and River Water Quality at GDSQ site Buxar is done using the available data generated during January 2019 to December 2019. Buxar is located at **25° 35' 0" N / 83° 59' 0" E** on the globe. In this study comparison of Water Quality parameter such as pH, Electrical Conductivity, Sodium, Potassium, Calcium, Magnesium and Chloride has been done along with Water level of both river and well w. r. t. mean Sea Level. Data generated upon analysis has been studied and it has been found that well water level is always higher than River water level by more or less 01meter throughout the year in 2019. All other water quality parameters mentioned above are also found in similar trend likewise Water level. Although somewhere few parameters are showing irregular trends in different seasons.

Introduction: Buxar is one of the district of Bihar province situated at **25° 35' 0" N / 83° 59' 0" E on the** globe at an elevation of 67 mtr(MSL). The major river flowing through this district is Ganga. It entrers in Bihar via Buxar so this holy river is selected for the source of river water sample in our study. The Well selected for the study is located neaby(1500m away) the right bank of the Ganga. These days this well is being used for the purpose of irrigation only.

Sampling: Sampling of River water and Well water has been done on the 1st working day of every month at around 8:30am. River Water Sampling has been done using Punjab type silt Sampler in the middle of the stream and middle of deapth of river water level. On the other hand well water sampling has been done using rope and bucket. Both of the Sampling have been done by follwing the guidlinelines issued by Central Water Commission. The collected samples are preserved in Icebox using ice and trasnported to Water Quality laboratory, LGD-II, CWC, Patna for further analysis and study after carring out analysis of some parameters viz. temperature, pH, Electrical Conductivity(Ec).

Analysis: The collected samples are analysed in same environmental condition in the laboratory by following standard protocol provided by the commission. Sodium(Na^+) and Potassium (K^+) are analysed by using Flamephotometer while Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Carbonate (CO_3^{2-}), Bicarbonate (HCO_3^-) and Cloride (Cl-) are analysed by titration method.

Data Calculation and Analysis: The data generated through analysis is calculated accordingly.

The data generated after the analysis of Well Water:

Month	pH	Ec	Na^+	K^+	Carbonate	bicarbonate	Ca^{2+}	Mg^{2+}	Cl^-
Jan-19	7.8	412	26.9	12.9	19.2	129.32	41.28	49.54	46
Feb-19	8.2	414	47.3	23.3	19.2	212.28	46.44	168.22	42
Mar-19	8.3	478	37.8	23.8	9.6	265.96	44.72	26.83	52
Apr-19	7.6	1020	12.9	81.4	19.2	239.12	51.6	22.7	56
May-19	8.6	1160	49.6	40.7	64.8	39.04	32.68	12.38	39
Jun-19	7.9	542	61.3	14.7	33.6	175.68	36.12	19.61	40
Jul-19	8.3	425	72.8	16.7	21.6	195.2	21.24	16.34	39
Aug-19	7.4	855	73.6	17.8	0	156.16	35.11	38.56	21
Sep-19	7.4	528	60.9	37.3	38.4	58..56	44.72	27.86	86
Oct-19	8.6	370	16.5	12.9	4.8	156.16	39.56	28.9	48
Nov-19	8.2	735	30.9	8.9	14.4	151.28	25.8	13.42	30
Dec-19	7.8	578	40.6	7.7	16.8	53.68	17.2	33.02	90

(all ionic concentration are in mg/l)

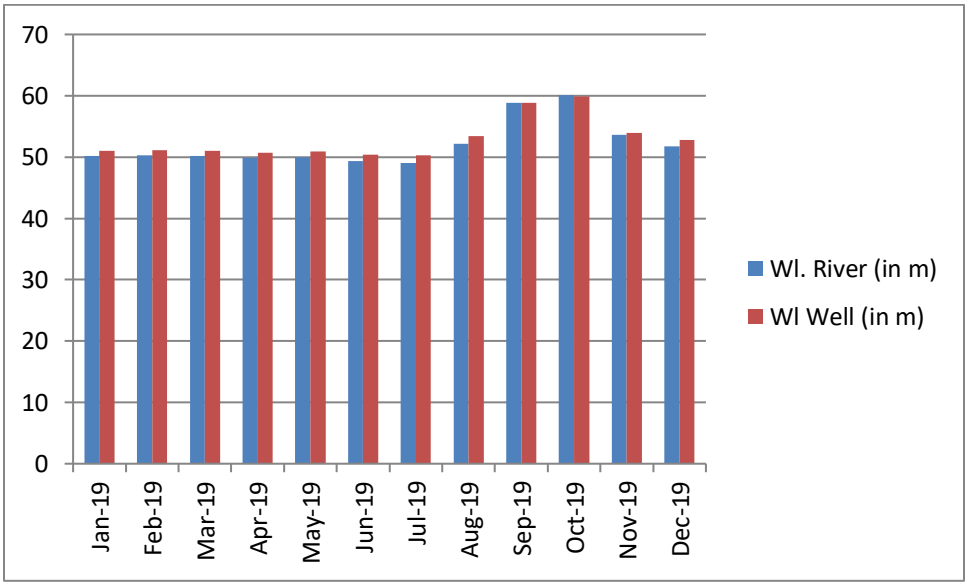
The data generated after the analysis of River Water:

Month	pH	Ec	Na^+	K^+	Carbonate	bicarbonate	Ca^{2+}	Mg^{2+}	Cl^-
Jan-19	8.1	298	25.6	13.9	14.4	114.68	30.96	25.8	40
Feb-19	8.2	298	19.6	22.9	16.8	195.2	34.4	20.64	38
Mar-19	8.1	308	17.2	24.4	14.4	183	32.68	27.86	42
Apr-19	8	306	32.6	22.9	14.4	136.64	32.68	28.9	38
May-19	8.8	961	52.1	12.3	14.4	183	37.84	19.61	57
Jun-19	7.4	443	56.1	11.2	9.6	187.88	27.52	18.58	56
Jul-19	8.2	414	30.8	13.8	14.4	187.88	18.41	12.9	49
Aug-19	8.3	346	29.4	15	14.4	163.48	18.9	11.48	19
Sep-19	8.1	360	31.5	16.8	15.2	170.24	24.8	27.82	28
Oct-19	8.4	380	36.1	18.2	14.4	185.23	29.1	37.5	35
Nov-19	7.8	392	37.1	19.8	16.8	53.68	30.96	45.41	26
Dec-19	8.1	289	11.6	30.9	9.6	80.52	34.4	26.83	31

(all ionic concentration are in mg/l)

Details of Water level (w.r.t. mean Sea level) and Discharge:

Month	Discharge (in Cumec)	River Water Level. (in m)	Well Water level (in m)
Jan-19	550	50.2	51.04
Feb-19	526	50.26	51.08
Mar-19	536.6	50.23	51.04
Apr-19	445.76	49.83	50.75
May-19	483.44	50.01	50.93
Jun-19	317.9	49.38	50.43
Jul-19	331.16	49.07	50.29
Aug-19	1200	52.18	53.46
Sep-19	15000	58.85	58.86
Oct-19	23590	60.11	59.94
Nov-19	2800	53.59	53.96
Dec-19	1156.81	51.7	52.79

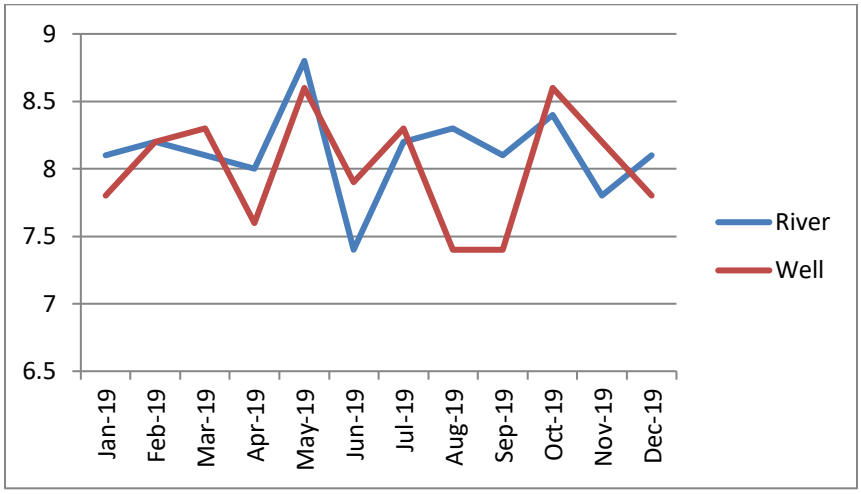


Water level (w.r.t. mean Sea level) of both Well and River from Jan-19 to Dec-19

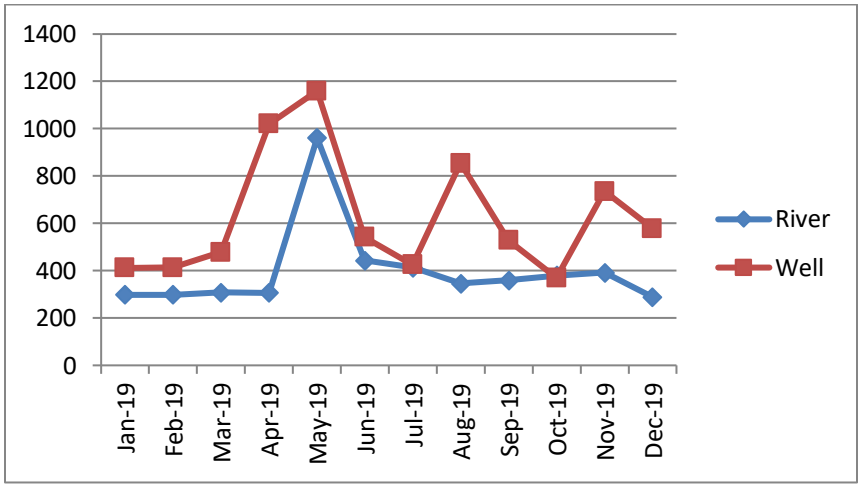
It is clear from the above bar graph that water level of well is higher than that of river throughout the year 2019 by almost 01mtr.

Similarly, Values of Water quality parameters of Well are higher than those of River which are shown in susequent graphs. However some irregular pattern are also found in folloeing graph for few parameters.

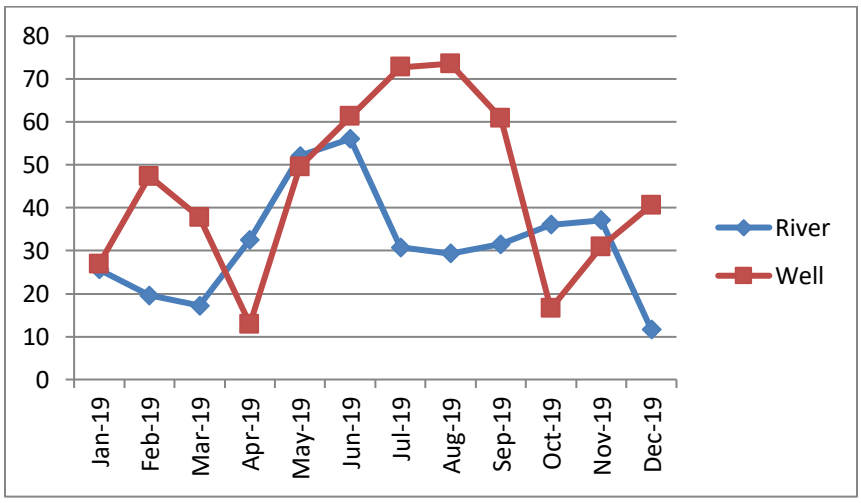
1. **pH:**



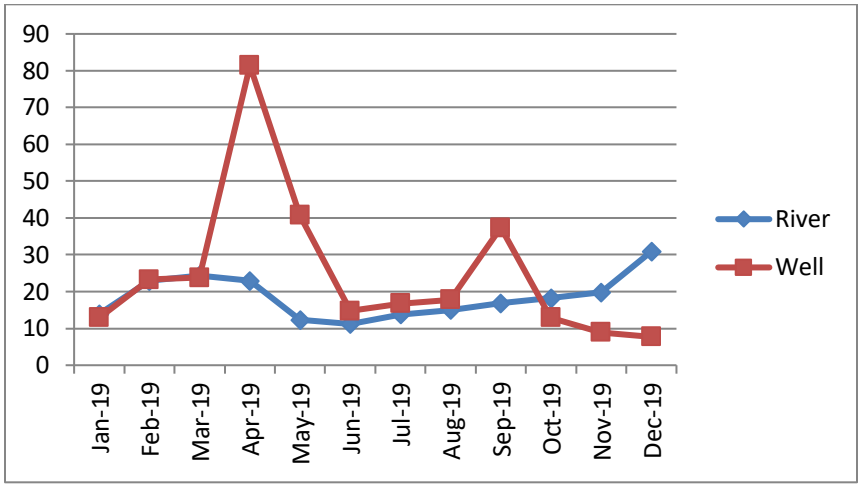
2. **Electricle Conductivity (Ec):**



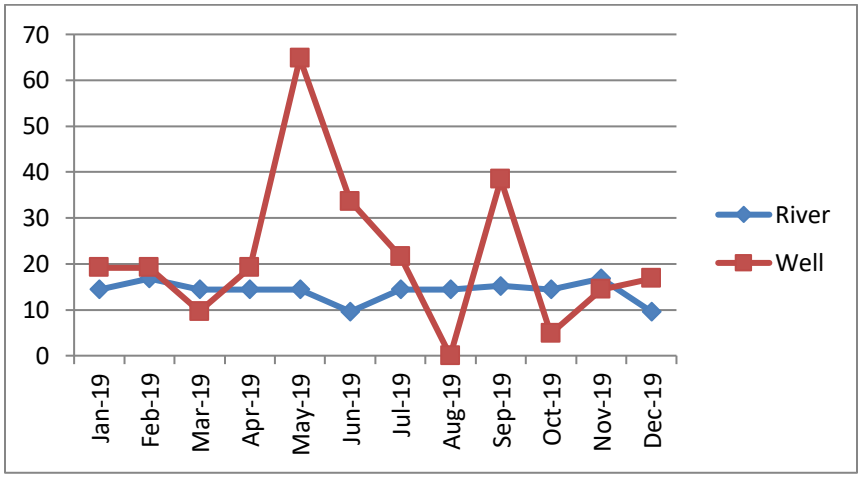
3. **Sodium:**



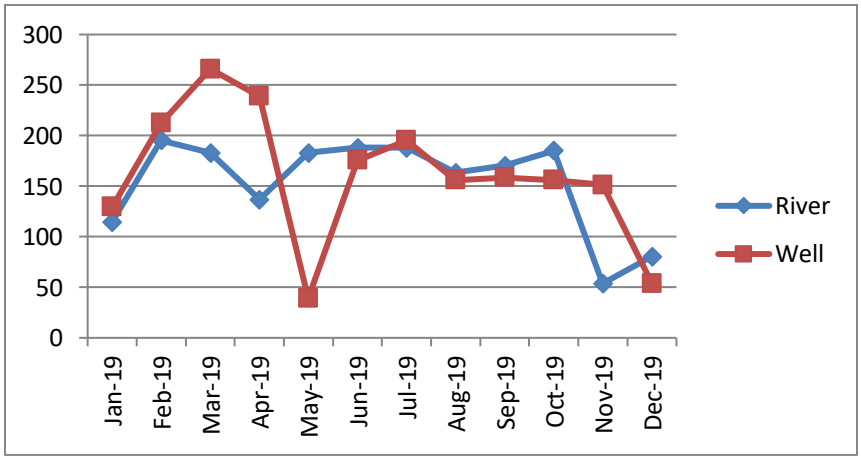
4. **Potassium:**



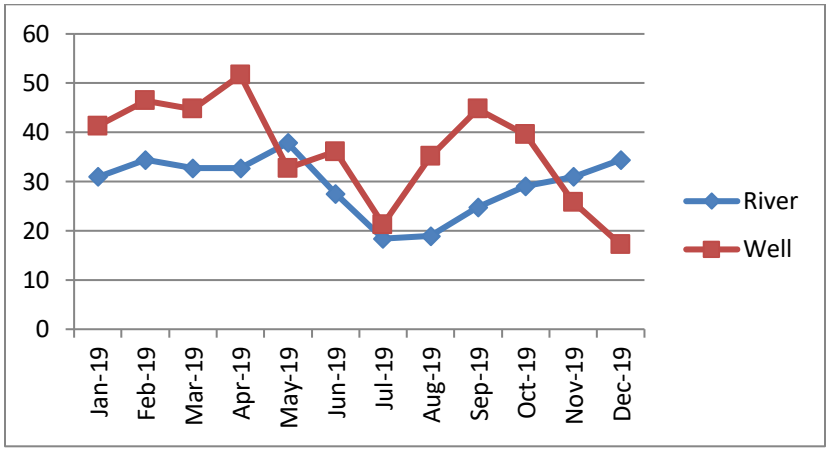
5. **Carbonate:**



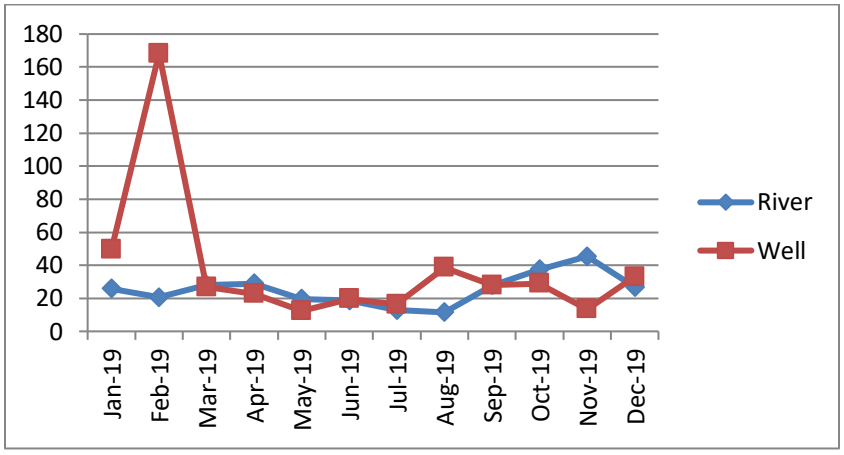
6. **Bibarbonate:**



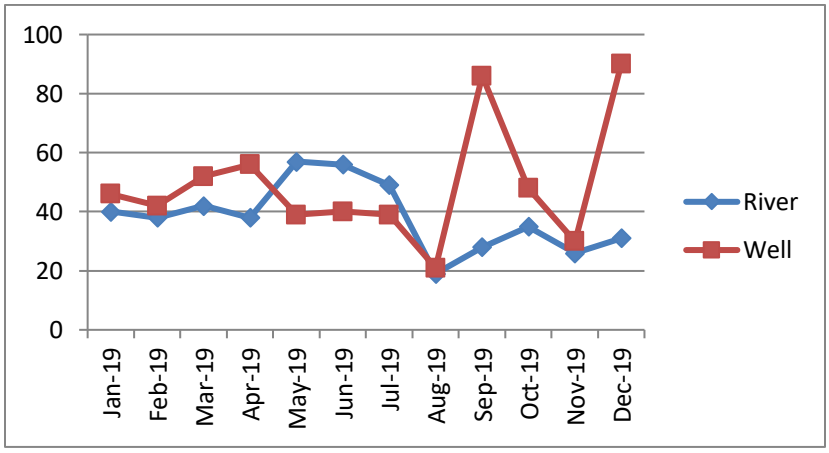
7. **Calcium:**



8. **Magnesium:**



9. **Choride:**



Conclusion: In this study it has been found that values of aformentioned Water quality parameters for Well water are higher than that of river water in the year of 2019 in all the seasons but before going to any solid conclusion further study is also required.

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Water Quality Study Report

Seasonal Variation of Ulhas River at Badlapur

Year 2018-19

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Seasonal Study of Water Quality Parameters of Ulhas River At Badalapur Site Under Upper Krishna Division, CWC, Pune.

Abstract:

Study of river water quality plays important role in evaluating and determining the pollution status and health of the water. Ulhas river is one of the important water bodies under upper Krishna Division Pune, Central Water Commission at Thane district in Maharashtra. In this study we have studied Level-II Physical and chemical parameters of water were monitored month-wise in the year 2018-2019.

1) *INTRODUCTION:*

The **Ulhas River** is a west flowing river in Western India in the state of Maharashtra draining an area of 4,637 km^2. This River is mainly a monsoon fed river and the fresh water flow dwindles down during non-monsoon seasons. It is used to supply drinking water to the cities of Badlapur and Navi Mumbai, Kalyan, Dombivali.

122 Km Length of the course of the Ulhas river. A river that has its beginnings in pristine streams flowing down from the Western Ghats at Rajmachi near Lonavala, the Ulhas ends as a smelly creek in the Arabian Sea.

3 districts that the river flows through - Pune, Raigad and Thane. Inhabitants of its banks use it for various purposes including washing clothes and fishing. The river flows through Khandala valley and interior Karjat. It then flows through Bhivpuri, Neral, Badlapur, Ambernath, Ulhasnagar, Shahad, Kalyan and Dombivli before joining the Vasai creek and, eventually, reaching the Arabian Sea.

There are number of industries situated along the either banks of the river, adding their effluents at various localities namely Ambivli, Ulhas Nagar, Dombivli, Bhiwandi and Thane City and loading the water body with pollutants heavily. Therefore, monitoring water parameters regularly can help in assessing the extent of pollution and planning the remedial measures.

2) *DISCUSSION:*

Water Quality Sampling Locations	Latitude & Longitude	Segment of Estuary/River
Badlapur Site	19° 16'36.98"N and 73°52'39.5"E	River Upstream

Central Water Commission is conducting Hydrological observations at Badlapur station for West flowing river Ulhas which are comes under Upper Krishna Division, Central Water Commission, Pune. The sample is collected at this site and in-situe parameters like pH, EC, Do, Colour, Odour and Temperature etc. is analyzed at site (as level-I) on monthly basis as well as the water sample is also sent to the divisional laboratory in Pune, for analysis of Level- II parameters on monthly basis.

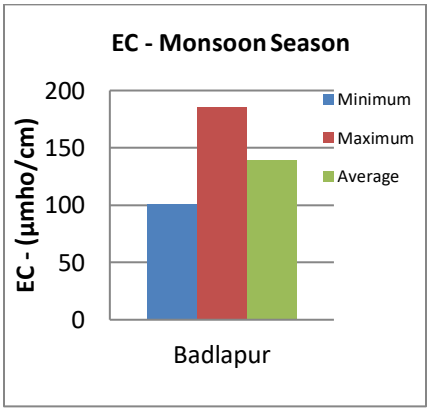
Level –II parameters viz. pH, EC, DO, BOD, COD, Cations, Anions and Total & Fecal Counts of Coliforms etc.

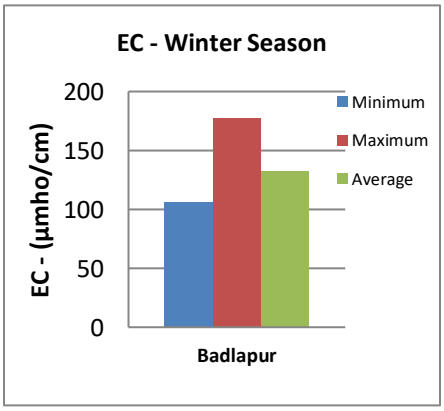
The Data is presented in this report is taken during the Year 2018-19, and it is represented season wise graphically.

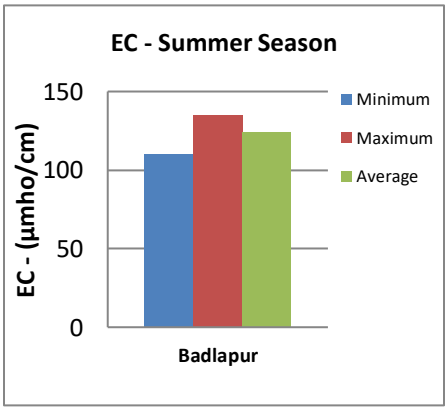
Table- as below,

1. **EC:**

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun – Sep			Oct – Jan			Feb – May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	101	186	140	106	177.0	132	110	135.0	124.25

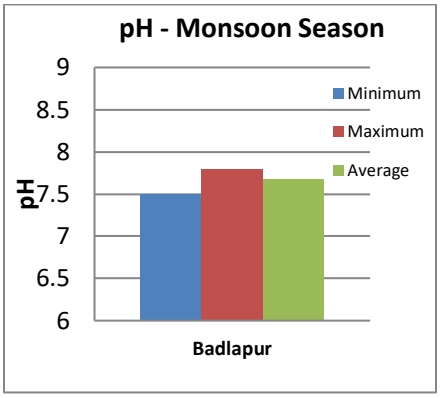


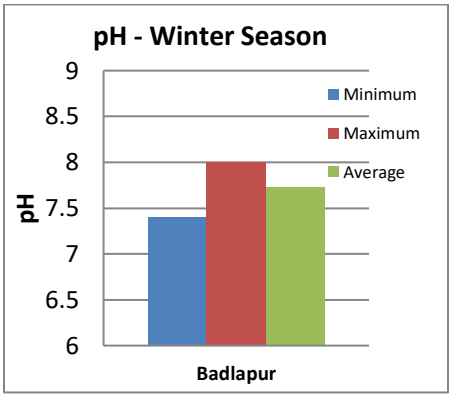


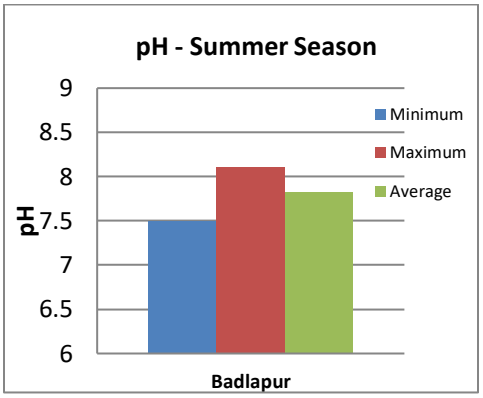


2. **pH:**

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb – May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	7.5	7.8	7.7	7.4	8.0	7.7	7.5	8.1	7.8

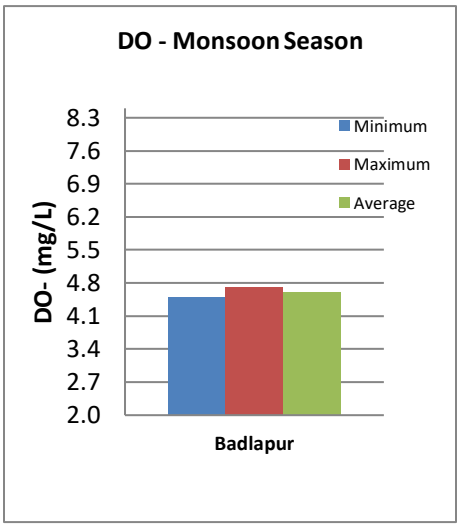


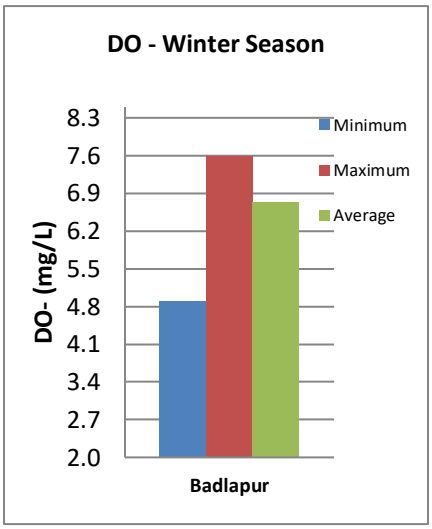


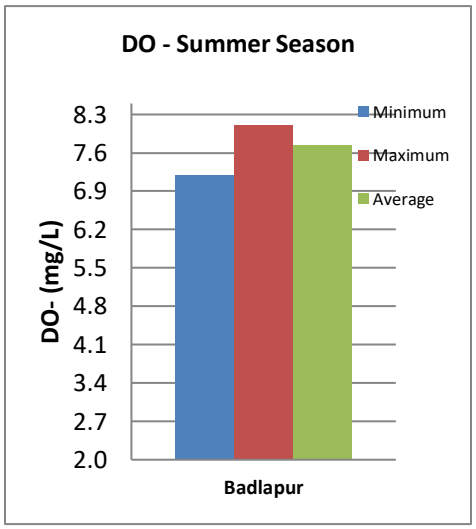


3. DO:

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb – May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	4.5	4.7	4.6	4.9	7.6	6.7	7.2	8.1	7.8

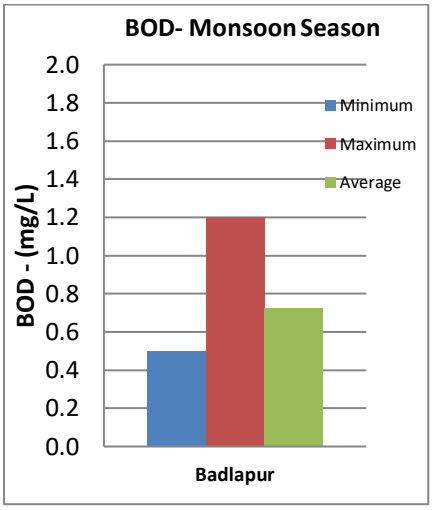


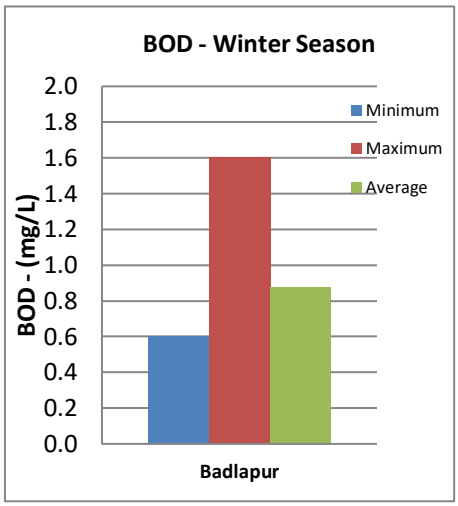


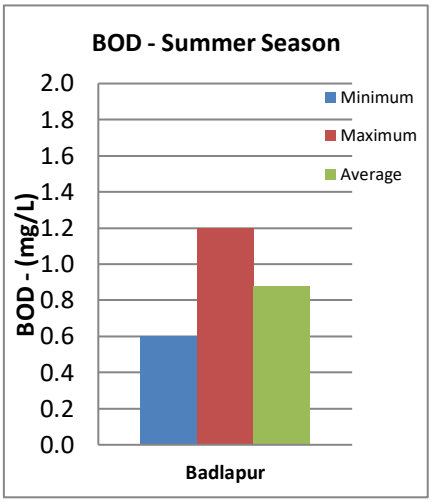


4. BOD:

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb – May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	0.5	1.2	0.7	0.6	1.6	0.9	0.6	1.2	0.9

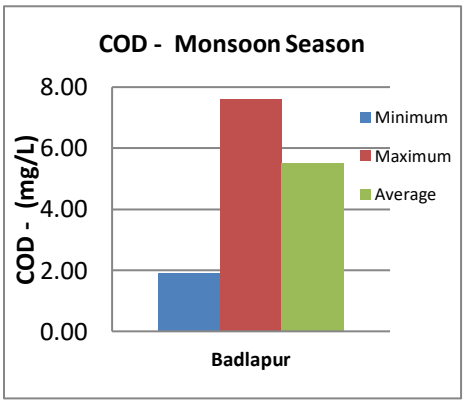


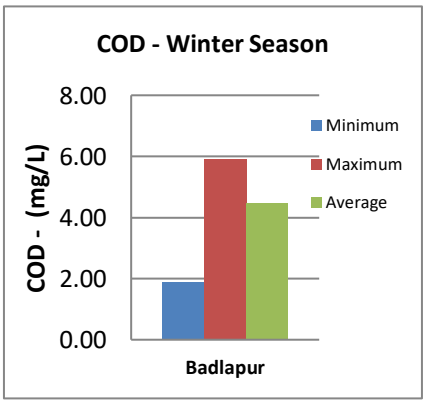


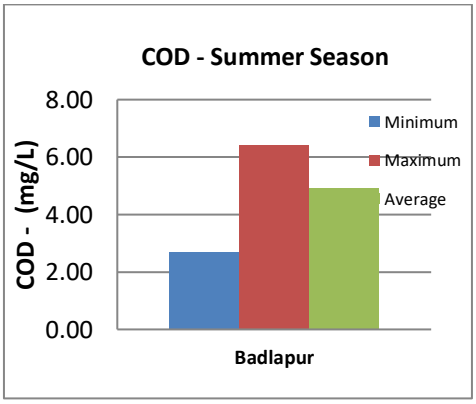


5. COD:

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	4.00	8.00	5.40	4.60	10.00	6.35	5.30	10.60	7.78

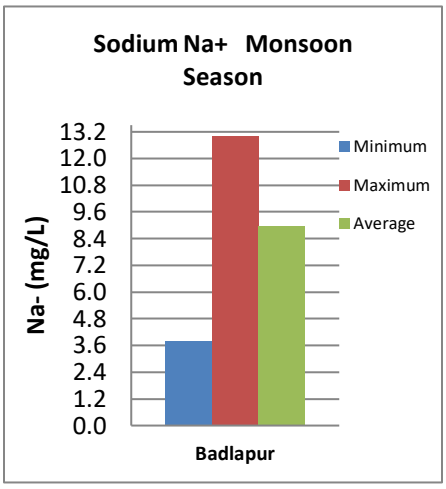


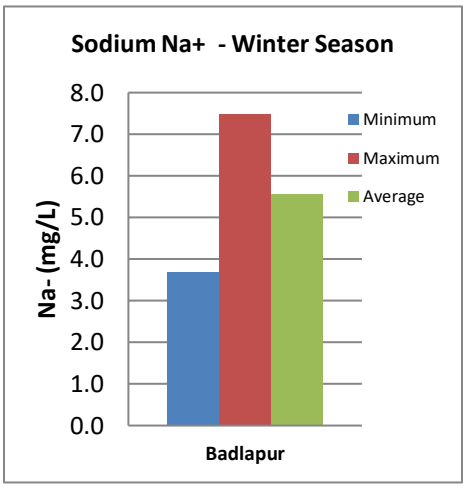


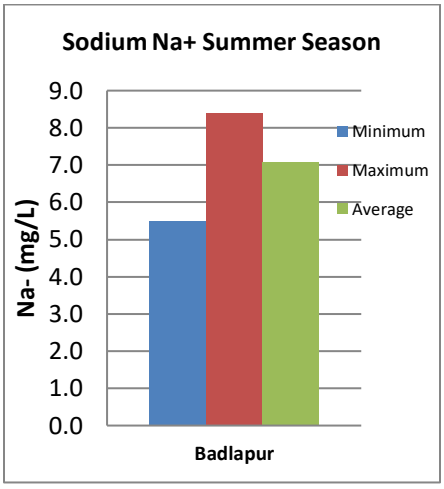


6. Sodium (Na^+) :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun – Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	3.8	13.0	8.98	3.7	7.5	5.58	5.5	8.4	7.08

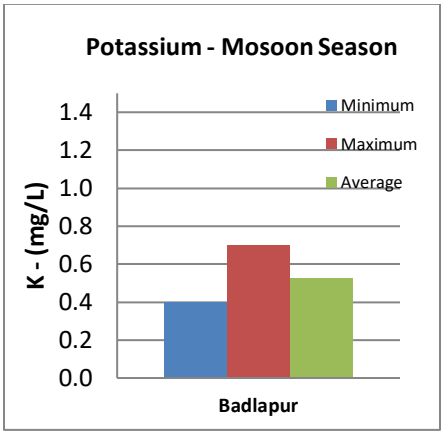


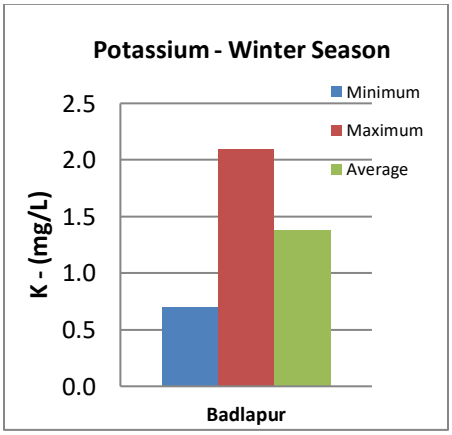


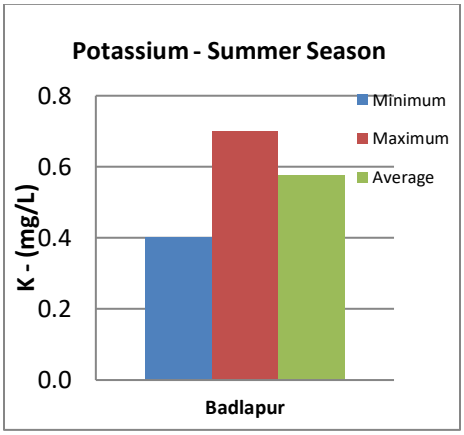


7. Potassium (K^+) :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	0.4	0.7	0.5	0.7	2.1	1.4	0.4	0.7	0.6

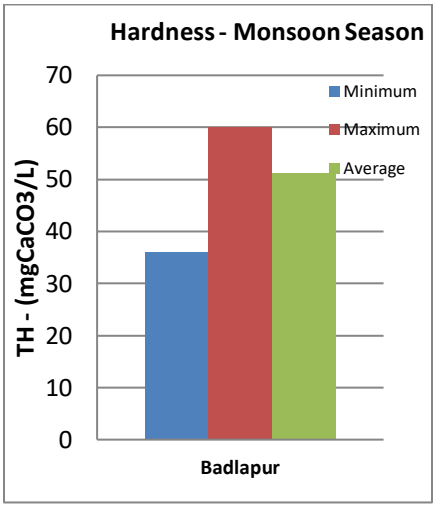


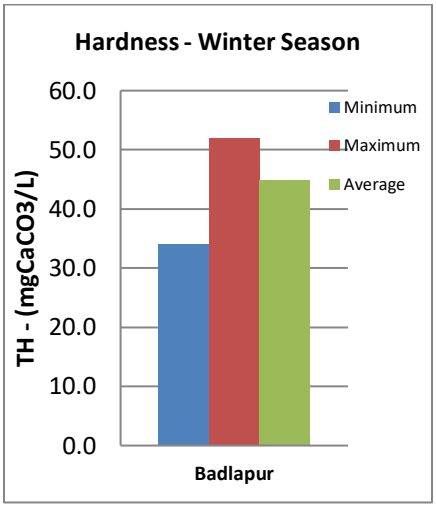


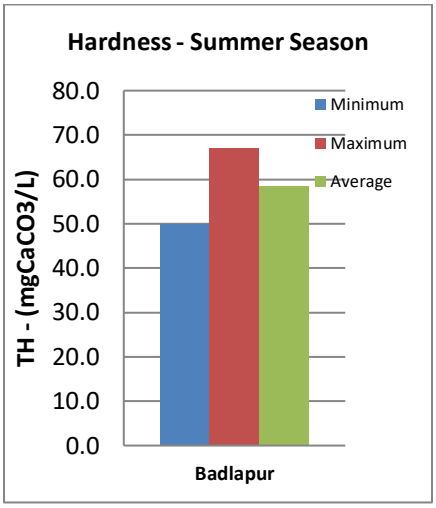


8. Total Hardness – (As $CaCO_3$) :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb – May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	36.0	60.0	51.3	34.0	52.0	45.0	50.0	67.0	58.5

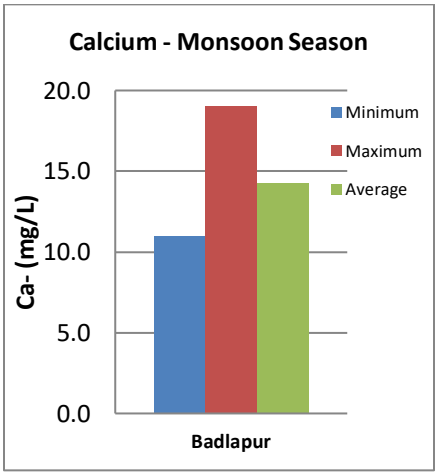


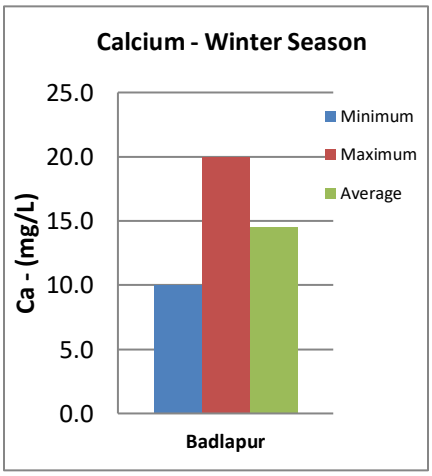


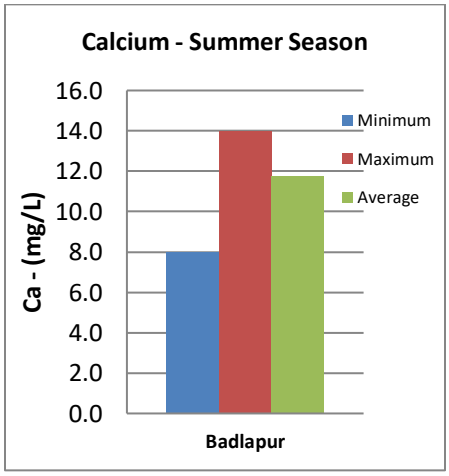


9. Calcium :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb – May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	11.0	19.0	14.3	10.0	20.0	14.5	8.0	14.0	11.8

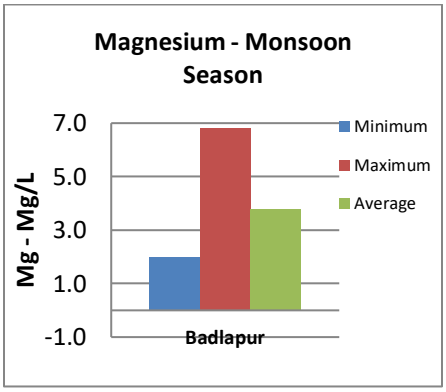


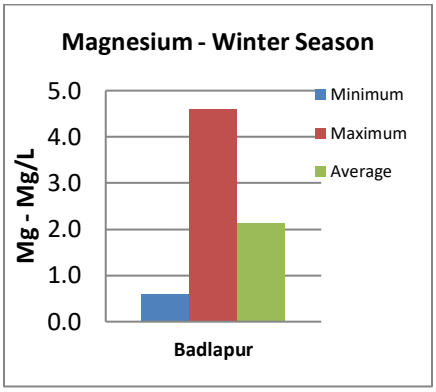


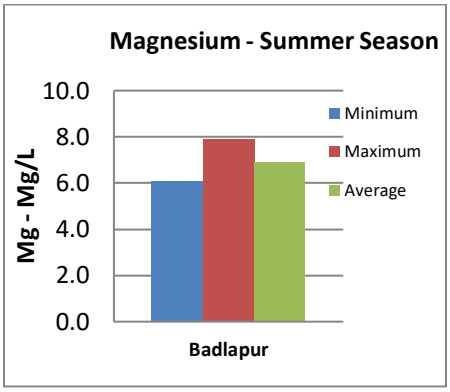


10. Magnesium :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	2.0	6.8	3.8	0.6	4.6	2.1	6.1	7.9	6.9

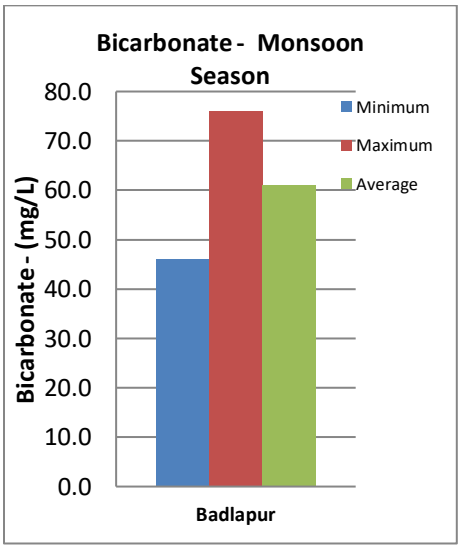


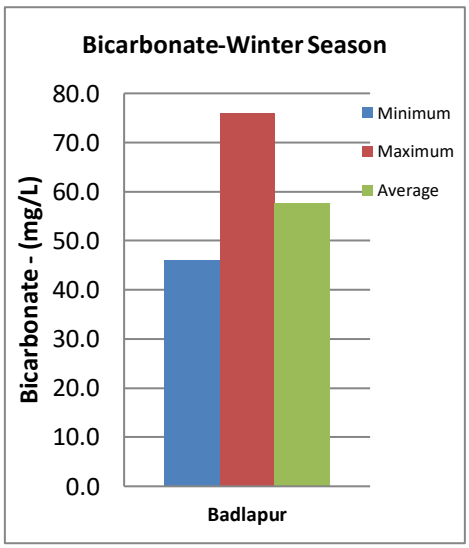


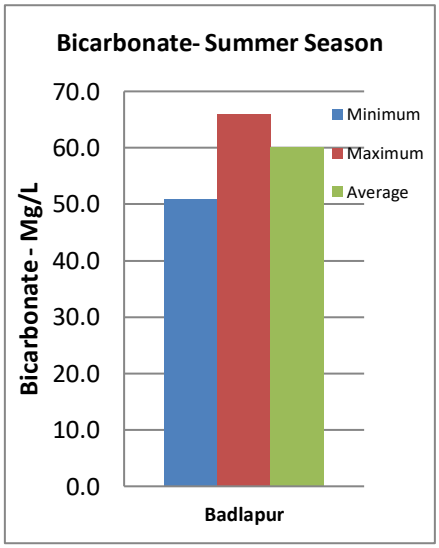


11. Bicarbonate :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	46.0	76.0	61.0	46.0	76.0	57.8	51.0	66.0	60.0

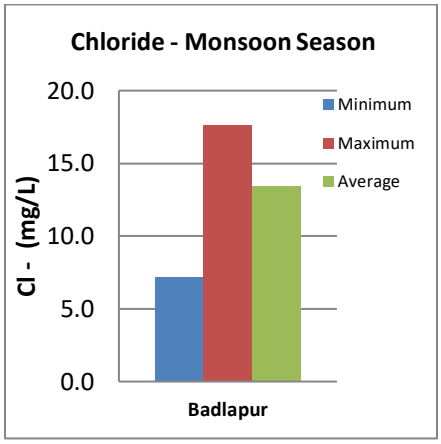


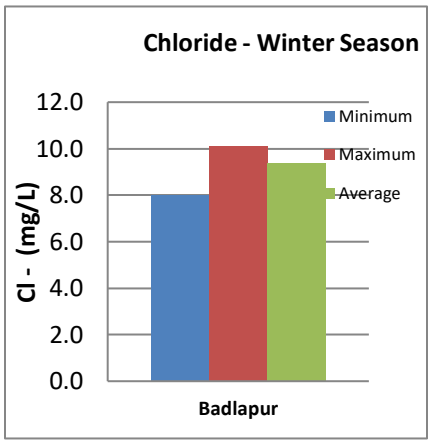


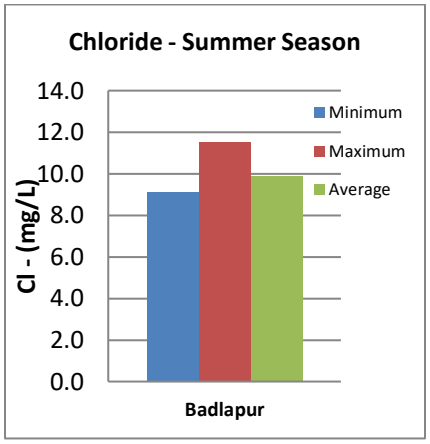


12. Chloride :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	7.2	17.6	13.5	8.0	10.1	9.4	9.1	11.5	9.9

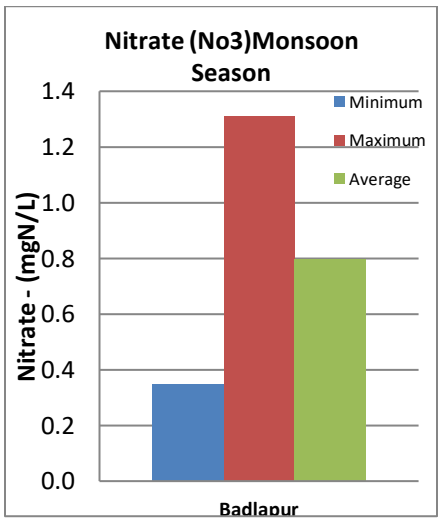


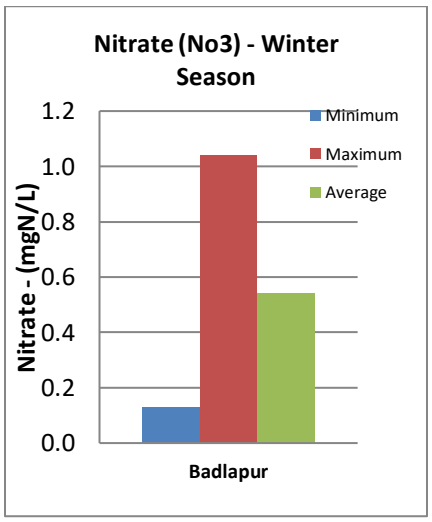


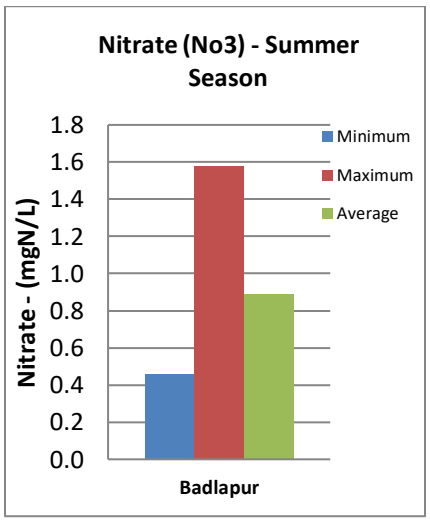


13. Nitrate (NO_3) :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun – Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	0.4	1.3	0.8	0.1	1.0	0.5	0.5	1.6	0.9

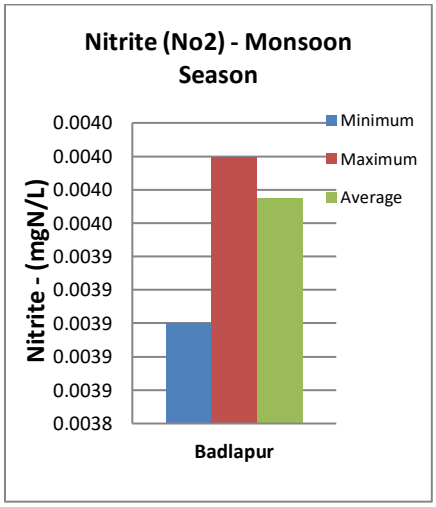


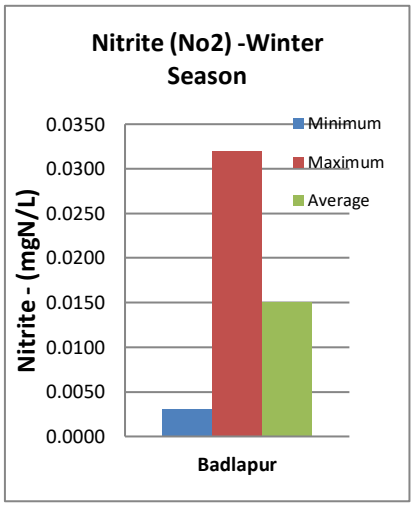


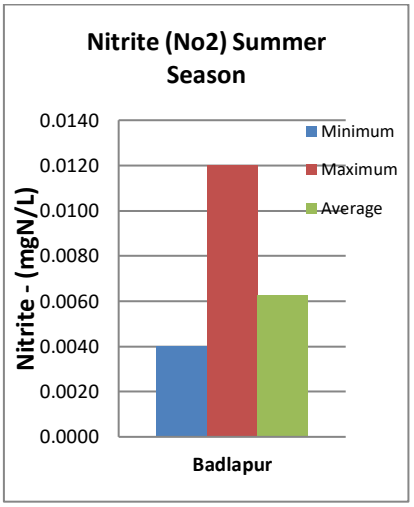


14. Nitrite (NO_2) :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	0.0039	0.0040	0.00398	0.0030	0.0320	0.0150	0.0040	0.0120	0.0063

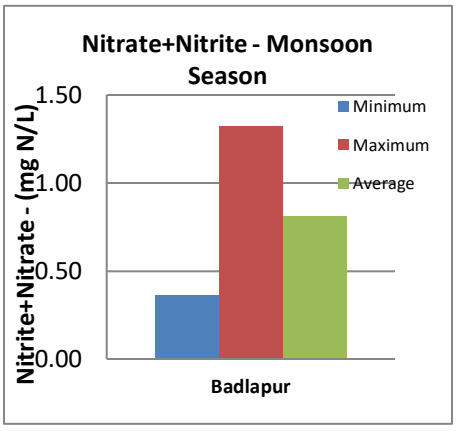


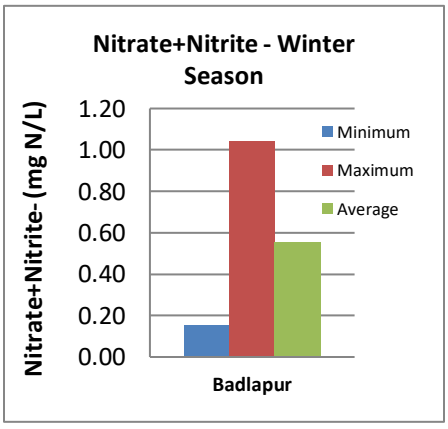


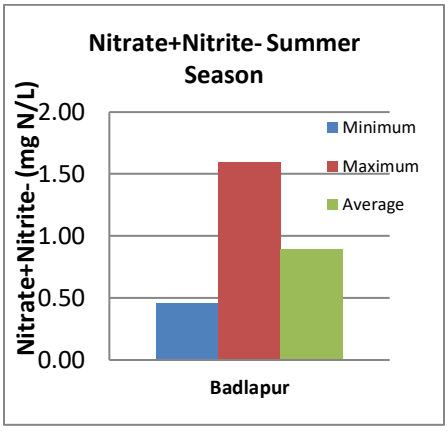


15. Nitrate + Nitrite :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	0.36	1.32	0.81	0.15	1.04	0.55	0.46	1.59	0.90

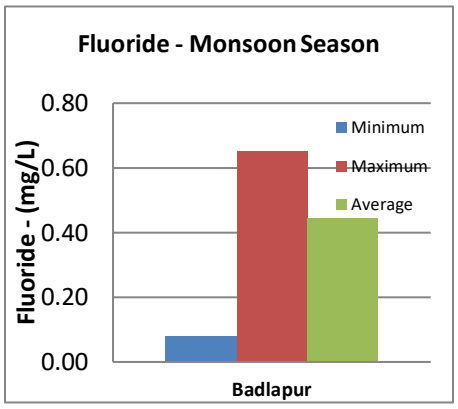


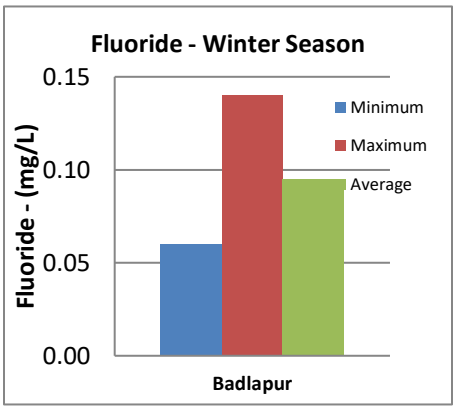


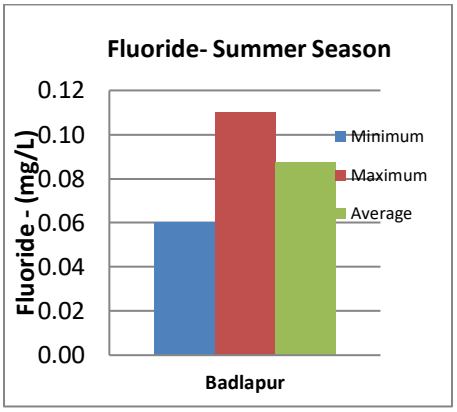


16. Fluoride :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	0.08	0.65	0.44	0.06	0.14	0.10	0.06	0.11	0.09

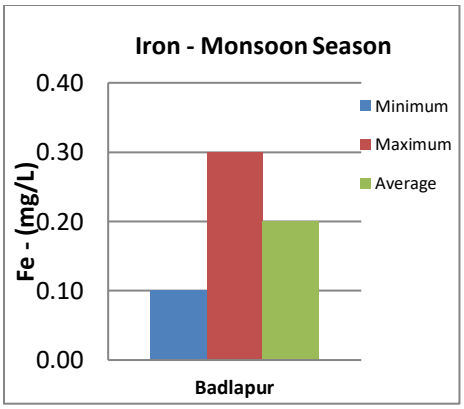


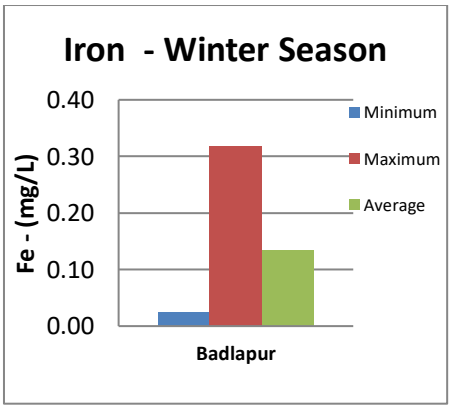


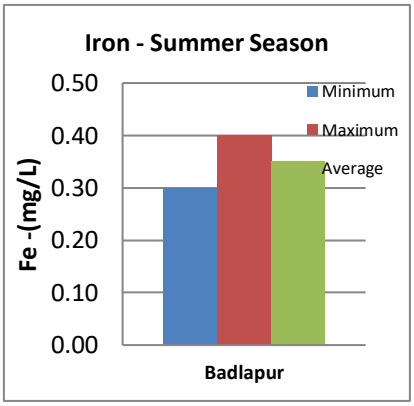


17. Iron :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	0.10	0.30	0.20	0.02	0.32	0.13	0.30	0.40	0.35

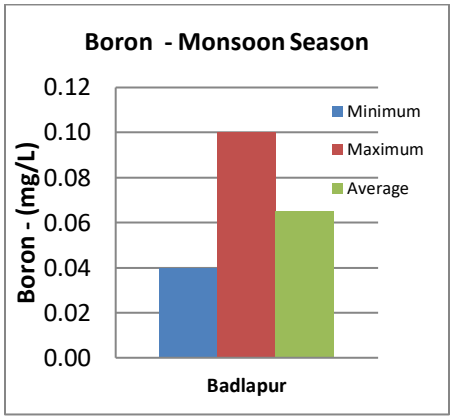


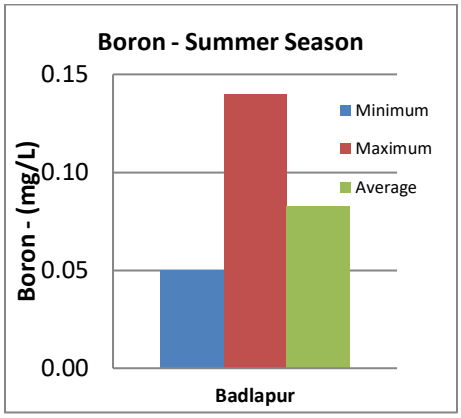


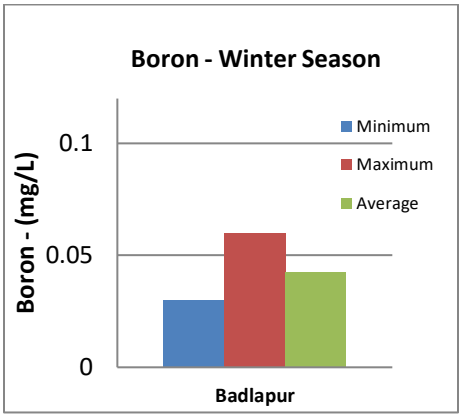


18. Boron :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb - May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	0.04	0.10	0.07	0.03	0.06	0.04	0.05	0.14	0.08

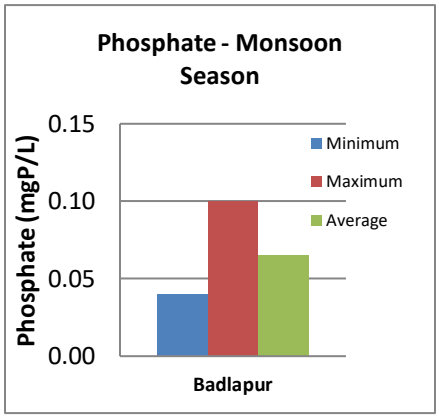


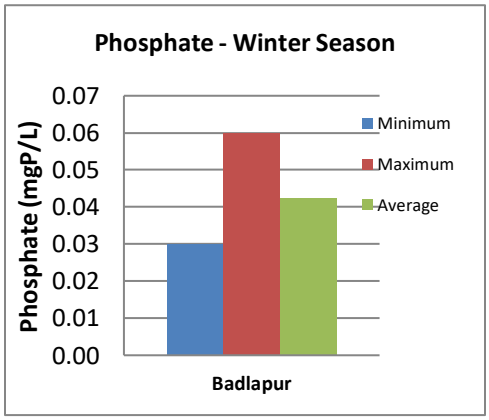


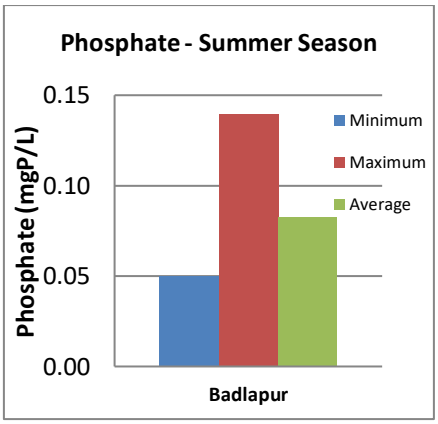


19. Phosphate :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb – May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	0.04	0.10	0.07	0.03	0.06	0.04	0.05	0.14	0.08

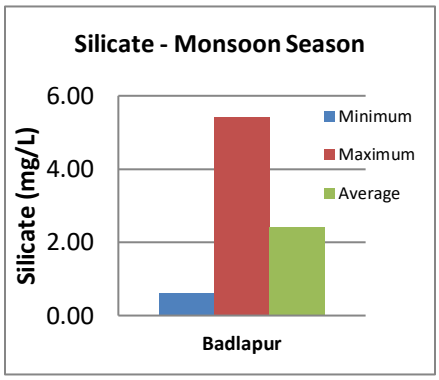


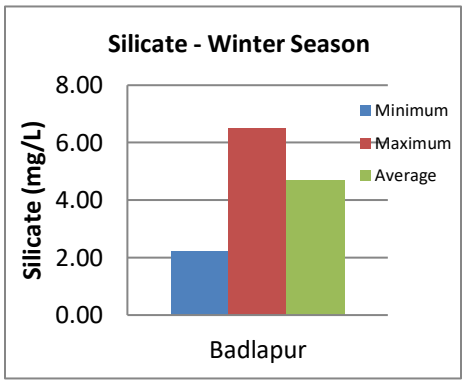


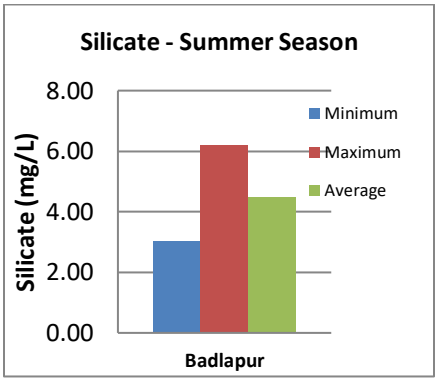


20. Silicate :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb – May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	0.60	5.40	2.43	2.20	6.50	4.68	3.00	6.20	4.48

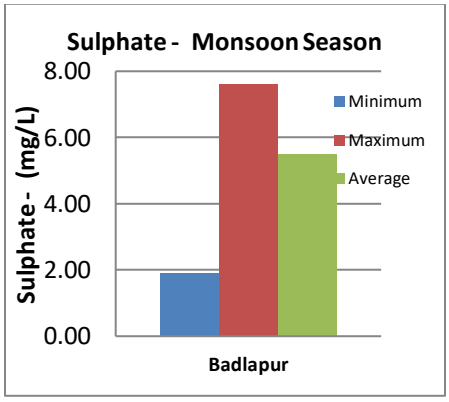


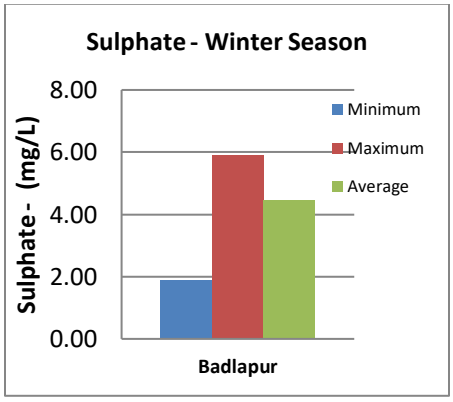


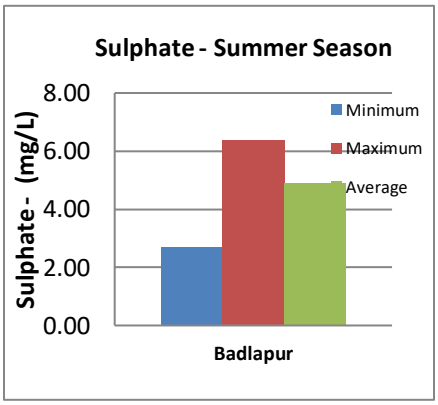


21. Sulphate :

Site Name	Monsoon Season			Winter Season			Summer Season		
	Jun - Sep			Oct - Jan			Feb – May		
	2018			2018-2019			2019		
	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*	Minimum	*Maximum*	*Average*
Badlapur	1.90	7.60	5.50	1.90	5.90	4.48	2.70	6.40	4.93







3. CONCLUSION:

The water quality data is obtained from the Badlapur site. The water is compared season wise & maximum, minimum and average data for the Year 2018-19 for following parameters like EC, pH, DO, BOD, Hardness, Calcium, Magnesium, Sodium, Potassium, Bicarbonate, Chloride, Sulphate, Phosphate, Nitrate, Nitrite, Nitrate + Nitrite, Boron, Fluoride, Iron, Silicate etc. are shown by graphs.

Conclusion about Water Quality trend:

During the observation period of Ulhas river, it is observed that at baseline station water is good for house hold, Consumption (but after disinfection) and agriculture purpose. The general observation on the above site is appended below.

- The water of Ulhas river is generally alkaline in nature.
- The extremities of parameters observed in sample at different season in said river system indicate that in general, within the prescribed limits for different designated uses as per Bureau of Indian Standards.
- Water of this river is suitable for growth of any type of crops, in general.
- The water of said river is generally bacteriologically unsafe.
- There is slightly significant stress on water of this river due to the impact of pollution load during the period under study.

4. Method Adopted for Analysis:

S. No.	Parameter	Protocol Used
1	pH	pH cell Potentio-metric
2	Conductivity (µmhos/ cm)	Conductivity cell Potentio-metric
3	Total Hardness as $CaCO_3$	EDTA Titrimetric
4	Calcium as Ca	EDTA Titrimetric
5	Magnesium as Mg	Calculation from TH and Ca.
6	Total alkalinity as $CaCO_3$	Titration
7	Chloride as Cl^-	Argentometric Titration
8	Biological Oxygen Demand	Bottle Incubation for 5 days at 20°C
9	Dissolved Oxygen	Winkler Azide Modification Titrimetric
10	Chemical Oxygen Demand (COD)	Open Reflux/ Chemical Titration
11	Nitrate as NO_3^-	Nitrate Electrode Method
12	Fluoride as F	Fluoride Electrode Method (ISE method);
13	Sodium as Na	Flame Emission Photometric Method
14	Potassium as K	Flame Emission Photometric Method
15	Sulphate (SO_4)	Turbidimetric method
16	Nitrogen Nitrite(NO_2-N)	Sulphanilamide, Spectrophotometric
17	Phosphorous, Orthophosphate (O-PO_4-P)	Ascorbic Acid Spectrophotometric
18	Silicate (SiO_2)	Ammonium Molybdate Spectrophotometric
19	Iron (Fe)	Phenanthroline Spectrophotometric
20	Boron (B)	Curcumin Spectrophotometric

Upper Krishna Division Water Quality Laboratory, CWC, Pune.
(NABL Accredited)

End

Report on Water Quality Scenario of Rivers

Upper & Middle Ganga Water Quality Laboratory

Middle Ganga Division-3

Central Water Commission

Varanasi

Contents:-

Introduction:-

The River Ganga is a symbol of faith, hope, culture and sanity, as well as a source of livelihood for millions since time immemorial. The Ganga and its tributaries provide a perennial source of irrigation to a large area, in addition to reaching the ground water all along their course. By supporting agriculture, animal husbandry and fisheries, tourism, river based trade and transport, the river contributes significantly to the livelihood, food and nutritional security of about one third of Indian population.

The Ganga river basin is the lifeline for millions sprawling across Himalayas of Nepal and India, through the great plains in India, to the world's biggest delta, straddling West Bengal and Bangladesh.

The Unique importance of this multifaceted Ganga basin stems from its geographical, historical, socio-cultural, environmental and economic value.

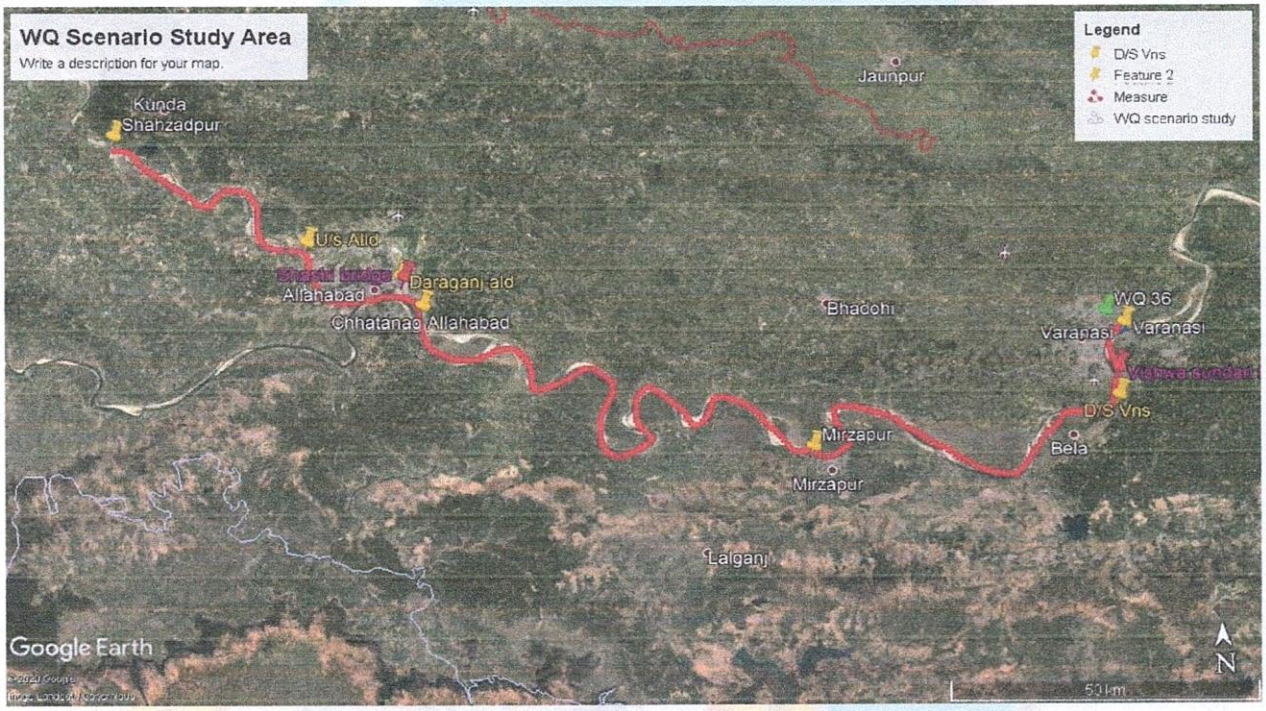
It has been facing serious threat due to discharge of increasing quantities of sewage effluents, industrial effluents and other pollutants on account of rapid urbanization, industrialization and agricultural activities.

In our stretch the Ganga receives its two principal right bank tributaries; the Yamuna river which flows the Delhi capital region and then roughly parallels the southeastward flow the Ganga before joining it near Prayagraj and the Tons river which flows north from Vindhya range in Madhya Pradesh state and joins the Ganga just downstream of Prayagraj.

With reference to the study on Water Quality Scenario of River we have decided to study of River Ganga stretching from Shahzadpur site (Distt. Kaushambi) to Varanasi site, covering nearly 250 km. Under this stretch it covers the cities Prayagraj (Confluence of Ganga and Yamuna river), Mirzapur & Varanasi. Four WQ sites (Shahzadpur, Prayagraj, Mirzapur and Varanasi) & two sampling points (Shastri Bridge & V.S. Bridge) also fall under this stretch.

Study Area:-

Our study area is stretching from left of the **river Ganga** at **Shahzadpur latitude 25° 40' 0"** and **longitude 81° 25' 0"** from here to **Varanasi latitude 25° 18' 59" and longitude 81° 1' 59"** which is ranging nearly 250 km covering Holy city Prayagraj, Mirzapur, At Prayagraj the confluence of river Ganga and Yamuna at Sangam. Which is nearly 63km D/S from Shahzadpur. Mirzapur is 90 km D/S from city Prayagraj.



Topic of Study:-

Following topics are studied -

- Study the seasonal variation in the river water quality.
- Study to find out the hotspot with respect to major WQ Parameters at Flux station.
- Study to find out the cause of deterioration of the river water quality.

Result and Discussion:-

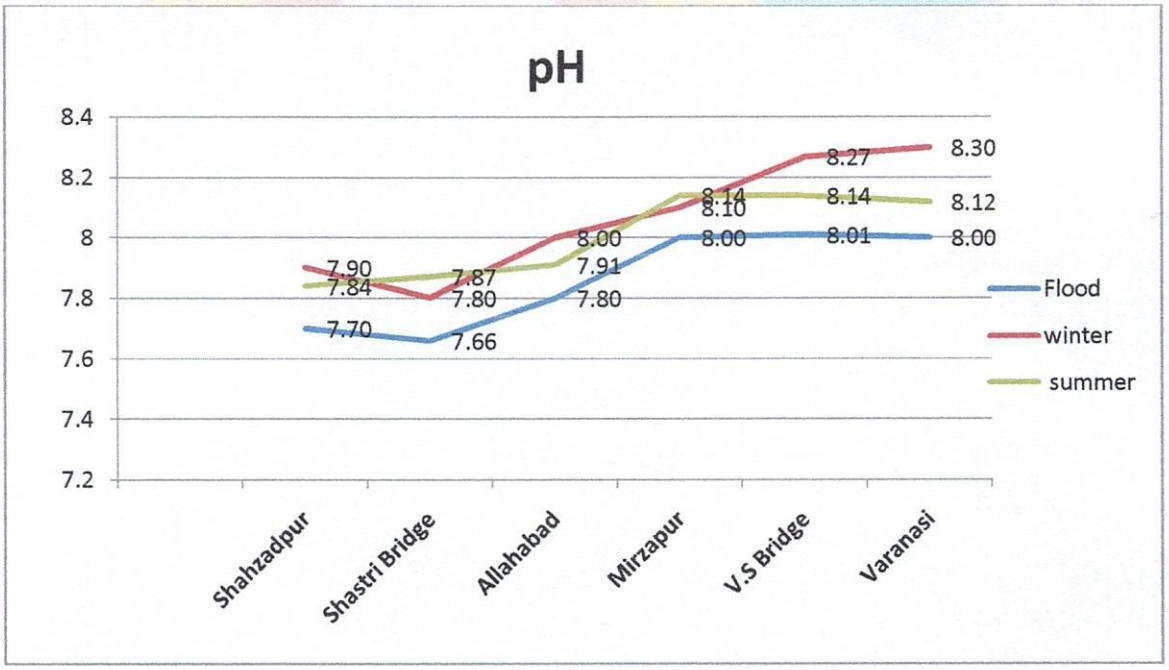
♦ Study of the seasonal variation in the river water quality

The study of **seasonal variation i.e. Flood (June-Oct), Winter (Nov-Feb) and Summer (March-April) in river water quality of the year 2019-2020 is being taken. The river water quality is analysed on the basis of the parameters pH, TDS, D.O. B.O.D , Total Coliform, Faecal Coliform & Nitrate-N** and the comparative seasonal variation is given below-

Seasonal Variation in the river water quality

pH

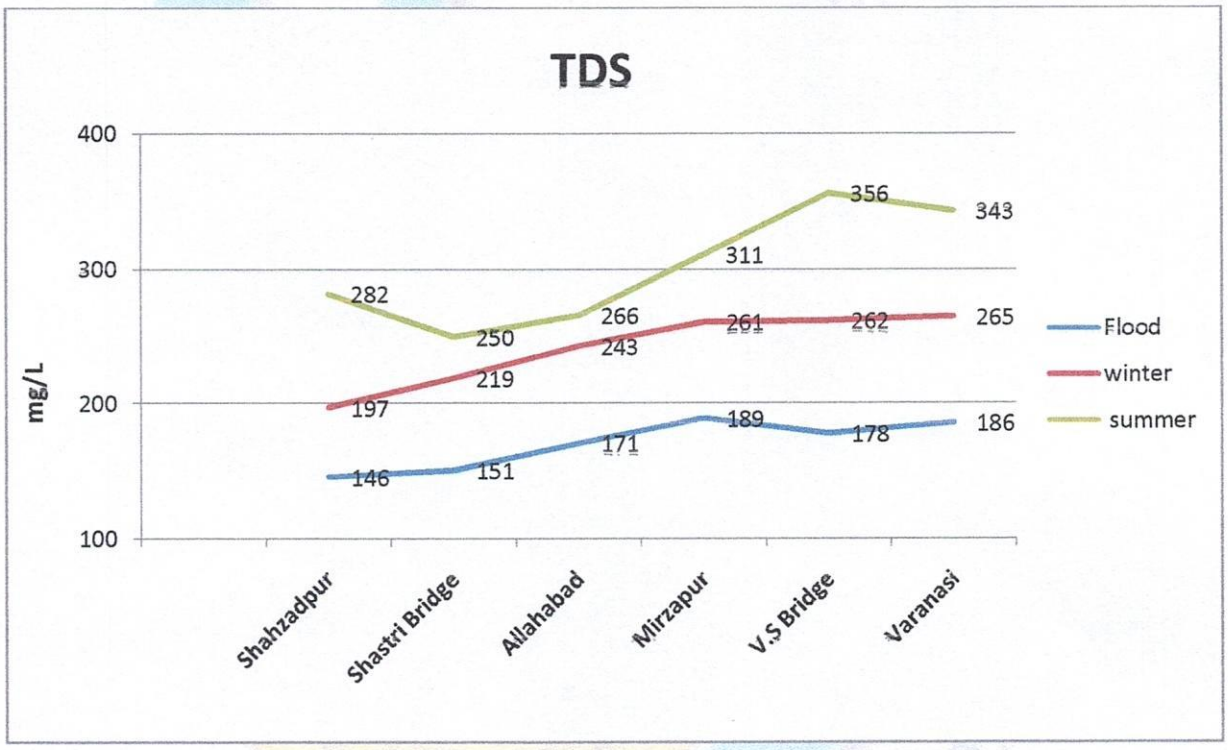
Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Shahzadpur	7.70	7.90	7.84
2	Shastri Bridge	7.66	7.80	7.87
3	Prayagraj	7.80	8.00	7.91
4	Mirzapur	8.00	8.10	8.14
5	V.S Bridge	8.01	8.27	8.14
6	Varanasi	8.00	8.30	8.12



- The graphical data shows variation in the value of pH , it is generally observed that when temperature decreases the value of pH increases and vice-versa. Also rain during flood season plays an important role as it dilutes the river water up to some extent. Hence it results in lower value of pH as compared to summer season.

TDS

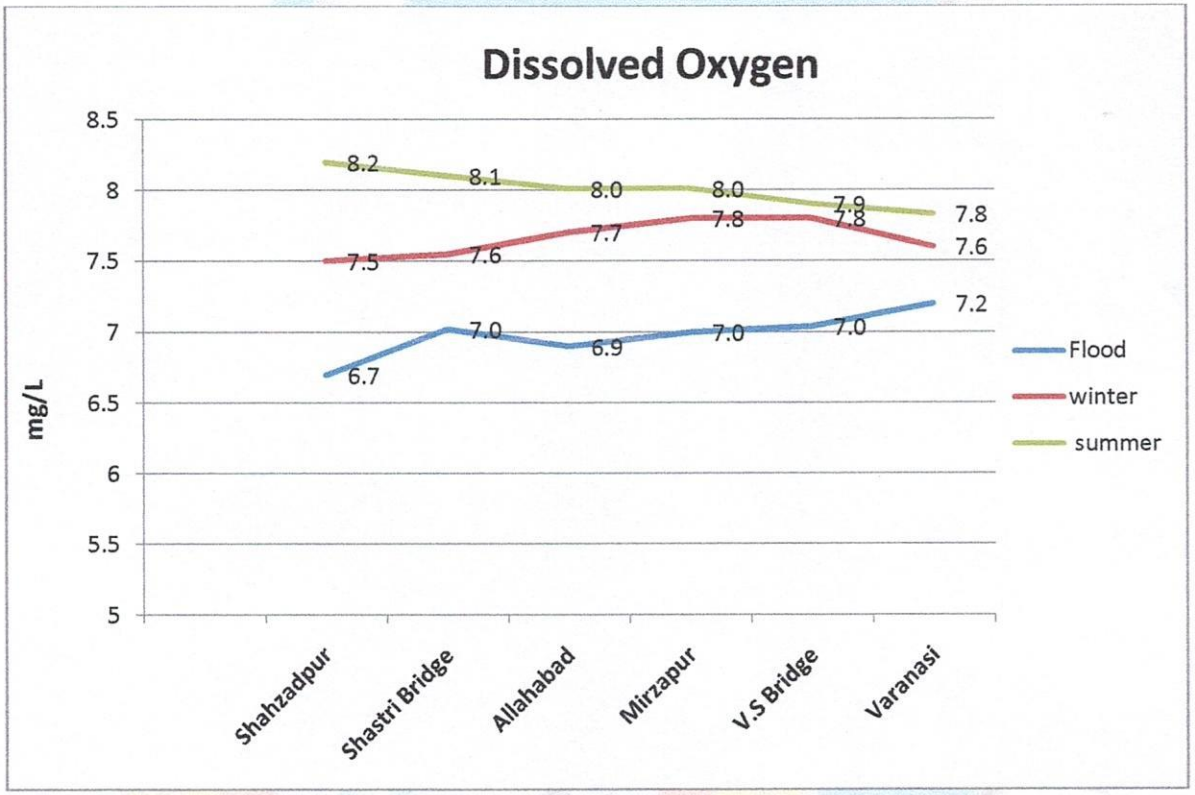
Sl. No.	Location of Sampling Point	Flood	winter	summer
1	Shahzadpur	146	197	282
2	Shastri Bridge	151	219	250
3	Prayagraj	171	243	266
4	Mirzapur	189	261	311
5	V.S Bridge	178	262	356
6	Varanasi	186	265	343



- The graphical data shows variation in the value of TDS depending upon the concentration of dissolved inorganic solids, in summer season TDS is maximum due to evaporation of river water and minimum in flood season due to dilution of river water.

Dissolved Oxygen (DO)

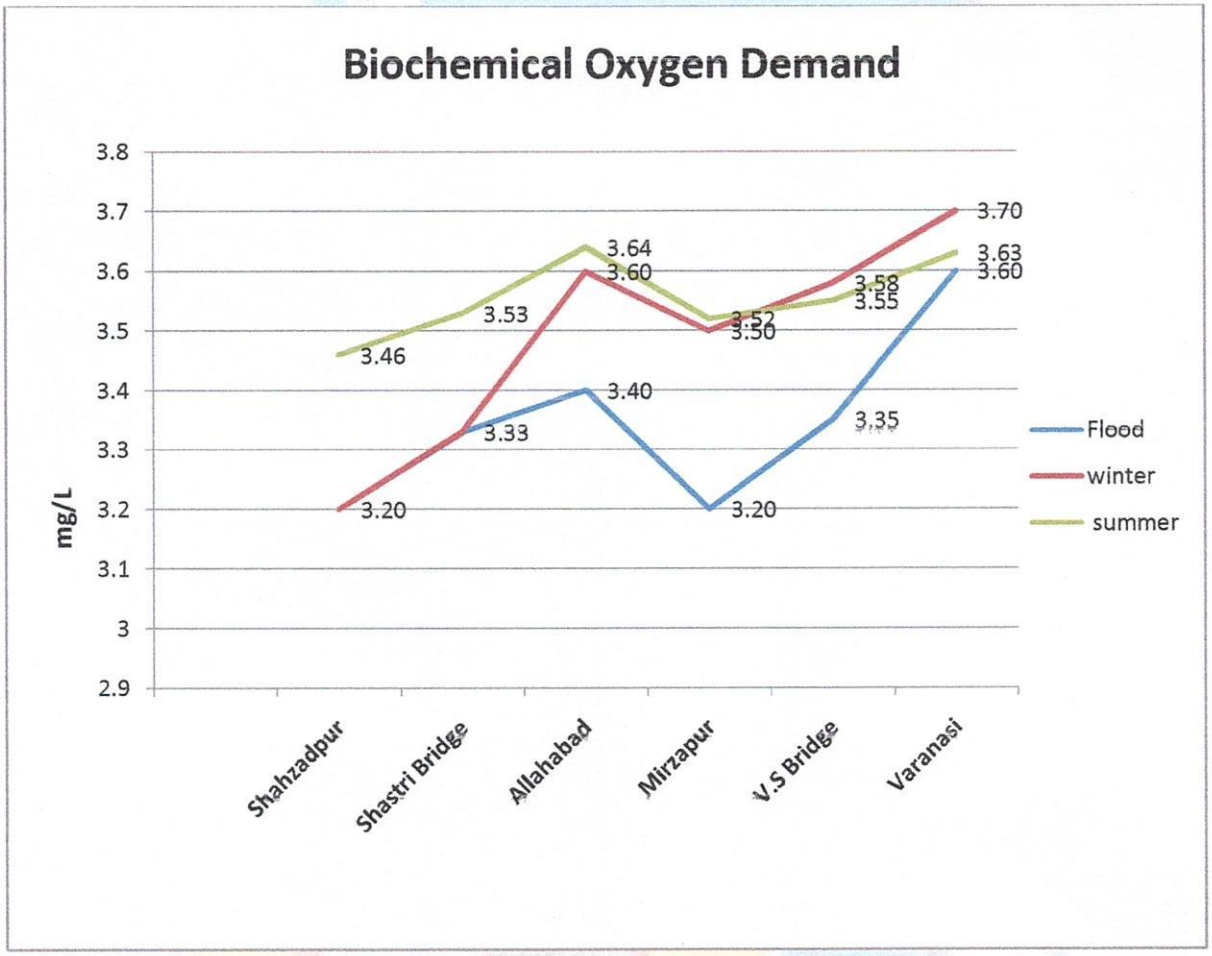
Sl. No.	Location of Sampling Point	Flood	winter	summer
1	Shahzadpur	6.7	7.5	8.2
2	Shastri Bridge	7.0	7.6	8.1
3	Prayagraj	6.9	7.7	8.0
4	Mirzapur	7.0	7.8	8.0
5	V.S Bridge	7.0	7.8	7.9
6	Varanasi	7.2	7.6	7.8



- The value of Dissolved Oxygen decreases with increase in temperature. But in the above graph the value of DO is high in summer as compared to winter and flood season. It can be attributed reduced anthropogenic sources of contamination of river water owing to the lockdown in the month of March and April.

Biochemical Oxygen Demand (BOD)

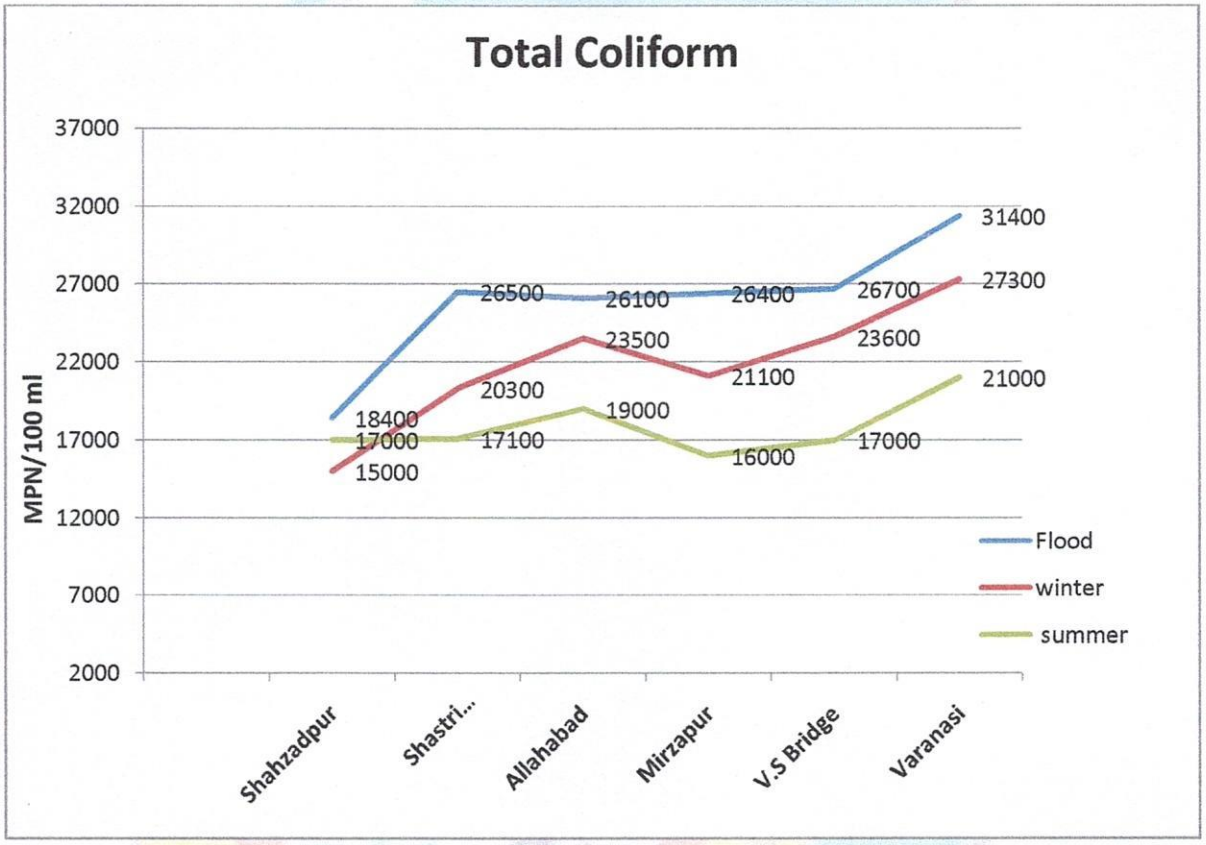
Sl. No.	Location of Sampling Point	Flood	winter	summer
1	Shahzadpur	3.20	3.20	3.46
2	Shastri Bridge	3.33	3.33	3.53
3	Prayagraj	3.40	3.60	3.64
4	Mirzapur	3.20	3.50	3.52
5	V.S Bridge	3.35	3.58	3.55
6	Varanasi	3.60	3.70	3.63



- The value of Biochemical Oxygen Demand (BOD) increases with increase in temperature. The above graph shows higher BOD in summer than winter. Lower value in the flood season is because of dilution of river water.

Total Coliform

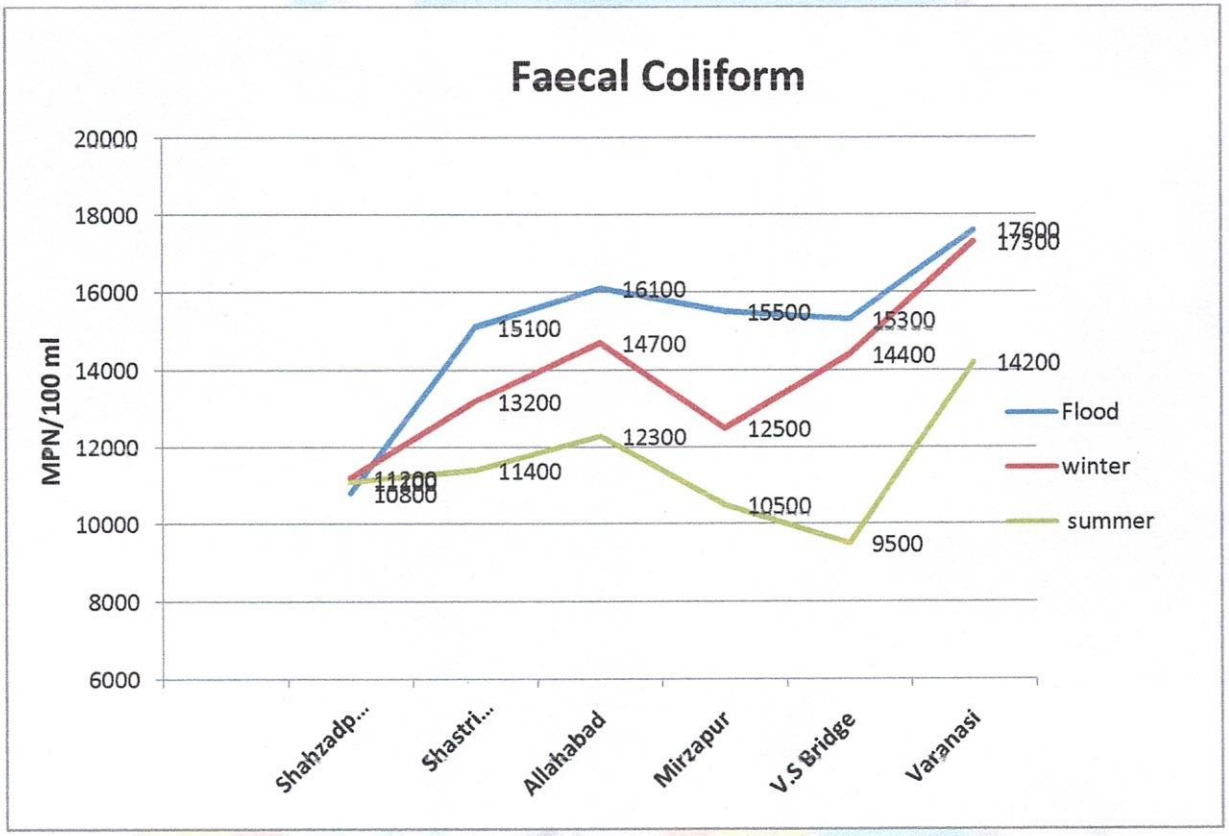
Sl. No.	Location of Sampling Point	Flood	winter	summer
1	Shahzadpur	18400	15000	17000
2	Shastri Bridge	26500	20300	17100
3	Prayagraj	26100	23500	19000
4	Mirzapur	26400	21100	16000
5	V.S Bridge	26700	23600	17000
6	Varanasi	31400	27300	21000



- The value of Total Coliform is highest in flood than winter and in winter season it is higher than summer season because of favourable condition (high temperature & organic waste) for growth of bacteria which are relatively higher in flood season as compared to winter and summer season .

Faecal Coliform

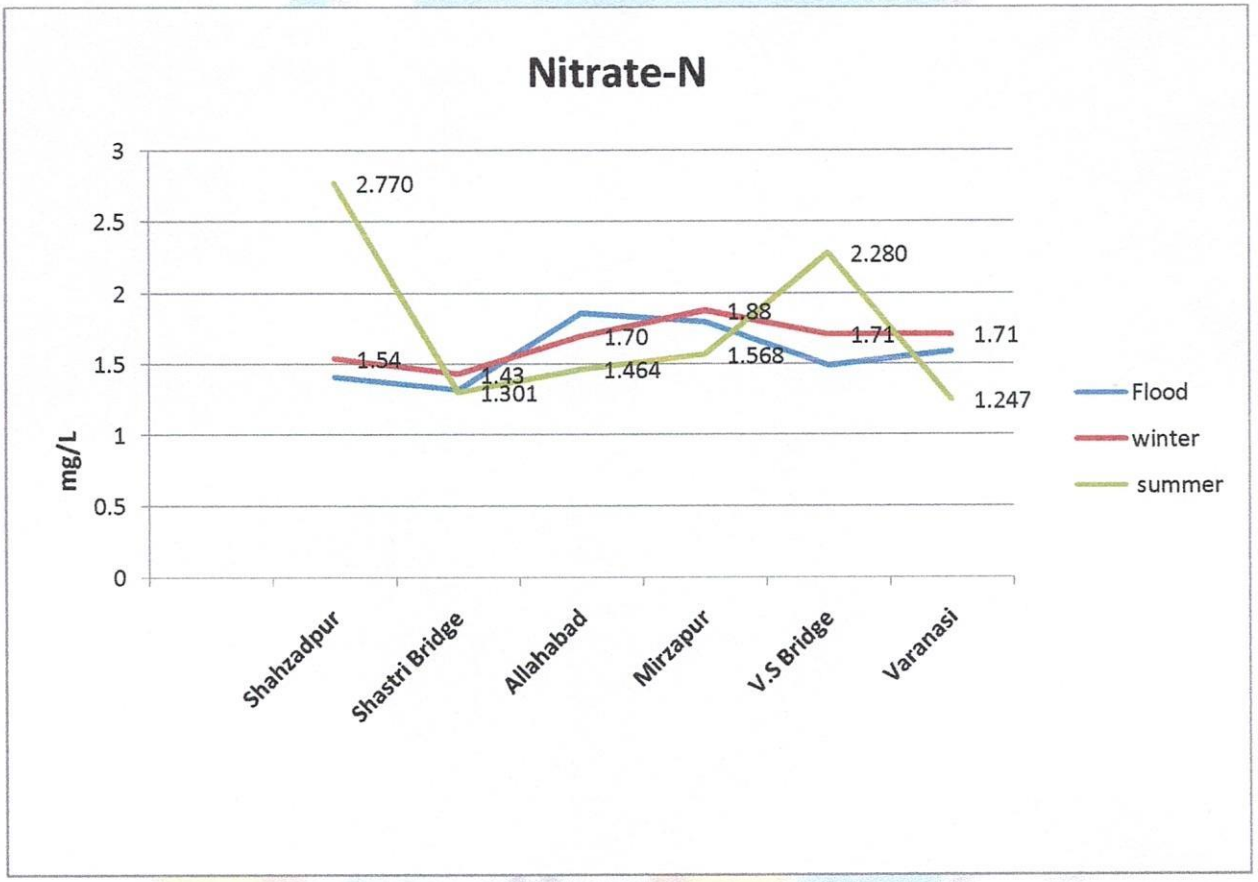
Sl. No.	Location of Sampling Point	Flood	winter	summer
1	Shahzadpur	10800	11200	11100
2	Shastri Bridge	15100	13200	11400
3	Prayagraj	16100	14700	12300
4	Mirzapur	15500	12500	10500
5	V.S Bridge	15300	14400	9500
6	Varanasi	17600	17300	14200



- The value of Faecal Coliform is highest in flood than winter and in winter season it is higher than summer season because of favourable condition (high temperature & organic waste) for growth of bacteria which are relatively higher in flood season as compared to winter and summer season .

Nitrate-N

Sl. No.	Location of Sampling Point	Flood	winter	summer
1	Shahzadpur	1.41	1.54	2.770
2	Shastri Bridge	1.32	1.43	1.301
3	Prayagraj	1.86	1.70	1.464
4	Mirzapur	1.80	1.88	1.568
5	V.S Bridge	1.49	1.71	2.280
6	Varanasi	1.59	1.71	1.247

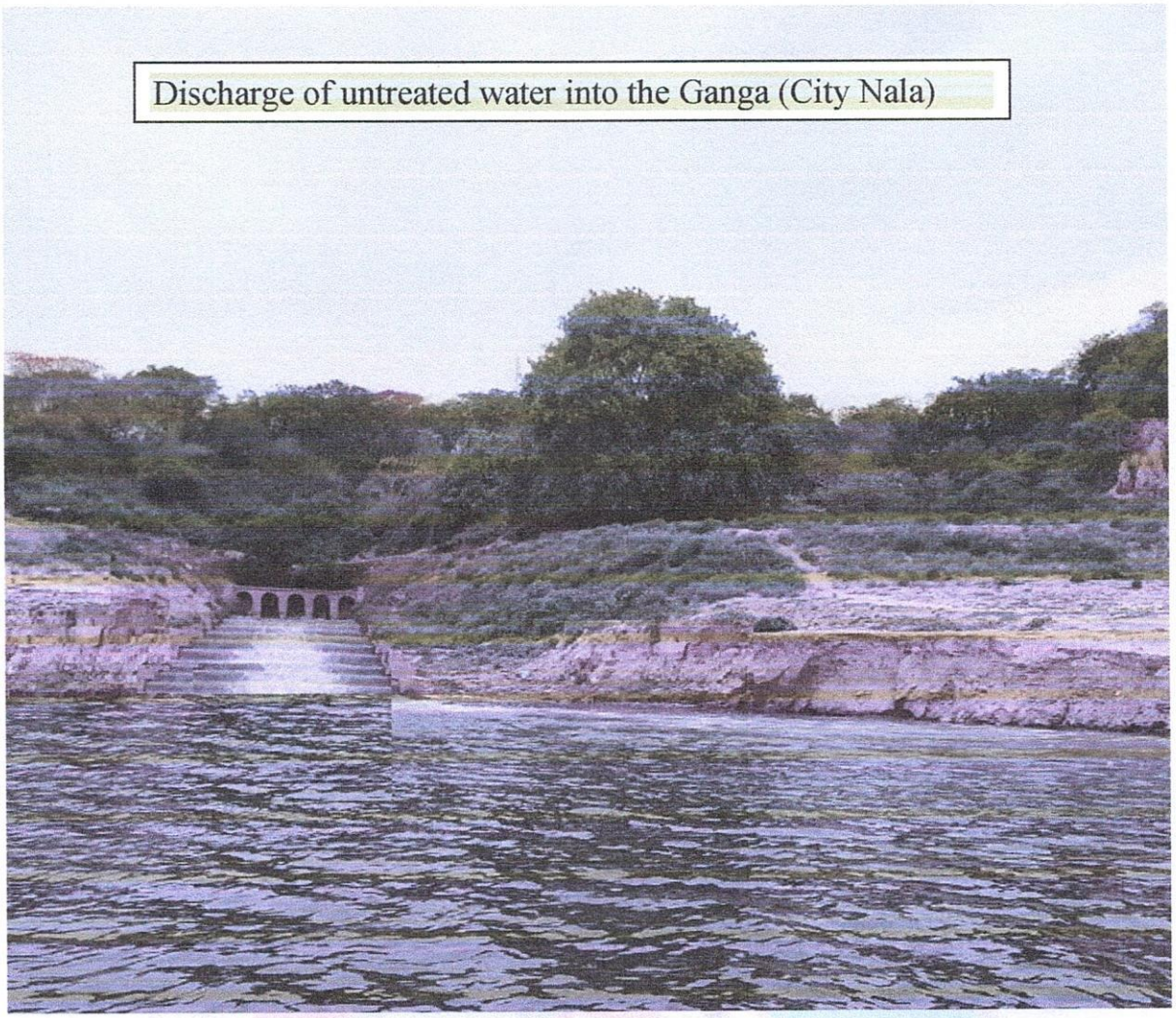


- Seasonal variation of Nitrate do not follow a fixed trend .Presence of Nitrate-N indicate uses of chemical fertilizer, nitrogenous byproducts from wastewater treatment and from oxidation of nitrogenous waste in human and animal excreta, including septic tanks and acid rain.

*Study to find out the hotspot with respect to major WQ parameters at flux station, Varanasi City:-

Sl.No.	Location of Sampling point	pH	Elec. Cond. (µmho/cm)	D.O. (mg/l)	B.O.D. (mg/l)	Total Coliform (MPN per 100ml)	
1	Garawaghat	9.1	410	7.73	3.21	23000	
2	V S Bridge	9.2	420	7.73	3.40	26000	
3	BHU Nala	9.1	420	7.53	3.79	28000	
4	Ram Nagar Bridge	9.2	440	7.33	3.99	28000	
5	Nagawan Nala	9.0	500	4.56	12.96	80000	
6	Assighat	9.0	510	4.16	12.94	85000	
7	Shivalaghat	8.6	480	5.35	9.06	60000	
8	Harishchandghat	8.6	470	5.94	5.75	45000	
9	Kshemeswarghat	8.9	450	6.74	5.16	38000	
10	Dashashwmedhghat	8.8	430	7.13	4.58	34000	
11	Manikarnikaghat	9.0	430	6.93	4.38	32000	
12	Gaayghat	9.2	430	6.93	4.18	33000	
13	Telia nala ghat	9.0	420	6.74	4.77	35000	
14	PWD ghat	8.9	440	6.93	4.18	30000	
15	Central Line of C.W.C.	9.0	390	7.13	3.99	28000	
16	City Nala	8.3	530	3.57	19.94	150000	Hotspot point
17	Varuna confluence	8.4	600	3.17	19.91	180000	Hotspot point
18	Sarai Mohana	8.4	560	4.36	14.11	160000	
19	1 Km D/s from C/Line	8.5	530	5.15	8.28	120000	
20	2 Km D/s from C/Line	8.5	500	5.55	7.10	75000	
21	3 Km D/s from C/Line	8.6	480	5.94	6.14	60000	
22	4 Km D/s from C/Line	8.6	470	6.14	5.75	55000	
23	5 Km D/s from C/Line	8.5	430	6.54	4.97	52000	
24	6 Km D/s from C/Line	8.6	460	6.54	5.16	48000	
25	7 Km D/s from C/Line	8.5	460	6.34	5.75	43000	
26	8 Km D/s from C/Line	8.5	450	6.54	5.55	35000	
27	9 Km D/s from C/Line	8.7	420	6.93	4.97	32000	
28	10 Km D/s from C/Line	8.5	450	6.93	4.58	30000	
29	11 Km D/s from C/Line	8.6	430	7.13	3.99	29000	
30	12 Km D/s from C/Line	8.6	430	7.13	3.79	27000	

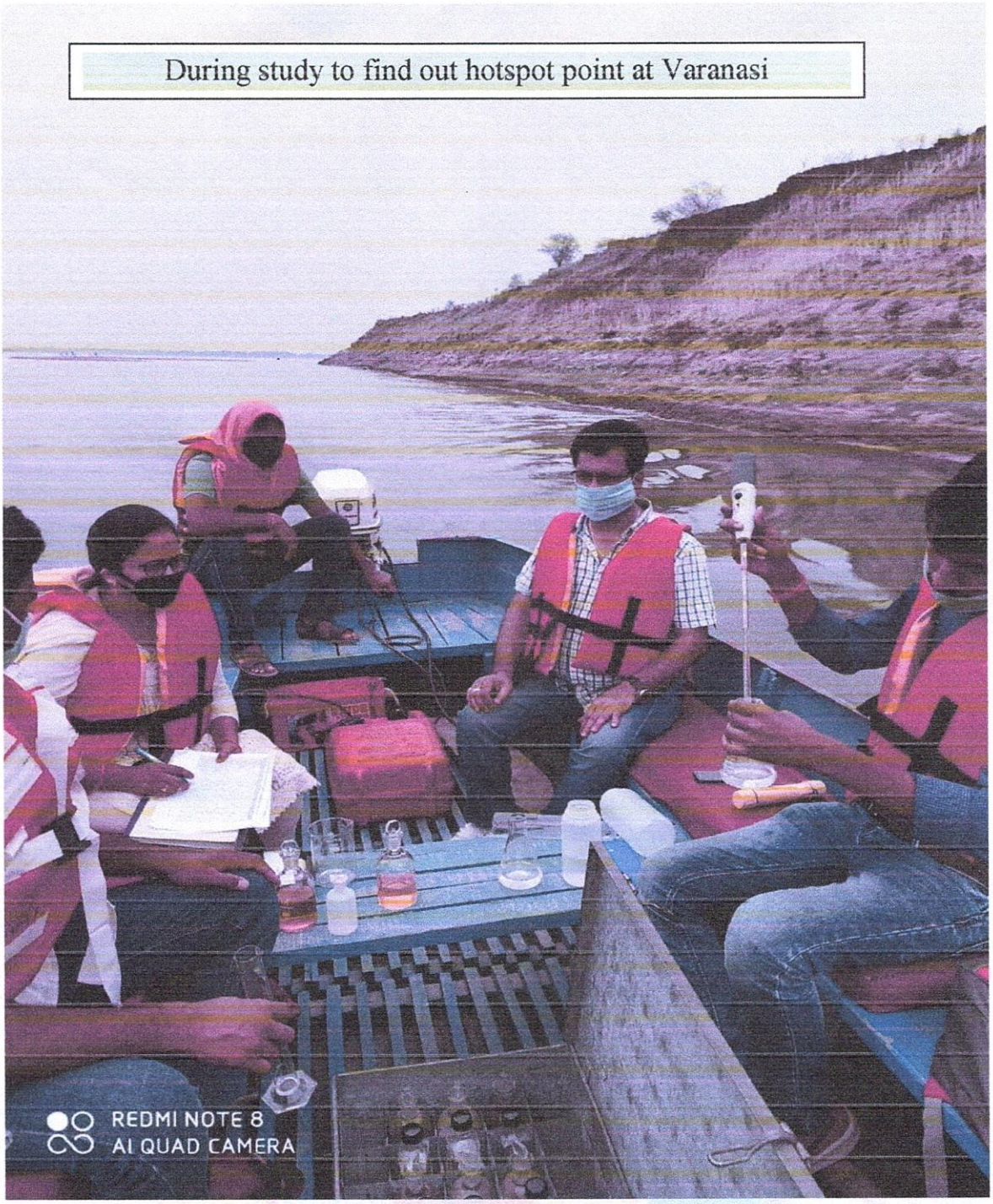
*The above experiment conducted on 27.05.2019 & 28.05.2019



Discharge of untreated water into the Ganga (City Nala)

The above study of water sample analysis based on parameters pH, EC, D.O. B.O.D & Total Coliform shows that the most polluted point is at Varuna river confluence to Ganga & City Nala which shows the high level of BOD and Total Coliform, also the DO value is very low. So the above study shows the hotspot point is Varuna Confluence & City Nala.

During study to find out hotspot point at Varanasi

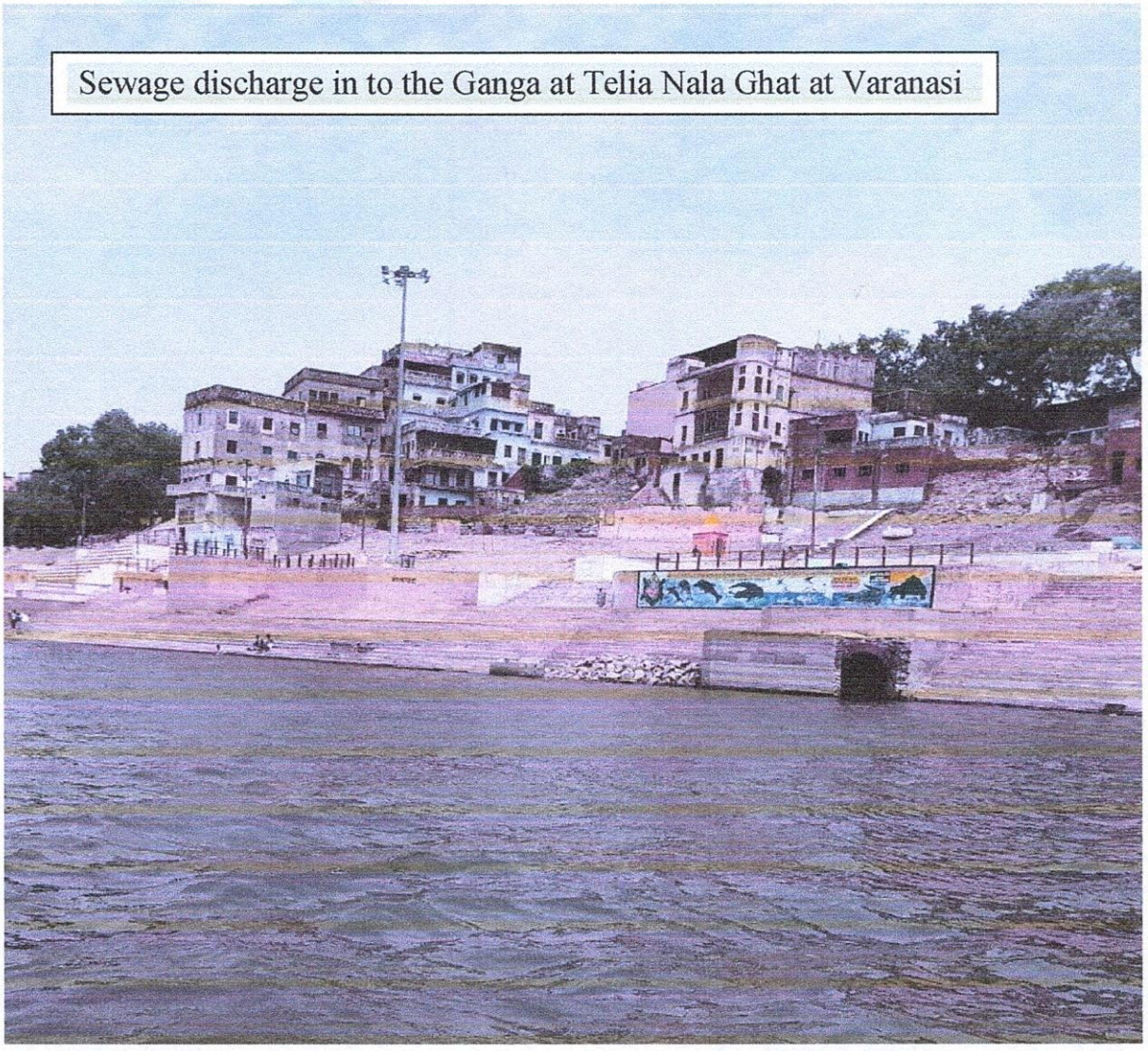


Study to find out the cause of deterioration of River Water Quality:-

The above study is based on the water quality parameters i.e. pH, TDS, DO, BOD, Total Coliform & Faecal Coliform & Nitrate-N along selected stretch. The data of collected sample analysis is attached in **Annexure-1**.

- Discharge of municipal effluents without proper treatment which was found at sites such as Kaizirpur & Kachar (Prayagraj), Effluents which was found at Naini (Prayagraj), and sewage discharge downstream from Mirzapur city. Discharge of domestic wastes such as the case of Nagwa Nala in Varanasi City and Varuna confluence.

Sewage discharge in to the Ganga at Telia Nala Ghat at Varanasi



- Excessive application of chemical fertilizer and pesticides is also one of the main reasons for WQ degradation. At the time of monsoon the pesticides and fertilizers gets washed away into river water and also seepage of chemicals due to excessive irrigation causes deterioration of ground water quality , which ultimately effects river water quality also.
- Due to the lack of appropriate infrastructure and sewage treatment plant untreated water from city i.e Prayagraj, Mirzapur and Varanasi falls in river Ganga .
- Religious activity at holy places like Sangam (Prayagraj), Varanasi people uses garland, flowers, plastic, chemical soap etc uses at the bank of the river Ganga that causes the pollution of river.

Conclusion:-

The study ***"Report on Water Quality Scenario of Rivers"*** in which - Study of the seasonal variation in the river water quality, Study to find out the Hotspot with respect to major WQ Parameters at Flux stations, Study to find out the cause of deterioration of the river water quality was done based on – pH, TDS, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Coliform, Faecal Coliform, & Nitrate-N. As per this study the main reasons for river WQ degradation is discharge of municipal effluents without proper treatment, excessive uses of chemical fertilizer and pesticides, lack of appropriate infrastructure and sewage treatment plant, religious activity at holy places among others . To counter the deterioration and degrading river Water Quality it is needed to prevent releasing untreated sewage, religious and other activity at bank of river Ganga i.e. uses garland, flowers, plastic, chemical soap etc should be regulated, also awareness about the proper uses of fertilizer and their disposal should be spread among farmers .

Shashwat 23/04/2020

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