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REPORTS ON WATER QUALITY SCENARIO OF RIVERS

VOLUME-III

CENTRAL WATER COMMISSION

Serving the Nation since 1945

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YAMUNA RIVER

Introduction

The Yamuna river sometimes called Jamuna, Kalindi river are lifeline of cities like Delhi and Agra. It is a north Indian river and counted among long rivers of India. It is second largest tributary river of the Ganges in northern India. Yamuna is next only to Ganga in her sacredness. Origin of Yamuna is from Yamunotri Glacier at a height of 6,387 meters on the south western slopes of Bandarpooch peaks in the uppermost region of the lower Himalaya in Uttarakhand. It travels a total length of 1,376 kilometres (855 mile) and has a drainage system of 366,223 square kilometers (141,399 sq mi), 40.2% of the entire Ganges Basin, before merging with the Ganges at Triveni Sangam, Allahabad, the site for the Kumbha Mela every twelve years. It is the longest river in India which does not directly flow to the sea. Yamuna crosses many states like Uttarakhand, Himachal Pradesh, Haryana and Uttar Pradesh, Passing by Uttarakhand and later Delhi, and meets its helper branches on the way, Including Tons, Its largest tributary in Uttarakhand, Chambal, its longest tributary which has its own large basin, followed by Sindh, the Betwa, and Ken. Most importantly it creates the highly fertile alluvial, Yamuna-Ganges Do abregion between itself and the Ganges in the Indo-Gangetic plain. With an annual flow of about 10,000 cubic billion metres (cbm) and usage of 4,400 cbm (of which irrigation constitutes 96 per cent), the river accounts for more than 70 per cent of Delhi water supplies. Just like the Ganges, the Yamuna too is highly respected in Hinduism and worshipped as goddess Yamuna, throughout its course. In Hindu mythology, she is the daughter of Sun God, Surya, and sister of Yama, the God of Death, hence also known as Yami and according to popular legends, bathing in its sacred waters frees one from the suffering of death. The water of Yamuna is of "reasonably good quality" through its length from Yamunotri in the Himalayas to Wazirabad in Delhi, about 375 kilometers , Yamuna got fully polluted between Wazirabad Barrage ,Okhla Barrage, Gokul Barrage, Agra City and Etawah City due to the discharge of waste water through drains. One official report describes the river as a "sewage drain" with biochemical oxygen demand (BOD) values ranging from 14 to 28 mg/l and high coliform content. There are three main sources of pollution in the river, namely households and municipal disposal sites, soil erosion resulting from deforestation occurring to make way for agriculture along with resulting chemical wash-off from fertilizers, herbicides, and pesticides and run-off from commercial activity and industrial sites.

Source

Yamuna originate from the Yamunotri Glacier at an elevation of 6,387 meters, on the south western slopes of Badrinath peak, which is in the Monsoorie range of lower Himalayas. Yamunotri Temple is a holy dedication to the goddess, it is the part of Chota Chardham Yatra Circuit. The Sant Markandeya wrote Markandeya Puran on the right Bank of River, which is on 13 kms treck route called as Markandey Tirtha. From here Yamuna flows southwards for about 200 kilometers through the lower Himalayas and the Shivalik Hills range. An important part of his early drainage area approx 2,3202 kilometers lies in Himanchal Pradesh and a main branch draining the upper catchment area is the Tons, Yamuna largest tributary, which rises from the Hari- ki-Dun Valley. It merges after Kalsi in Dehradun. Other tributaries in the region are the Giri, Rishi Ganga, Kunta, Hanuman Ganga and Bata. Thereafter Yamuna go down on to the plains of Doon Valley at Dak

Pathar in Dehradun. The Yamuna creats natural state border between Himanchal Pradesh and Uttarakhand states and downwards between the states of Haryana, Delhi and Uttar Paradesh. After touches the Ind- Gangetic plain, the largest alluvial fertile plain in the world, the Yamuna run almost parallel to Ganga. It creats the Ganga Yamuna Dobe region spread across 69,0002 kilometers, one third of the entire plain. Yamuna passes by Delhi, Haryana and Uttar Pradesh before merging with the Ganga at the sacred point Triveni Sangam at Allahabad.

History

It Seems that the Name of Yamuna is obtain by the Sanskrit Word Yama□ means twins and it may have applied to river because its run parrellal to the Gangas. The name of Yamuna is mentioned in Rig-Veda at many places which was composed between 1700-1100 B.c. and also in the Atharava Veda. In the Rig Veda, it is said that Yama and Yami the twins were extremely fond of each other and lived an idyllic life on Earth where the day never ended , they went where they pleased and did what they wanted. It is also said that Lord Shiva could not tolerate the sadness after the death of Satidevi. At last when he went to Yamuna river, It became so black as it absorbs all the sorrows of Shiva. The story is further detailed in 16th Century Sanskrit hymn, Yamunashtakam an ode by the philosopher Vallabhacharya. The chant also praises her for being the source of spiritual ability. Yamuna is a holder of love and compassion. Yamuna can grant us freedom even from death, the realm of her elder brother. In the survey of Selucus I Nicator, Yamuna mentiones as Lomanes and Magasthanese a greek traveler and geographer visited India before 288 BC at the time of Chandragupta's death, also mention the river in his text Indica. In Mahabharata Indraprastha was also situated on the banks of Yamuna. It is considered to the modern day city of Delhi.

Religious Significance

Yamuna is also known as Yami, is the sister of Yama, the god of death, and the daughter of Surya devta and his wife Saranyu. Yamuna ji has very important position in Pushti Marga. A sect of Hinduism based on the Suddhaadvaita, in which Shri Krishna is supreme being, growed by Vallabhacharya (Mahaprabhuji), and having a large folloeing in India. The river Yamuna is also connected with the religious stories of Krishna also mentioned in Purans like as Kalia Daman, The subduing of Kalia. According to legends Yamuna is closely related to Lord Krishna and Mahabharata. Krishna was taken cross the Yamuna on the night of his birth. Krishna and Gopis also used to play on the bank of the Yamuna as children.

Yamuna at Agra

The river Yamuna, linked to the sacred river Ganga, meanders through Agra passing many Mughal sites of special interest including Chinni ka Rauza, Imtiad ud Daula. The Taj Mahal and the most of the thriving city is located on the west bank of the river which played an important role in the development and construction of the Taj Mahal. Approx all the Mughal monumemts and mausoleums are near the bank of Yamuna. Yamuna is the life line of Agra city. Yamuna fulfills the need of water in Agra city and makes it look more beautiful. When the Taj reflects in Yamuna water this is amazing to see.

Major tributaries of Yamuna River

A detailed information about the tributaries of River Yamuna are as follows:

Tons River

Tons river is the biggest and most extensive tributary of the **Yamuna**. It springs in the 6315 m tall Bandar poonch mountain. The **yamuna** has the huge drainage area in the **Himachal Pradesh**. The Tons River joins **Yamuna river** beneath Kalsi close to the **Dehradun**, Uttarakhand.

Sindh River

Sindh River originates on the Malwa Plateau in Vidisha district, and flows north-northeast through the districts of Guna, Ashoknagar, Shivpuri, Datia, Gwalior and Bhind in Madhya Pradesh to join the Yamuna River in Etawah district, Uttar Pradesh.

Hindon River

The **Hindon River** is a wholy rain-fed river. The river has its source in the Saharanpur District from Upper Shivalik in the Lower Himalayan Range. The Hindon River has a drainage basin of 7 083 km^2 and its passes a length of 400 km through the Meerut District, Muzaffarnagar District, Ghaziabad, Baghpat District, Noida, Greater Noida. It prior to meeting **Yamuna river** just exterior to Delhi.

Ken River

The **Ken river** flows through the Bundel khand which is the area of the Madhya Pradesh and Uttar Pradesh. The **ken river** has its source close to the Ahirgawan village in Jabalpur district and runs a length of 427 km. It prior to fusing with the **Yamuna river** at Chilla village in the vicinity of Fatehpur in Uttar Pradesh. The total drainage area of the Ken River is 28,058 km.

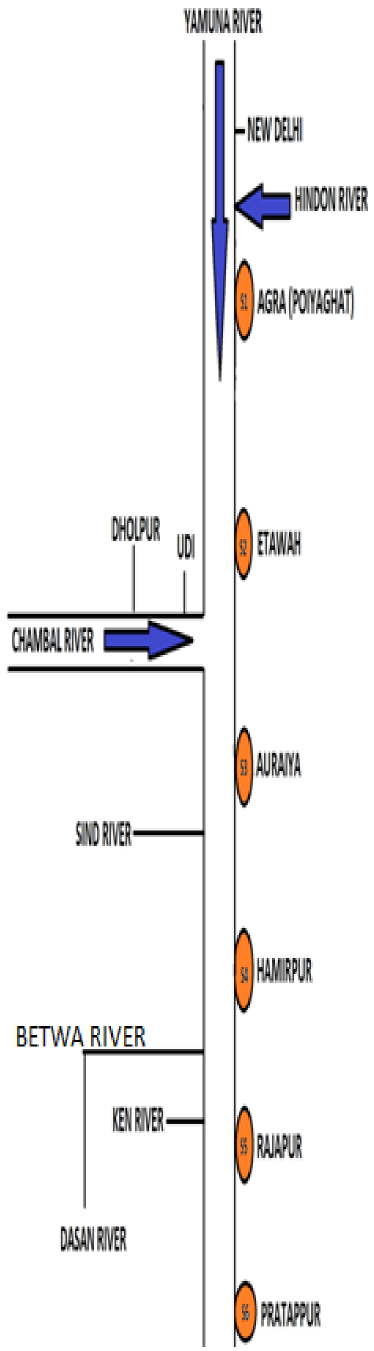
Chambal River

The **Chambal River** is also known as Charmanvati in prehistoric periods. The river runs across Madhya Pradesh and Rajasthan. The river has a drainage area of 143,219 km and navigates an overall distance of 960 km. The river has its origin in the Vindhya Range which is assist in hydroelectric power creation at Rana Pratap Sagar dam, Gandhi Sagar dam, and Jawahar Sagar dam. It prior to fusing with the Yamuna to the south east of Sohan Goan in Etawah district of Uttar Pradesh.

Betwa River

Betwa or Vetravati originates in Vindhya Range just north of Hoshangabad in Madhya Pradesh and flows north-east through Madhya Pradesh and flow through Orchha to Uttar Pradesh. It meets **Yamuna** at Hamirpur town in Uttar Pradesh.

LINE DIAGRAM OF YAMUNA RIVER



Sites on Yamuna River S1-AGRA, S2-ETAWAH, S3-AURAIYA, S4- HAMIRPUR, S5-RAJAPUR, S6- PRATAPPUR.

AGRA

Agra is a city on the banks of the Yamuna river in the Indian state of Uttar Pradesh. It is 206 kilometres south of the national capital New Delhi. Agra is the fourth-most populous city in Uttar Pradesh and 24th in India.

Area: 87 km^2
Elevation: 171 m

History of Agra.

Agra is a famous tourist spot and is the home of one of 7 wonders of the World, Taj Mahal. Tourists from all over the world will frequently visit this place. Being located in the bank of Yamuna River, Agra is a part of Golden triangle along with Jaipur and Delhi. Almost millions of travellers visit this beautiful city. Agra is the only city after Delhi which had more than 10 five-star hotels. Yamuna river in Agra is to be considered as **Blue River**. It is the best city which offers great food and shopping experience.

Site : Poiyaghat , Agra

The distance from Lower Yamuna Water Quality Laboratory, CWC, Agra to poiyaghat site is 12 kms and this site is flux station and Gauge, Discharge , Silt and W.Q. site.

General Particulars:-

Site : Agra (Poiyaghat)

State : Uttar Pradesh

Division : L.Y.D, Agra

Independent River : Ganga

River Basin : Ganga-Brahm-Meg

Bank : Right

Tributary : Yamuna

Longitude : 78°01'24"E.

Drainage Area : 49052 Sq. Km

Latitude : 27°15'17"N

Zero Of Gauge : 146.000(m.s.l)

Code : GY000N7

District : Agra

Sub division : LY SD-II Agra

ETAWAH

History:

Etawah is a city on the banks of Yamuna River in the state of Western Uttar Pradesh in India. Etawah is about 120 km east of Agra . It is also the sangam or confluence of the Yamuna and Chambal rivers in D/S of Etawah. This Site is Trend Station and Gauge, Discharge , Silt and W.Q. site.

General Particulars:-

Site : ETAWAH

State : Uttar Pradesh

Division : L.Y.D, Agra

River Basin : Ganga-Brahm-Meghna

Tributary : Yamuna

Drainage Area : 98717 Sq. Km

Latitude : 26°44’48”N

Zero Of Gage : 114.000 (m.s.l)

Code : GY000J7

District : ETAWAH

Sub division : LY SD-II Hamirpur

Independent River : Ganga

Bank : RIGHT

Longitude : 78°59’12”E.

AURAIYA

History

River System: The rivers and streams of the Auraiya and Etawah districts jointly consist of the Yamuna its two large affluent, the Chambal and, the Kuwari; the Sengar, and its tributary Sirsa; The Rind or Arind and its tributaries the Ahenya, the Puraha and the Pandu. This Site is Trend Station and Gauge, Discharge , Silt and W.Q. site.

General Particulars:-

Site : Auraiya

State : Uttar Pradesh

Division : L.Y.D, Agra

Independent River : Ganga

River Basin : Ganga-Brahm-Meghna

Bank : Left

Tributary : Yamuna

Longitude : 79°28’41”E.

Drainage Area : 261331 Sq. Km

Latitude : 26°25’45”N

Zero Of Gage : 99.000(m.s.I)

Code : GY000H3

District : Auraiya

Sub division : LY SD-II Hamirpur

HAMIRPUR

Description

Hamirpur is a city and a municipal board in Hamirpur district in the Indian state of Uttar Pradesh . This Site is Trend Station and Gauge, Discharge , Silt and W.Q. site.

Rivers :

Yamuna : This river forms north boundry of the district. The river first touches the district at the village Haraulipur in tehsil Hamirpur, where it forms a sudden loop. Flowing then east to Jamrehi Tir, it curves abruptly south to Sikrohi and then continues south-east part Hamirpur to Baragaon where the Betwa joins it. Its length of Betwa in Hamirpur district is approximately 56 km. This river flows along the north-western border of the District from the point where the Dhasan joins it to the village of Kuprat separating tehsil Rath from district Jalaun. It enters the district near the village of Beri and flows separating tehsils Rath and Maudaha from tehsil Hamirpur. Its length in Hamirpur district is approximately 65 km. Other rivers lying in the district are Dhasaan, Barma, Ken, Chndraval and Pandwaha. These rivers are used for irrigation purpose. A dam named Swami Bramhananad Dam (Moudaha Dam) has been constructed on the river Barma.

General Particulars:-

Site : Hamirpur

State : Uttar Pradesh

Division : L.Y.D, Agra

Independent River : Ganga

River Basin : Ganga-Brahm-Meg

Bank : Right

Tributary : Yamuna

Longitude : 80°09’14”E.

Drainage Area : 276789 Sq. Km

Latitude : 25°57’37”N

Zero Of Gage : 88.000(m.s.I)

Code : GY000E9

District : Hamirpur

Sub division : LY SD-III Agra

RAJAPUR

Description:

It is situated at the Yamuna river bank. This Site is Trend Station and Gauge, Discharge , Silt and W.Q. site.

Note. The Rajapur site Water Quality Station Started from 2014.

General Particulars:-

Site : RAJAPUR

State : Uttar Pradesh

Division : L.Y.D, Agra

Independent River : Ganga

River Basin : Ganga-Brahm-Meghna

Bank : Left

Tributary : Yamuna

Longitude : 81°09'15"E.

Drainage Area : 364552 Sq. Km

Latitude : 25°23'23"N

Zero Of Gage : -

Code : GY000B7

District : Chitrakoot

Sub division : Band

PRATAPPUR (ALLAHABAD DISTT.)

Pratappur:

The **Yamuna**, sometimes called **Jamuna** is the longest and the second largest tributary river of the Ganges (Ganga) in northern India. Originating from the Yamunotri Glacier at a height of 6,387 metres on the south western slopes of Banderpooch peaks in the uppermost region of the Lower Himalayas in Uttarakhand, it travels a total length of 1,376 kilometers (855 mi) and has a drainage system of 366,223 square kilometres (141,399 sq mi), 40.2% of the entire Ganges Basin, before merging with the Ganges at Triveni Sangam, Allahabad. It is the longest river in India which does not directly flow to the sea.

The pratappur site under flux station and this site distance from Agra to Pratappur site at nearest 450 km.

General Particulars:-

Site : Pratappur

State : Uttar Pradesh

Division : L.Y.D, Agra **Independent River : Ganga**

River Basin : Ganga-Brahm-Meg **Bank : Right**

Tributary : Yamuna **Longitude : 81°40'00"E.**

Drainage Area : 366522 Sq. Km

Latitude : 25°22'00"N

Zero Of Gage : 70.000(m.s.l)

Code : GY000A8

District : Allahabad

Sub division : Ken SD, Banda

Station on Yamuna River.

S.No.	Sites	Base/Trend/Flux
1	Agra(Poiyaghat)	Flux Station
2	Etawah	Trend
3	Auriya	Trend
4	Hamirpur	Trend
5	Rajapur	Trend
6	Pratappur	Flux Station

Table No. 1

Total parameters analyzed at Lower yamuna water quality laboratory (LYWQL) NABL.

Sl.No.	Name of the parameter	Category	Sl.No.	Name of the parameter	Category
1	Temperature	In-site WQ parameters	16	Phosphate	Nutrients
2	Color		17	Nitrogen- Nitrite	
3	Odor		18	Nitrate	
4	pH		19	Sulphate	Major anions
5	Conductivity		20	Chloride	
6	Dissolved Oxygen		21	Carbonate	
7	Total Dissolved Solids		22	Bicarbonate	
8	Chemical Oxygen demand	Oxygen demand parameters			
9	Bio-chemical oxygen Demand		23	Calcium	Major Cations
			24	Magnesium	
10	Total coli form	Biological parameters	25	Sodium	
11	Fecal coli form		26	Potassium	
12	Iron	Other In- organics	27	Total Hardness	
13	Fluoride		28	Total Alkalinity	
14	Boron		29	Sodium adsorption Ratio	Irrigation Standards
15	Silica		30	Residual Sodium Carbonate	

Table No. 2

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.

FIELD PARAMETER

1. TEMPERATURE:

The temperature of a surface water body depends on its location, season and time of the day. The temperature of tropical and sub-tropical rivers may vary from 10^{o}C to 30^{o}C. Warm temperatures result in:

- Decrease of solubility of gases in water, such as, O_2, CO_2 and N_2
- Increase in the metabolic and growth rates of the aquatic organisms
- increase in volatilization and chemical reaction rates of substances
- increase the die-away rate of micro-organisms, which are not normal inhabitant of the aquatic environment.

Considering the above factors, it is seen that the warm water environment, along with organic pollution, would lead to a greater stress on the oxygen resources of the stream. In the case of addition of nutrients, it would also lead to eutrophication of the water body.

2. COLOUR :

Ordinarily, surface waters do not have any true color. Naturally present minerals and humic acids in dissolved state may impart their characteristic hues. Presence of suspended matter may give an apparent color. Green, yellow-brown or red color may be the result of presence of different microorganisms, particularly, algae. Presence of suspended, inorganic matter may also result in an apparent colour.

3. ODOUR :

Fresh water is odour free. Presence of odour suggests higher than normal biological activity due to the presence of decomposable organic material contributed by human or industrial wastes or excessive growth of algae and other plants. Odour is caused by production of volatile organic compounds and inorganics, such as, NH_3 and H_2S. It is more pronounced when the dissolved oxygen in water is less than about 25% of its saturation value. Industrial wastes can also create odours directly.

4. SOLIDS :

Suspended solids in water may consist of silt, clay and other fine inorganic and organic particles. Planktons may also contribute to the suspended solid load. Normally, the particles range from 10 nm to 0.1 µm in diameter. Their concentration depends on the location of the water body and changes from season to season. During rainy season, it may change hourly during a rainfall event. It is greatly influenced by the catchment area characteristics. Turbidity, which is a related parameter, is interference to the passage of light or scattering of light by suspended particles in a column of water.

5. TOTAL DISSOLVED SOLIDS :

A total dissolved solid (TDS) refers to the residue left after evaporation of a known volume of water at 180 ±2°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 TDS value for river water depends largely on the ratio of the contribution of the overland flow to the subsoil flow. It may vary from less than 50 mg/L to a few thousand mg/L Surface evaporation in arid climates and agricultural return waters increase the TDS considerably.

6. ELECTRICAL CONDUCTIVITY :

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 µ.S/cm and is expressed at 25^{o}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. The value of EC may serve as an approximate index of the total content of dissolved substances in water samples. TDS, mg/L may be obtained by multiplying EC, µmhos/cm, by a factor ranging between 0.55 and 0.9. A commonly used value is 0.67. In order to increase the accuracy of the evaluation of the mineral content of waters from EC measurements, it is necessary to establish such correlations, for each body of water. The conductivity of most fresh waters ranges from 10 to 1000 µmhos/cm. It is, at times, used as an indication of ingress of sea water in estuarine region of a river.

7. pH :

The hydrogen ion concentration in water is expressed in terms of pH. It is defined as the logarithm of inverse of hydrogen ion concentration in moles/L. The pH value of natural waters mostly depends on free carbon dioxide, bicarbonates and carbonate ions. The equilibrium condition may be changed by the intensity of photosynthetic process (which consumes carbon dioxide) and the biochemical oxidation of organic substances (which produces carbon dioxide), as well as chemical conversions of some mineral substances, such as reduction-oxidation reactions of ammonia, sulphur containing minerals, iron, etc. 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 neutralize acidity or alkalinity, respectively. Measurement of these parameters along with pH may be required when solubility and ionic equilibria of various chemical species are under investigation.

Lower Yamuna Water Quality Laboratory following APHA Methods.

Sl.No	Parameter	Methodology	Standard method
1	Temperature	Laboratory and field methods	APHA-2550B
2	Color	Visual comparison method	APHA- 2120B
3	Odor		
4	pH	Electrometric method	APHA- 4500 H^+B
5	Conductivity	Laboratory method	APHA- 2510 B
6	Total Dissolved solids	Total dissolved solids dried at 180^0C	APHA- 2540 C
7	Chemical Oxygen demand	Closed Reflux colorimetric method	APHA- 5220 D
8	Bio-chemical oxygen Demand	5-day BOD test	APHA- 5210 B
9	Dissolved Oxygen (In-situ)	Azide modification method	APHA- 4500 O C
10	Total coli form	Standard total coli form fermentation technique	APHA- 9221B
11	Fecal coli form	Thermotolerant fecal coli form procedure	APHA- 9221 E
12	Iron	Phenathroline method	APHA- 3500 Fe B
13	Fluoride	Ion selective Electrode method	APHA- 4500 F^-C
14	Boron	Curcumin method	APHA- 4500 B B
15	Nitrate	Nitrate Electrode method	APHA- 4500 NO_3^-D
16	Sulphate	Turbidimetric method	APHA-4500 SO_4^{2-}E
17	Chloride	Argentometric method	APHA- 4500 Cl^-B
18	Calcium	EDTA titrimetric method	APHA- 3500 Ca B
19	Potassium	Flame photometric method	APHA-3500 K B
20	Total Alkalinity	Titration method	APHA- 2330B
21	Total Hardness	EDTA titrimetric method	APHA- 2340C
22	Sodium	Flame emission photometric method	APHA- 3500 Na B
23	Magnesium	Calculation method	APHA- 3500 Mg B
24	Nitrite	Colorimetric method	APHA- 4500 NO_2^-B
25	Silicate	Heteropoly Blue method	APHA- 4500 SiO_2D

Table No. 3

All waters in the environment contain dissolved salts. However, some species occur more frequently and at greater concentrations than others. This illustrated in table below.

List of major and secondary constituents in water:-

Major Constituents (1.0 to 1000 mg/L)	Secondary Constituents (0.01 to 10.0 mg/L)
Sodium	Iron
Calcium	Potassium
Magnesium	Carbonate
Bi-carbonate	Nitrate
Sulphate	Fluoride
Chloride	Boron
Silica	Carbonate

Table No. 4

Rivers carry dissolved ions they receive from ground water and surface runoff to the sea. The dissolved ions include HCO_3^-, Ca^{++}, $SO_4^=$, H_4SiO_4, Cl^-, Na^+, Mg^{++}, K^+, PO_4^{3-}. Total dissolved solids in rivers are about 100mg/Liter to 1000 mg/l, roughly 20 to 200 times the concentration in rain water. Most of the increase is due to weathering of minerals. Rivers also carry small rock fragments and minerals produced in weathering reactions such as clays. These particles, carried mostly in suspension, contain the elements Al, Fe, Si, Ca, K, Mg, Na and P.

List of major cations and anions.

MAJOR CATIONS	MAJOR ANIONS
Calcium	Bi-carbonate
Magnesium	Carbonate
Sodium	Sulphate
Potassium	Chloride

Table No. 5

Other Major Ions in Water

- Sodium – high levels often associated with pollution
- Potassium – generally low (< 10 mg/L in natural fresh waters)
- Bicarbonate normally ranges from 25 to 400 mg/L
- Carbonate in fresh waters is normally dilute (<10 mg/L)
- Sulfate is normally between 2 and 80 mg/L
- Chloride is normally less than 40 mg/L in unpolluted waters
- Nitrate is significant in some areas

Potassium:

The concentration of Potassium ions (K^+) in natural fresh waters is generally low (normally less than 10 mg/L). Sea water and brines contain much higher concentrations. However, Potassium ions are highly soluble and are essential for most forms of life. Potassium in the water environment is readily taken up by aquatic life.

Carbonates and Bi-carbonates:

The concentration of carbonates and bicarbonates in water has a major effect on both the hardness (see also calcium and magnesium above) and the alkalinity (capacity to neutralize acidity) of water. The relative amounts of carbonate, bicarbonate and carbonic acid (dissolved carbon dioxide gas) in water is related to the pH. Under normal surface water pH conditions (i.e., less than pH = 9), bicarbonate predominates. Bicarbonate concentrations in natural waters range from less than 25 mg/L in areas of non-carbonate rocks to over 400 mg/L where carbonate rocks are present. Carbonate concentrations in surface and ground waters by contrast are usually low and nearly always less than 10 mg/L.

Sulphate:

Sulphate is present in all surface waters as it arises from rocks and from sea water which contains a high sulphate concentration. In addition to its role as a plant nutrient, high concentrations of sulphate can be problematic as they make the water corrosive to building materials (e.g., concrete) and are capable of being reduced to hydrogen sulfide (a toxic, foul-smelling gas) when zero dissolved oxygen conditions prevail in the water body. Normally, sulphate concentrations in surface waters are between 2 and 80 mg/L although they may exceed 1000 mg/L if industrial discharges or sulphate-rich minerals are present. The WHO guideline value for sulphate in drinking water is 400 mg/L.

Chloride:

Chlorides in fresh waters generally come from rocks, the sea or sewage, agricultural and industrial effluents. Fresh water concentrations of chloride are normally less than 40 mg/L and can be as low as 2 mg/L in waters, which have not been subject to pollution. Chloride concentrations over 100 mg/L give the water a salty taste and thereby make it unsuitable for drinking by humans or animals.

Nitrate:

Though nitrate is not listed as a major ion, high concentrations of nitrate upto 200 mg NO_3^- N/L have been reported from many sites in the country where municipal wastewater or leachate from garbage dumps has contaminated the groundwater. Excessive amount of nitrate in drinking water causes methaemoglobinaemia in bottle fed infants. WHO has recommended a guideline value of 10 mg NO_3-N/L. (45mg/L NO_3)

DRINKING WATER STANDARDS:-

In view of the direct consumption of water by human beings, the domestic water supply is considered to be most important use of water and drinking use has been given first priority on utilization of water resources the National Water Policy. In India, agencies like the Bureau Of Indian Standard (BIS) and Indian Council of Medical Research (ICMR) have formulated drinking water standards. The World Health Organization (WHO) has also laid down drinking water standards, which are considered international standards. Values of the parameters according to BIS: 10500, 2012 (with versions covered in this water quality range given below table.

Details of Indian Standard : 10500, 2012

S.No.	Substance Characteristic	Acceptable Limit	Persmissible limits
1	pH	6.5-8.5	No Relaxation
2	Dissolved Solids	500 µ.s/c.m	2000 µ.s/c.m
3	Total Hardness	200 mg/lit	600 mg/lit
4	Calcium	75 mg/lit	200 mg/lit
5	Magnesium	30 mg/lit	100 mg/lit
6	Sulphate	200 mg/lit	400 mg/lit
7	Chloride	250 mg/lit	1000 mg/lit
8	Total Alkalinity	200 mg/lit	400 mg/lit
9	Nitrate(NO_3)	45 mg/lit	No Relaxation
10	Sodium	-	-
11	potassium	-	-

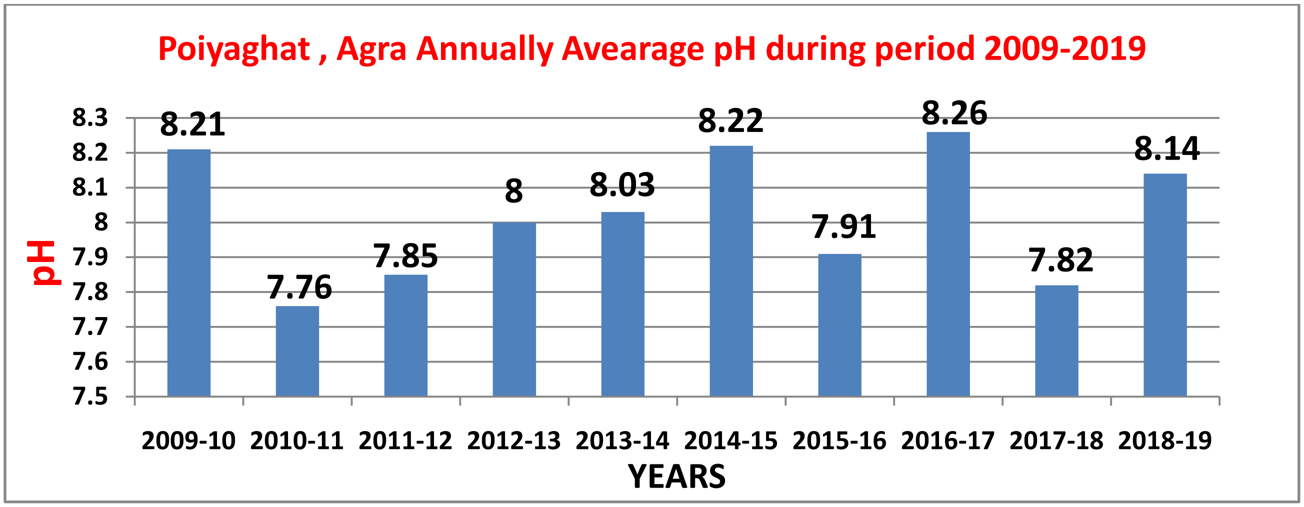
Table No. 6

Above the all parameters (pig.06) are major cations and anions parameters and given below details of parameters analysis procedure and details of graph.

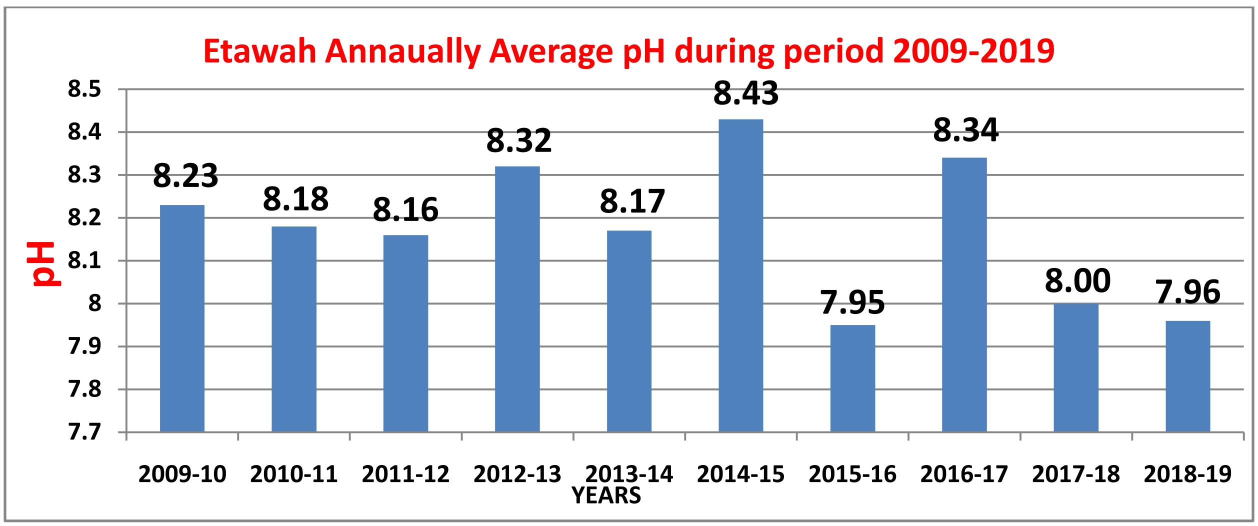
pH

PROCEDURE:-

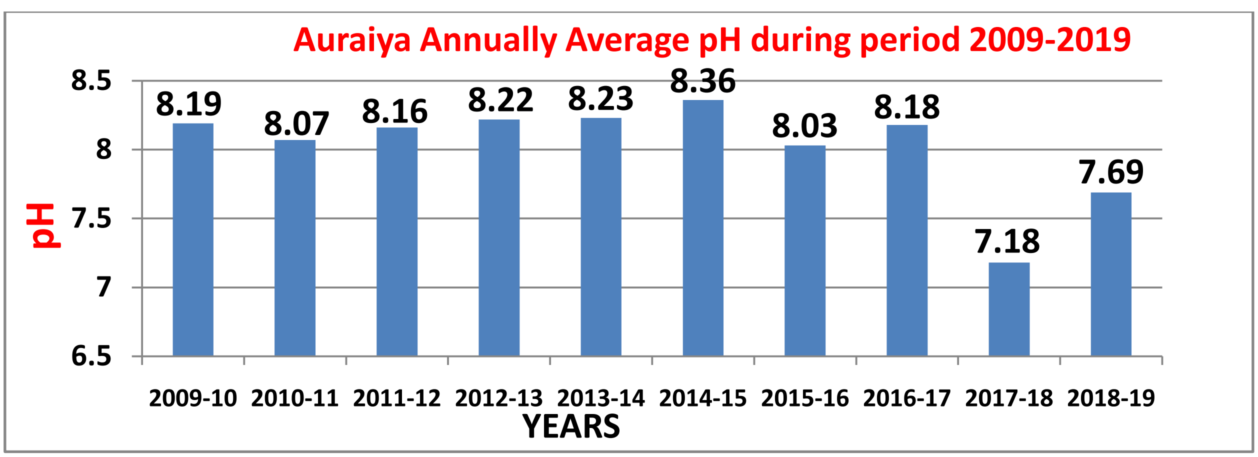
- It is defined as Negative Logarithm of Hydrogen Ion Concentration.
- pH = - log10[H+] or log[1/H+]
- It is a scale lf intensity of acidity or alkalinity and measures the concentration of Hydrogen Ion in water.
- Normally acidity or alkalinity of water, depends upon the concentration of H+ or OH- ions.
- If H+ ions are more than OH- ions, the water will be acidic and if OH- ions are more than H+ ions the water is basic in nature.
- Its scale varies from 1 to 14 water having pH=7 is neutral, less than 7.0 is acidic and more than 7.0 is basic (alkaline).
- For the many of its beneficial uses pH from 6.5 to 8.5 is suitable as per CPCB's guidelines. The pH of various solutions is generally measured by e.m.f. (electro motive force) measurements.
- In this type of measurement the potential at one electrode (reference electrode) remains fixed, while that of other electrode (indicator electrode) depends upon the activity of H+ ions in the solution in which it dips.
- The pH solutions (pH=4.0, pH=7.0, pH=10.0) are performed. These solutions are prepared from pH tablets available in the market or standard pH solutions available in the market.
- The electrode system is calibrated against buffer solutions of pH=4.0, 7.0, & 10.0. because buffer solutions may deteriorate as a result of contamination, these are prepared freshly for a single time use.
- If the electrode of distilled water in the beaker does not show 7.0, then three point calibration of the instrument with pH solution of pH=4.0, 7.0, & 10.0 is done by moving appropriate 'calibration' knob & temperature compensation knob by adjusting temperature at the 25°c room temperature.
- Calibration of the instrument is repeated till the instrument become stable.
- Another beaker is taken, rinsed with distilled water, dried with tissue paper, sample is added, electrode is dipped into beaker containing sample and pH value of the sample is observed from digital unit of the pH meter.
- Range **6.5 to 8.5.**



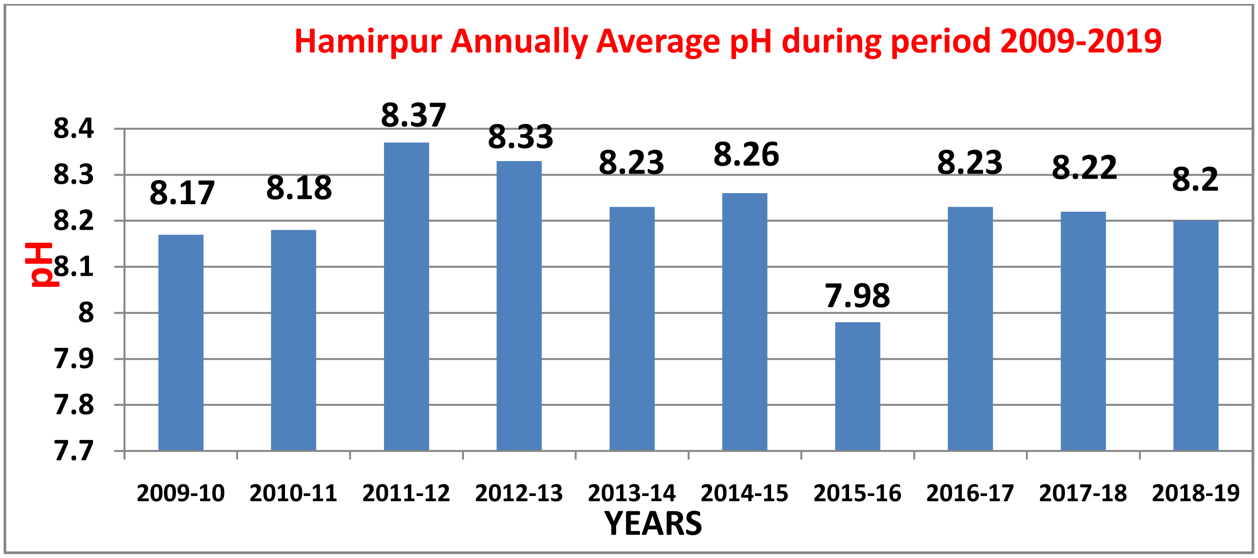
The pH parameter at Poiyaghat Site has no trend.



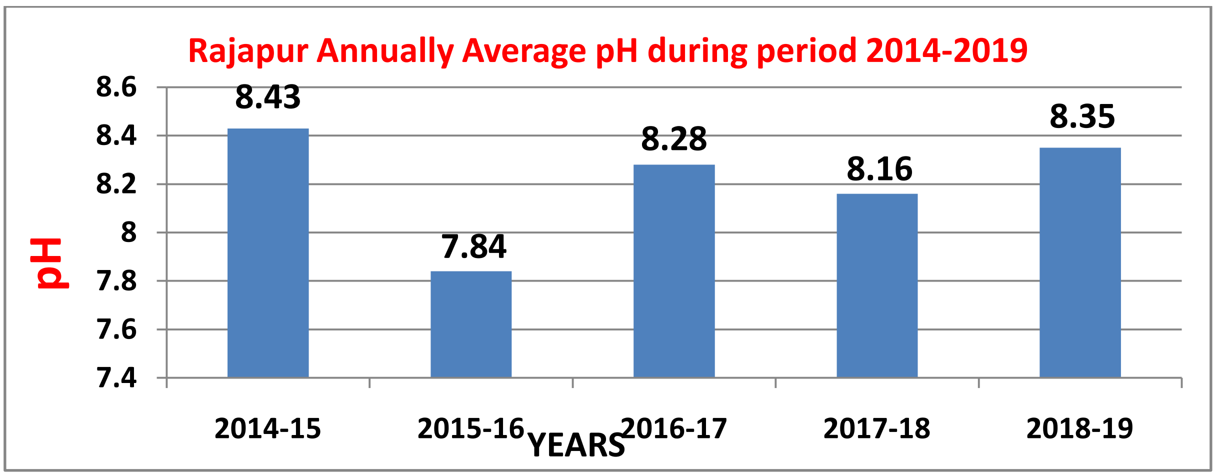
The pH parameter at Etawah Site has no trend.



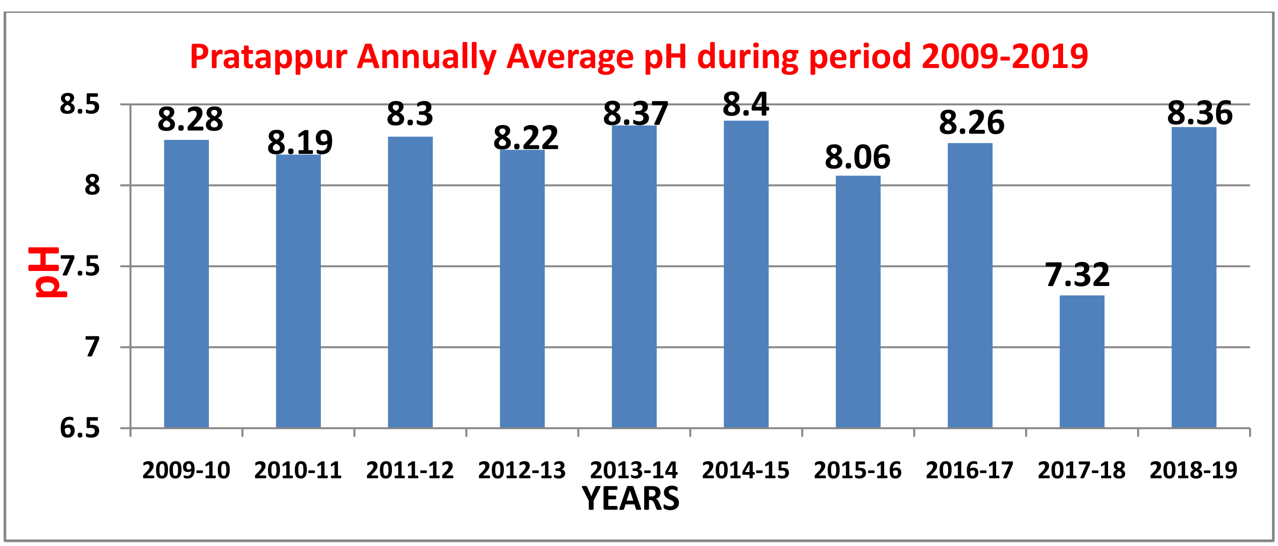
The pH parameter at Auraiya Site has no trend.



The pH parameter at Hamirpur Site has no trend.



The pH parameter at Rajapur Site has no trend.



The pH parameter at Pratappur Site has no trend.

ELECTRICAL CONDUCTIVITY [E.C]

Conductivity is a numerical expression of the ability of an aqueous solution to carry electric current.

Pure water is a poor conductor of electricity. Acids, Bases and salts present in it, make it a good conductor of electrically.

Acids, Bases and salts are called electrolytes. Electrolytes dissolve in solution, dissociate into positive and negative ions which impart conductivity.

Thus higher the concentration of electrolytes or ions in water more is its electrical conductance.

Electrical conductivity depends upon the presence of ions, their total concentration, mobility, valance and temperature.

Determination of conductivity of water is a quick way for measuring the approximate total ion concentration in it.

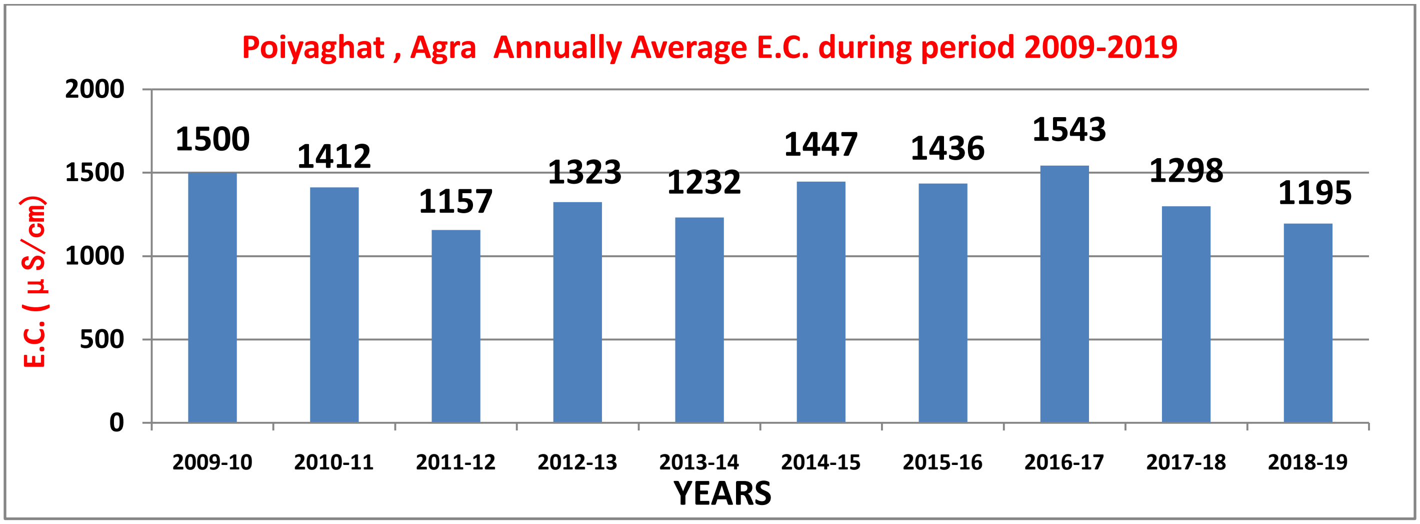
It has been found that, conductivity at 25° C multiplied by a factor between 0.5 to 0.7, can be used to predict the concentration of total dissolved solids unless the water is of unusual compostion.

In industries particularly for using in boilers water having much less EC is required to prevent scale formation.

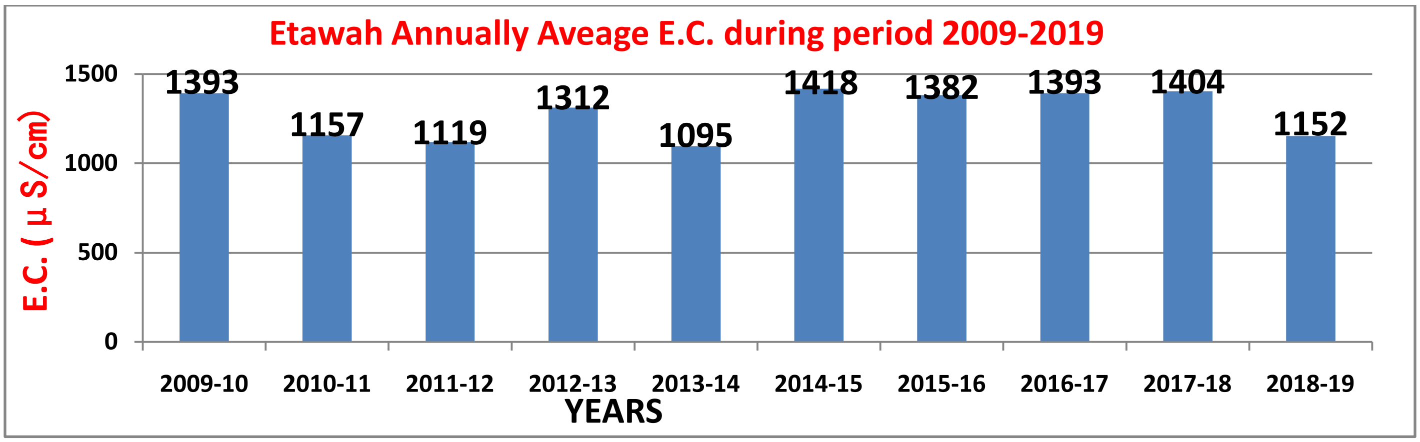
A more convenient unit in water analysis is micro mhos. When the cell constant is known and applied, the measured conductance is converted to specific conductance or conductivity the reciprocal resistance.

Ks=1/Rs where **Ks**=conductivity, **Rs**= specific resistance

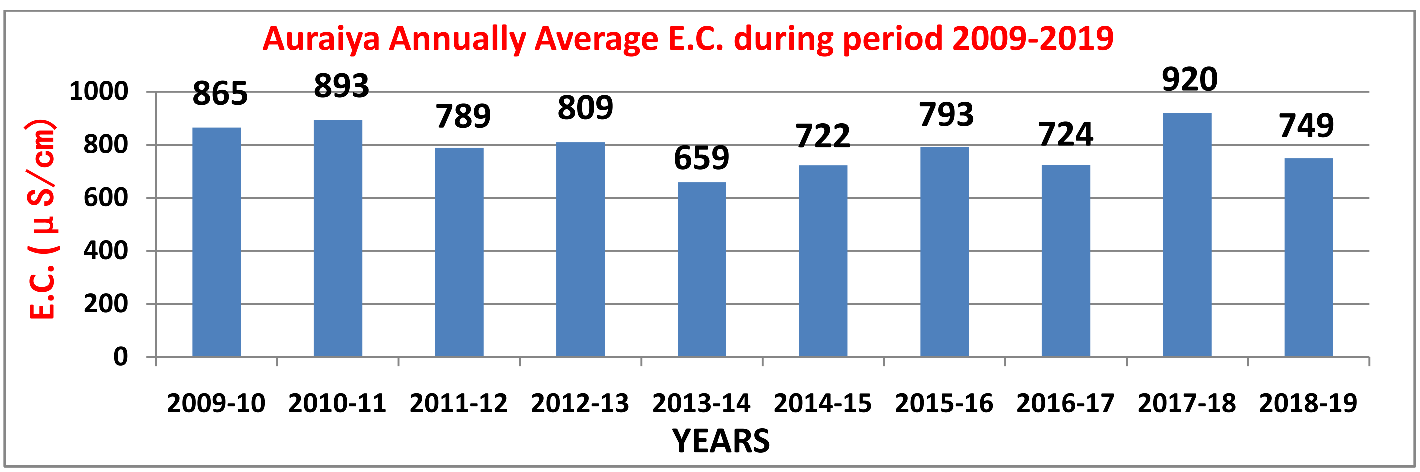
Standard conductivity calibration solution is prepared first by taking a measured quantity of potassium chloride salt dissolved in a specified amount of distilled or de-ionised water (conductivity of 0.01 M KCl solution at 25°C . 1413 µmho/cm.



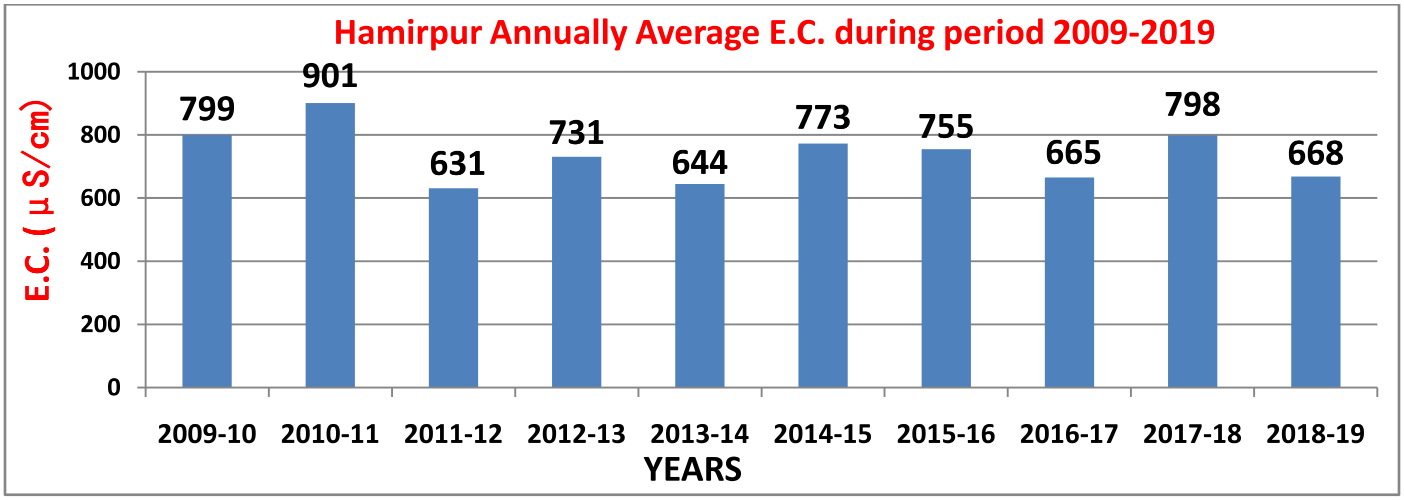
The E.C. parameter at Poiyaghat Site has no trend.



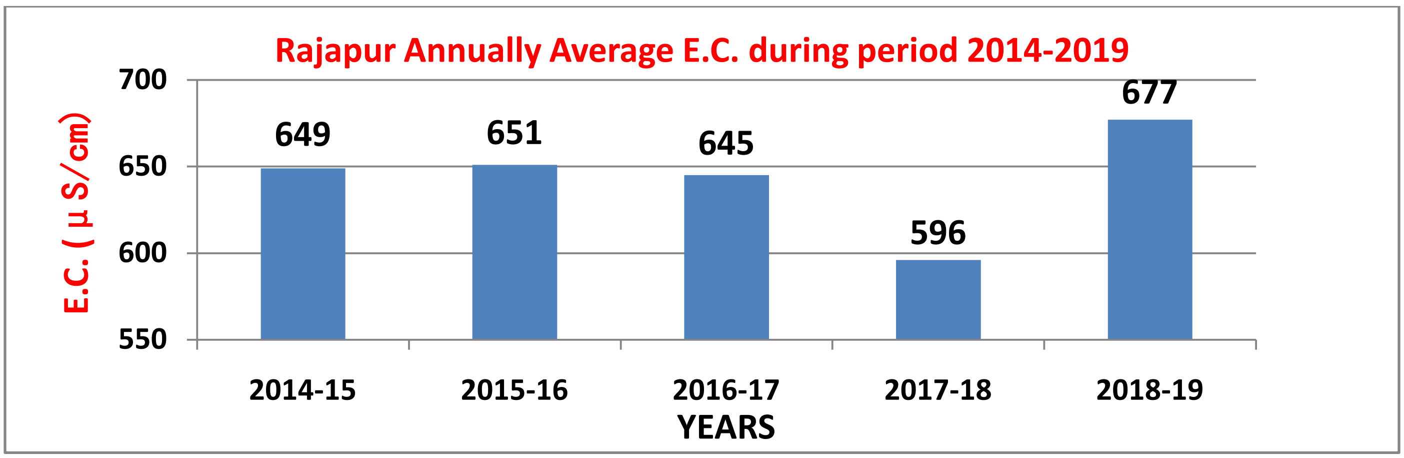
The E.C. parameter at Etawah Site has no trend.



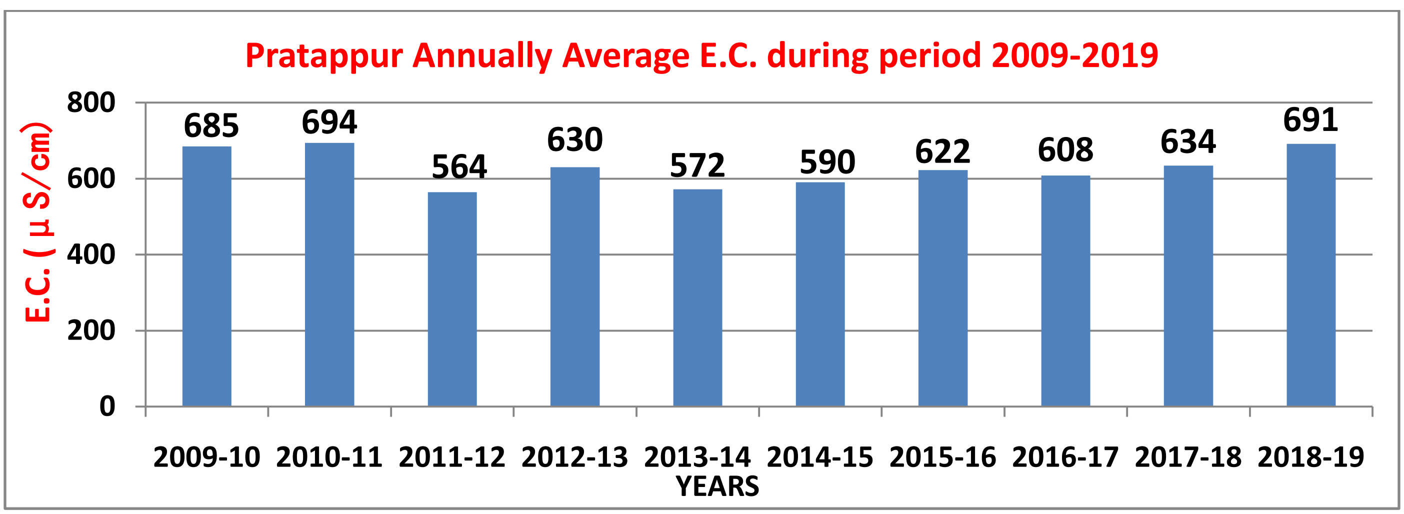
The E.C. parameter at Auraiya Site has no trend.



The E.C. parameter at Hamirpur Site has no trend.



The E.C. parameter at Rajapur Site has no trend.



The E.C. parameter at Pratappur Site has no trend.

TOTAL HARDNESS

Total hardness is the sum of calcium hardness as CaCO3 and Magnesium hardness reported as CaCO3 milligram per liter. Hardness is a measure of the capacity of water to precipitate soap.

Soap is precipitated chiefly by Calcium & Magnesium ions present in a water supply. Other polyvalent cations may also precipitate soap, but they often are in complex forms.

The anions responsible for hardness are mainly carbonate, Bicarbonate and sulphate.

In order to get total hardness value of a water sample its calcium & magnesium concentrations are determined first. Calcium and Magnesium concentration are determined by complex metric titration method.

Ethylenediaminetetraacetate (EDTA) and its disodium salt form a chelated soluble complex when added to a certain metal cation.

If a small amount of dye such as Eriochrome Black T is added to an aqueous solution containing calcium & Magnesium ions at pH = 10, the solution becomes wine red by the formation of a complex.

If standard EDTA is added as a titrant, the EDTA has got a strong tendency towards Ca^{++} and Mg^{++} ions there by forming complexes.

Thus the former complex (wine red colour) is broken down and a new complex (blue colour) is formed. The formation of blue colour makes the end point of titration.

For this purpose (i) standard EDTA titrant of known strength (ii) standard calcium carbonate solution for standardization of EDTA (ii) Ammonium chloride + ammonium hydroxide buffer solution (iv) 10% KOH solution (v) Eriochrome black T indicator and (vi) Murexide indicator are used. As EDTA is not a primary standards, its strength is obtained by titrating known volume of primary standard such as CaCa3 of known strength with EDTA.

A known volume of water sample is taken in duplicate (one for Calcium + Magnesium and another for calcium only) into 250 ml conical flask.

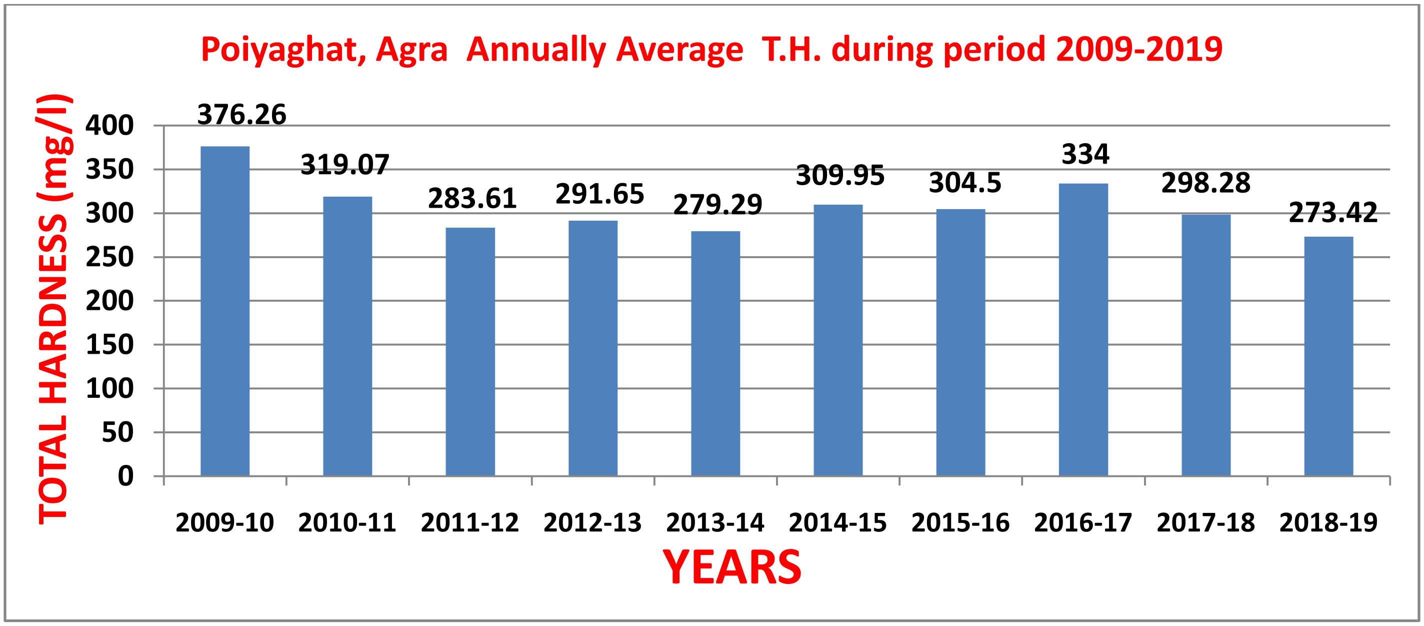
To the first flask, NH4Cl+NH4OH buffer solution is added (to create a medium of pH=10.0) followed by addition of few drops of Eriochrome black T indicator.

The flask turns wine-red in colour. Then it is titrated with standard EDTA titrant upto the appearance of blue colour. Appearance of crystal violent colour. Appearance of crustal violent colour makes the end point of calcium determination.

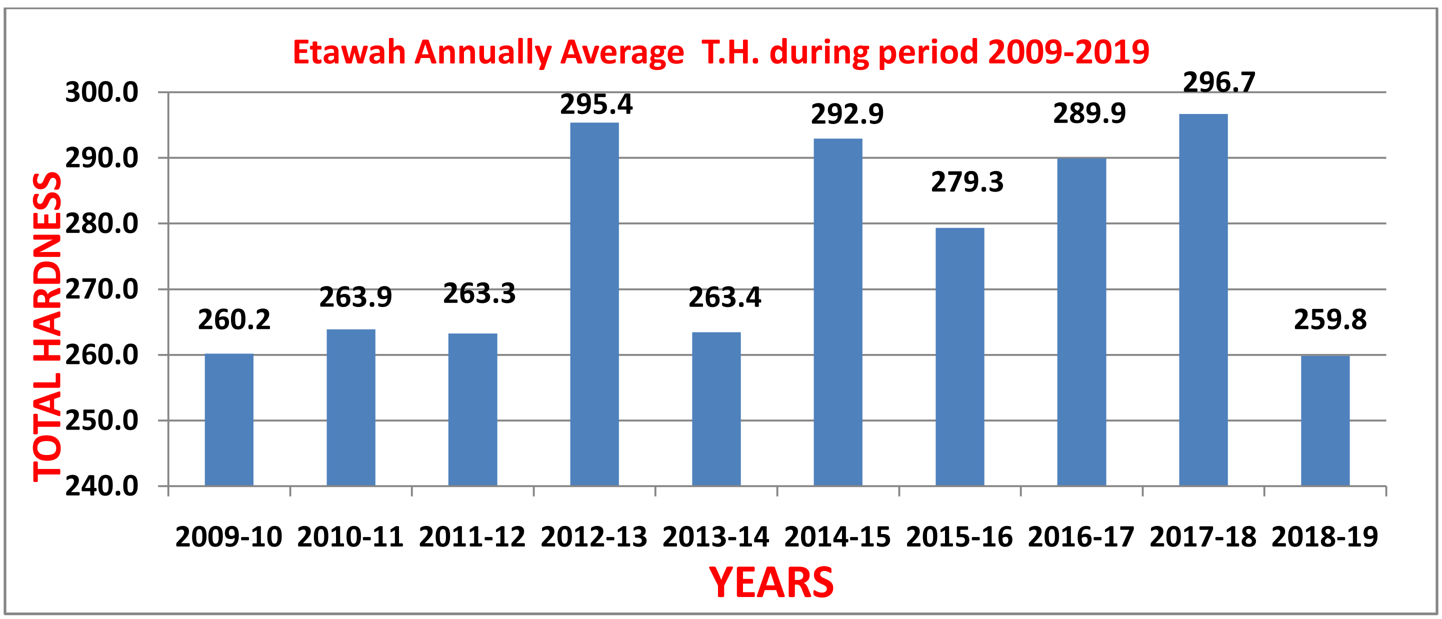
The concentrations of calcium and magnesium are calculated from the volume EDTA consumed for Ca+Mg (ii) volume of EDTA consumed for Ca only (iii) different in volume of EDTA consumed [(Ca+Mg) –Ca only] (iv) volume of sample taken and (v) strength of EDTA [normality(N)].

Sum of total hardness as CaCO3 and Magnesium hardness as CaCO3 gives total hardness as CaCO3 in mg/lit.

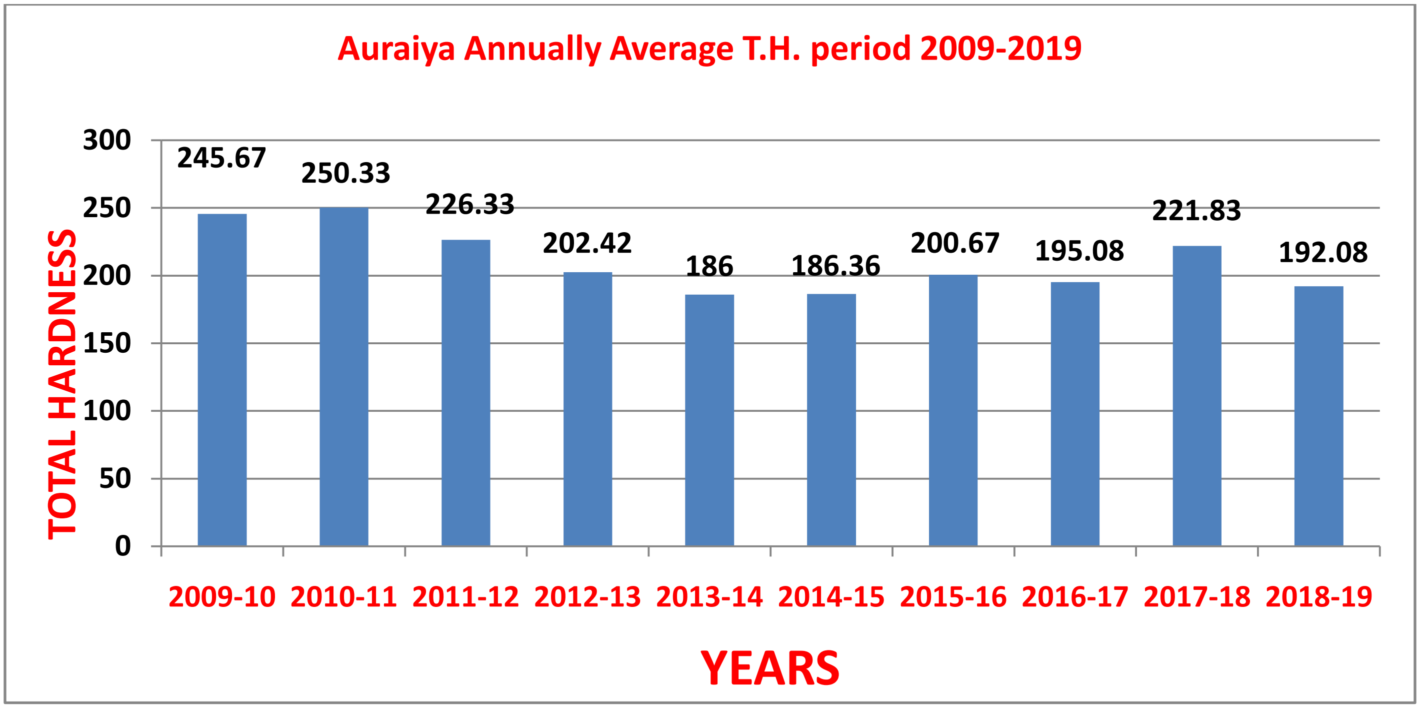
The allowed of total hardness (as CaCO3) in drinking water should be less than or equal to 200 mg/lit.



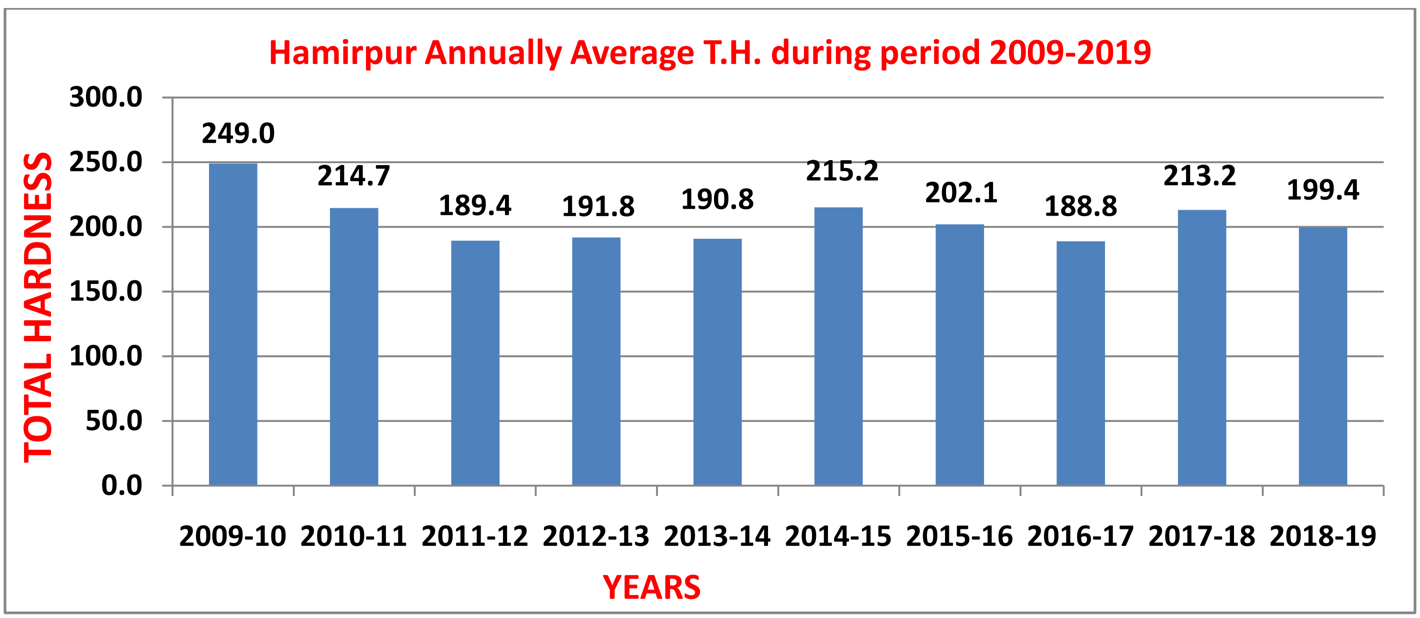
The Total Hardness parameter at Poiyaghat Site has no trend.



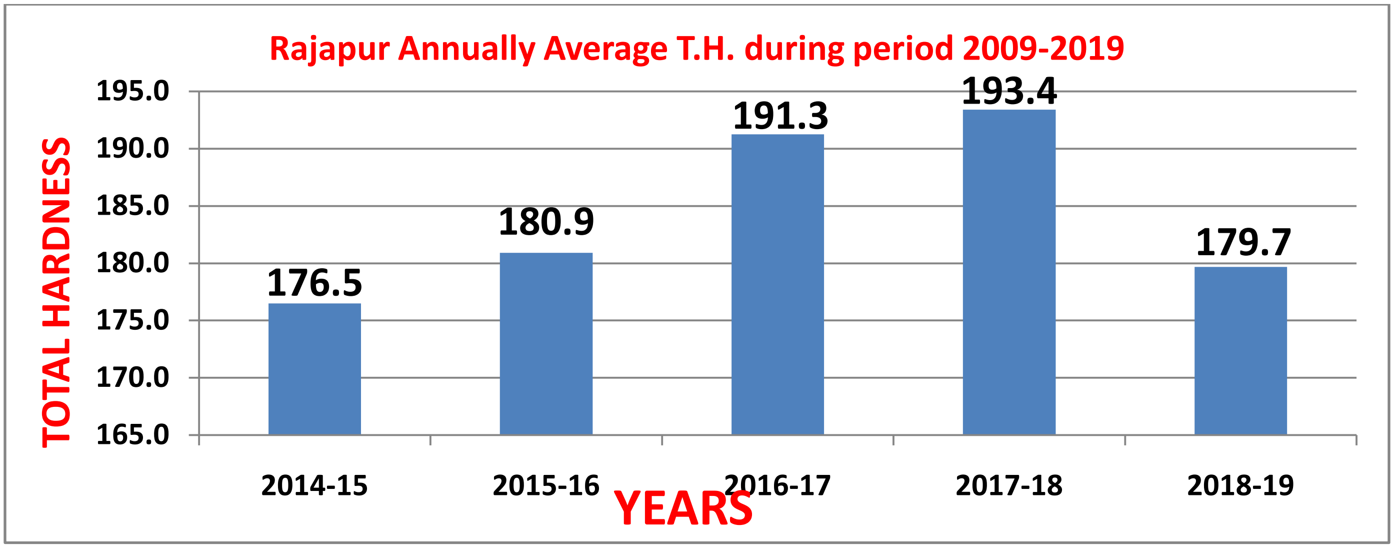
The Total Hardness parameter at Etawah Site has no trend.



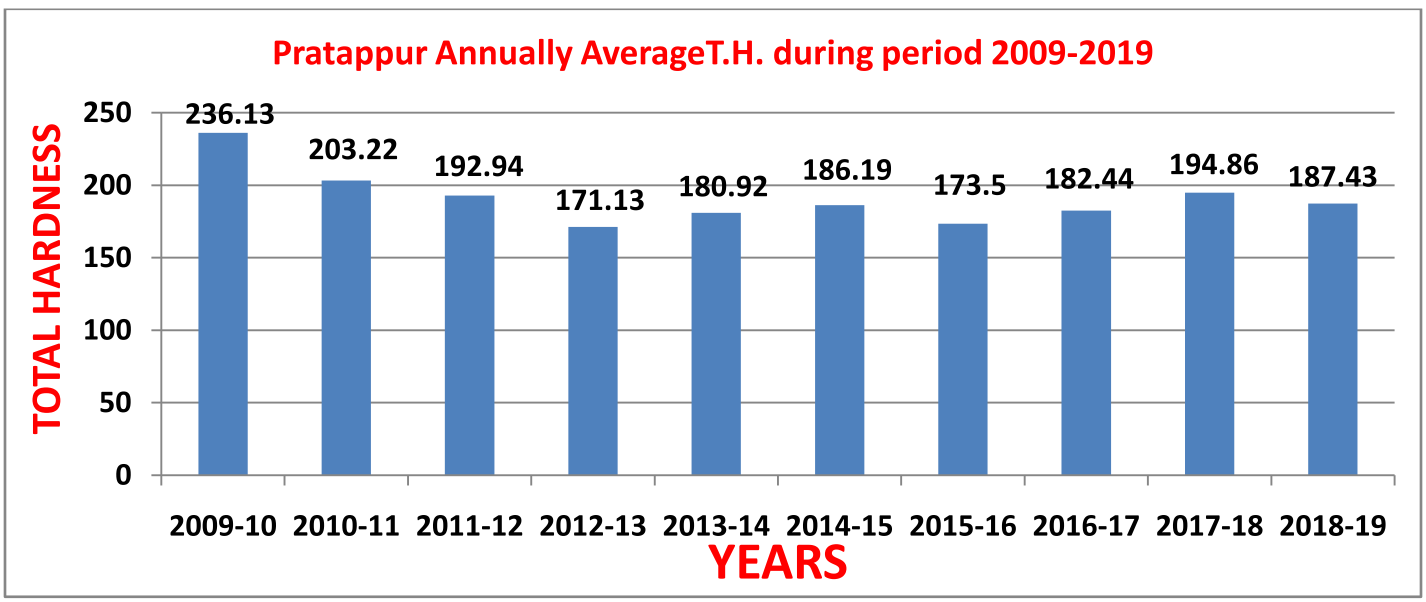
The Total Hardness parameter at Auraiya Site has no trend.



The Total Hardness parameter at Hamirpur Site has no trend.



The Total Hardness parameter at Rajapur Site has no trend.



The Total Hardness parameter at Pratappur Site has no trend.

CALCIUM

Principle:- When EDTA (ethylenediaminetetraacetic acid or its salts) is added to water containing both calcium and magnesium, it combines first with the calcium. Calcium can be determined directly, with EDTA when the pH is made sufficiently high that the magnesium is largely precipitated as the hydroxide and an indicator is used that combines with calcium only. Several indicators give a color change when all of the calcium, has been complexed by the EDTA at a pH of 12 to 13.

Interference:- Under conditions of this test, the following concentrations of ions cause no interference with the calcium hardness determination Cu^{+2}, 2 mg/lit; Fe^{+2} 20 mg/lit, Fe^{+3} ,20 mg/lit; Mn+2, 10 mg/lit; Zn+2, 5 mg/lit; and Sn+4,5 mg/lit. orthophosphate precipitates calcium at the pH of the test. Strontium and barium give a positive interference and alkalinity in excess of 300 mg/lit may cause an indistinct end point in hard waters.

Standard EDTA titration 0.01M:- weigh 3.723 gr. Di-sodium salt of EDTA, EDTA dehydrate dissolve in distilled water and dilute to 1000ml store in polyethylene bottle, 1ml = 400. µg Ca standardize EDTA against standard calcium solution periodically following the method described below.

Standard Calcium solution.

Weigh 1.000 gr anhydrous CaCO3 in 500ml flask (primary standard) add 1+1 Hcl in small amounts through a small funnel till all CaCO3 is dissolved. Add 200 ml distilled water and boil for a few minutes to expel CO2. Cool and add a few drops of methyl red indicator and adjust to intermediate orange color by adding 3N NH4OH 1+1 Hcl,as required. Transfer quantitatively and dilute to 1000ml with distilled water, 1ml = 400.0 µg Ca.

Procedure:- Take 50 ml sample an aliquot diluted to 25ml such that the calcium content is not more than 10 mg. samples which contain alkalinity greater than 300 mg/l should be neutralized with acid, boiled for 1 min and cooled before titration.

Add 2ml NaOH solution or volume sufficient to produce a pH of 12 to 13.

Start titration immediately after addition of the alkali add 0.1 to0.2 gr indicator mixture titrate with EDTA solution with continuous mixing till the colour changes from pink to purple.

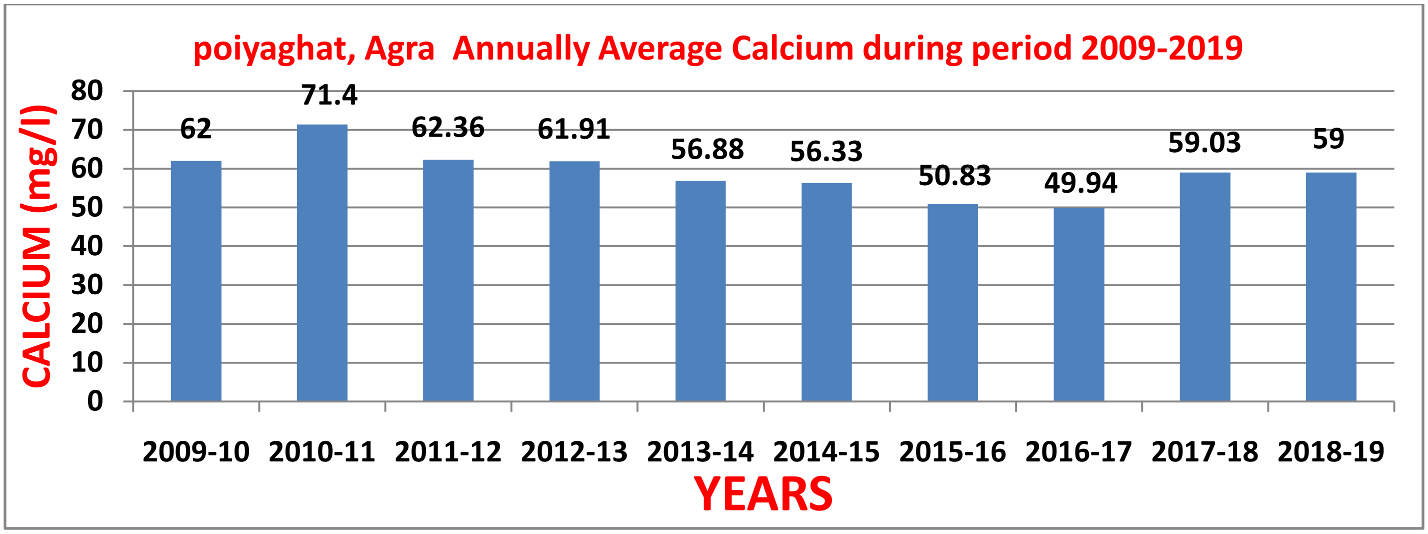
Check end point by adding 1 to 2 drops excess titrant to make certain that no further colour change occurs.

Calcium limits 75 mg/lit.

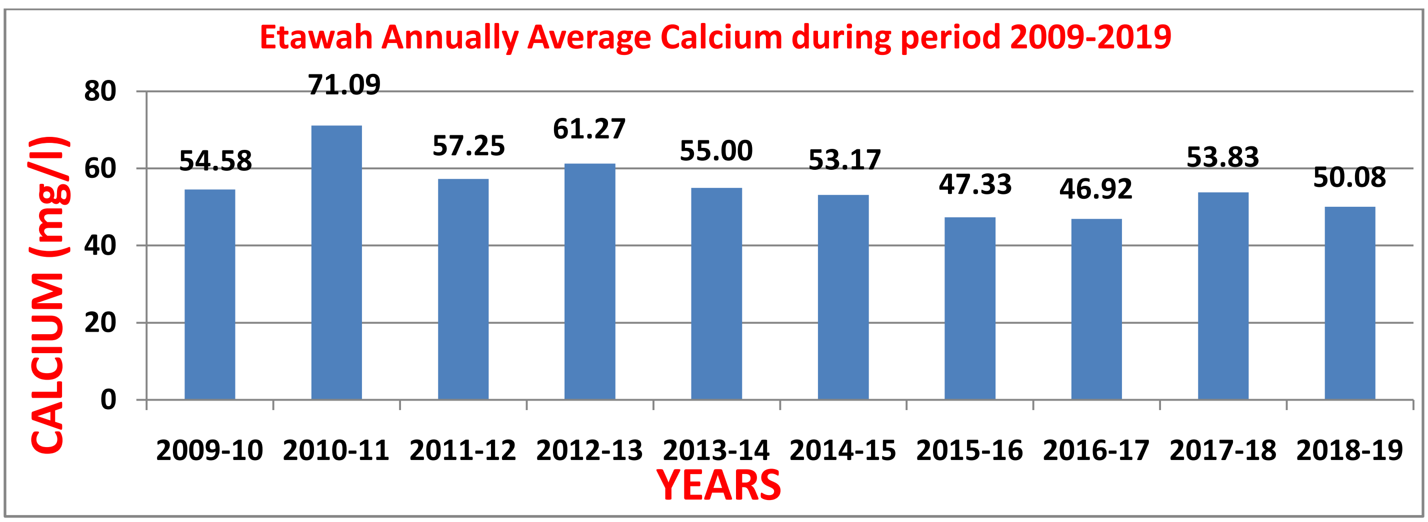
Calculation: Mg Ca/L= AXBX400

A= mL titrant for sample

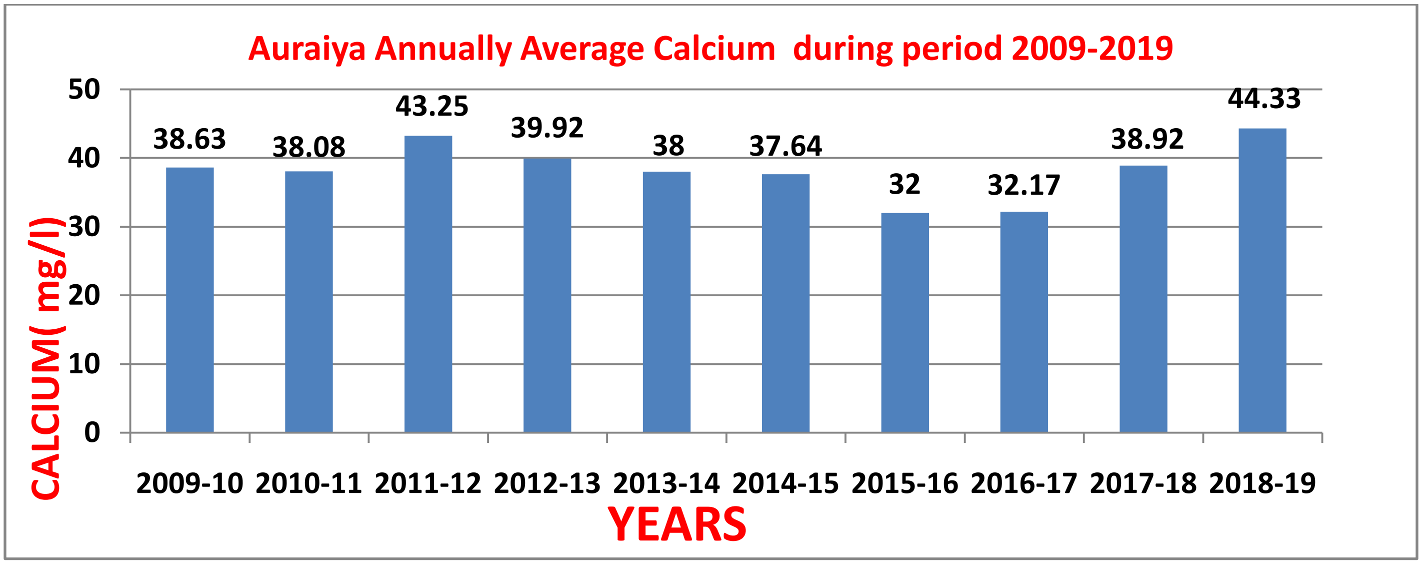
B= mL of standard calcium solution taken for titrant.



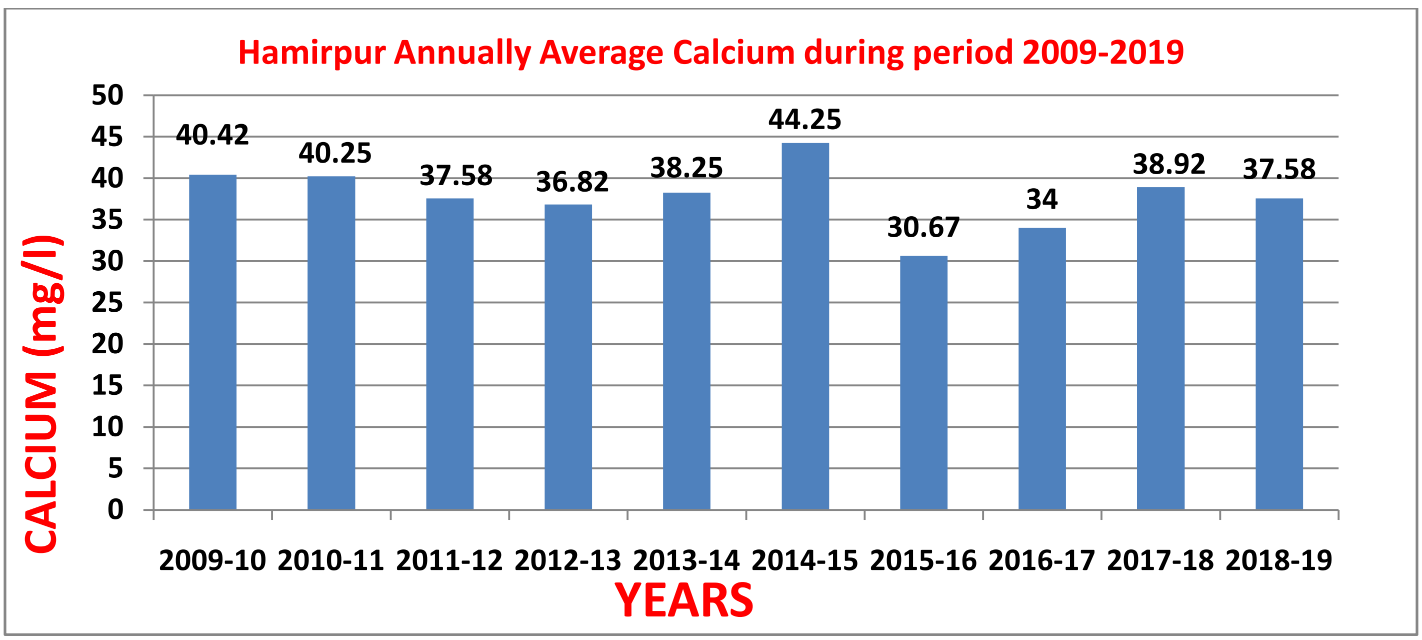
The Calcium parameter at Poiyaghat Site has no trend.



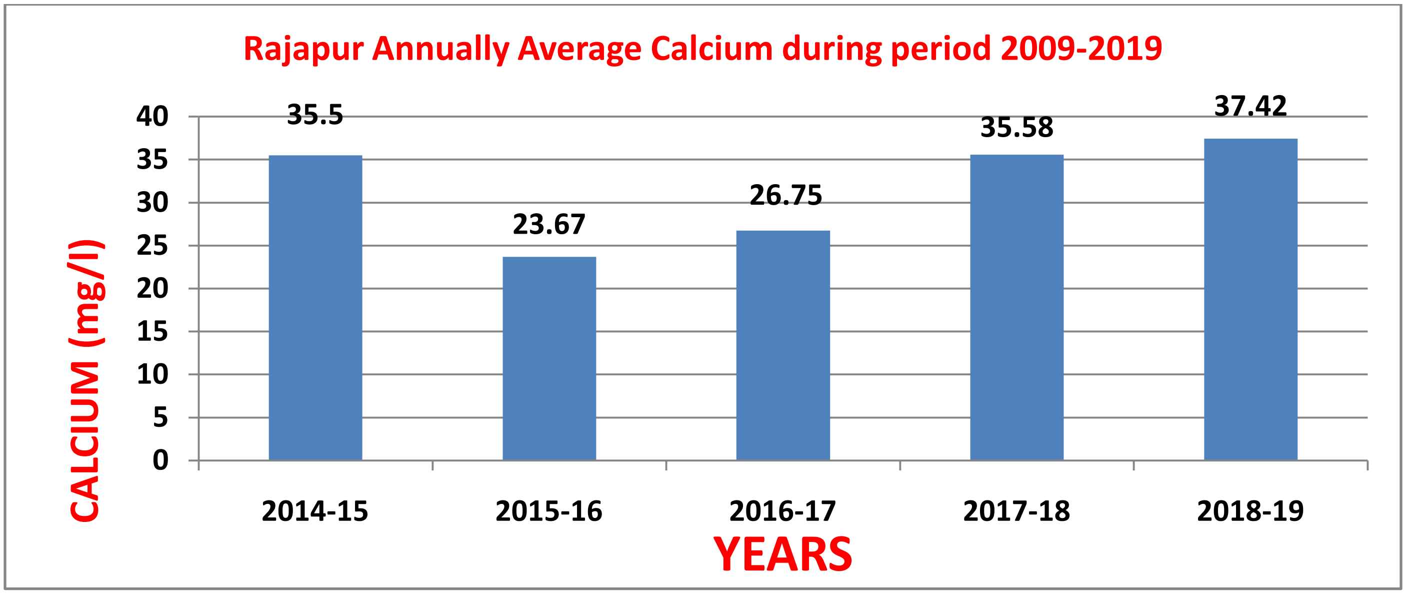
The Calcium parameter at Etawah Site has no trend.



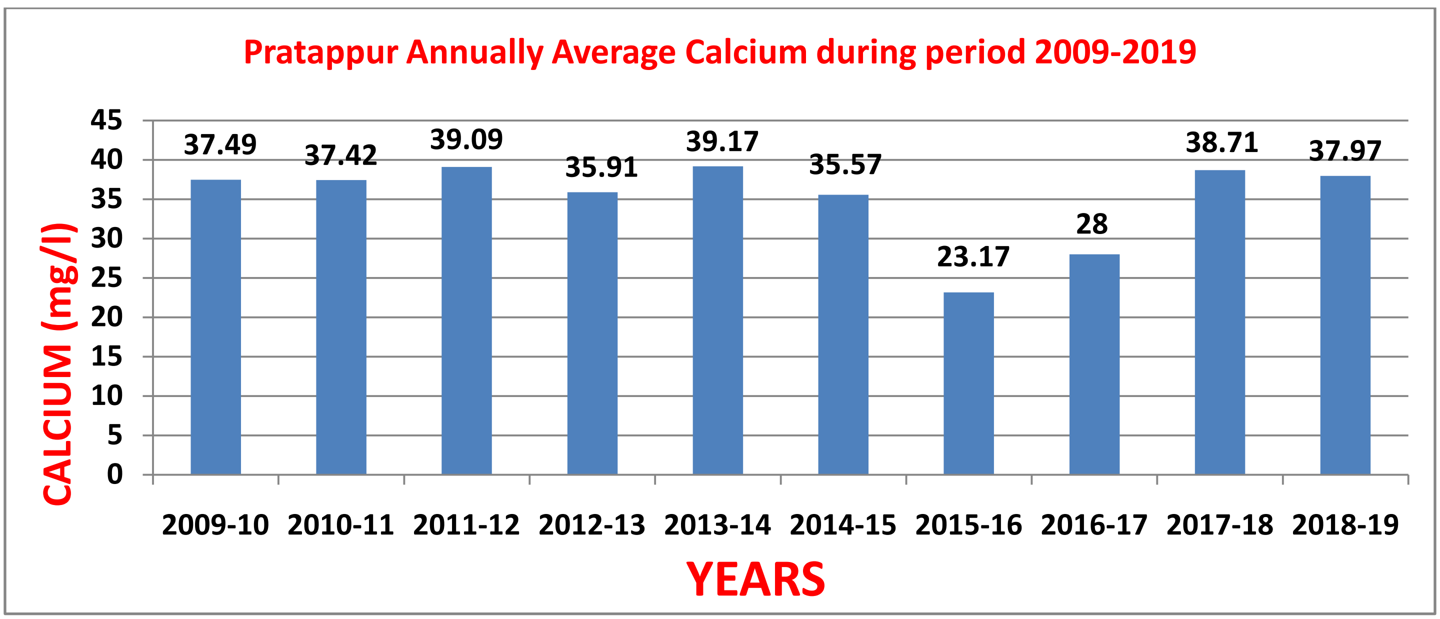
The Calcium parameter at Auraiya Site has no trend.



The Calcium parameter at Hamirpur Site has no trend.



The Calcium parameter at Rajapur Site has no trend.



The Calcium parameter at Pratappur Site has no trend.

MAGNESIUM

Principle:-

Magnesium may be estimated as the difference between hardness and calcium as $CaCO_3$ if interfering metals are present in non-interfering concentrations in the calcium titration and suitable inhibitors are used in the total hardness titration.

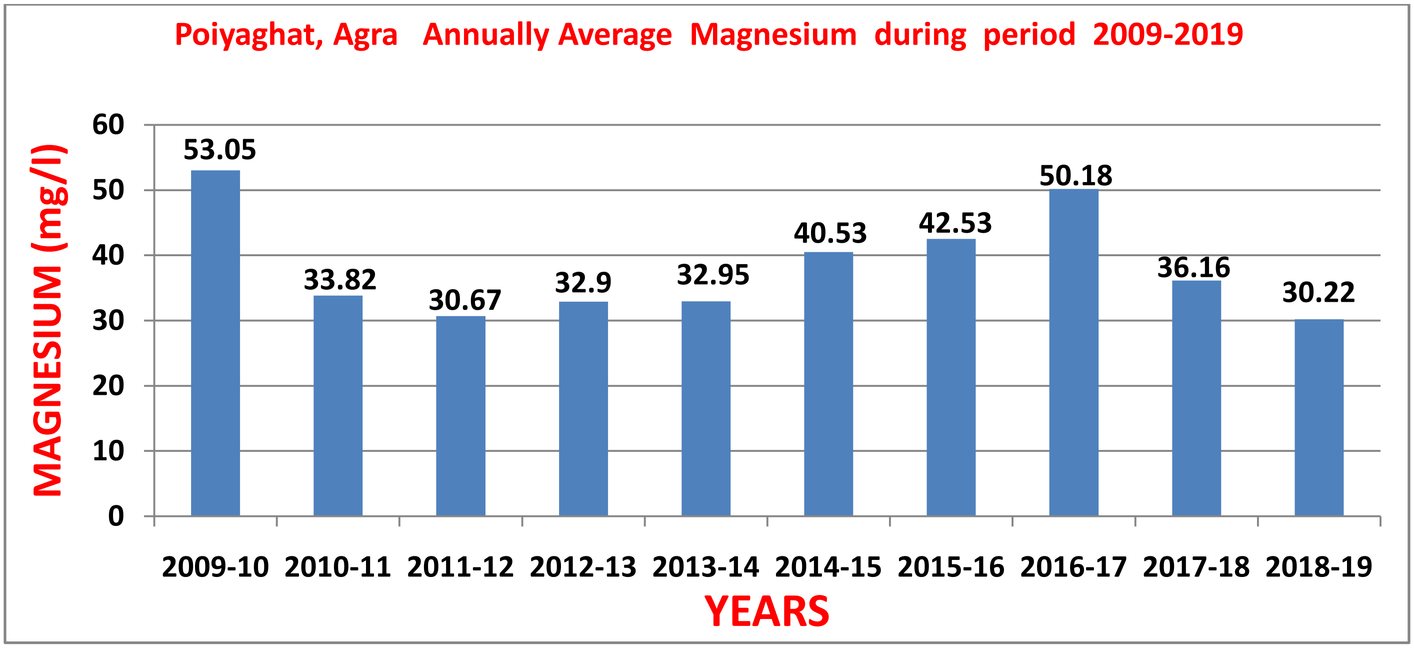
Procedure:-

Get the values for total hardness and calcium hardness determination by EDTA and calculate magnesium.

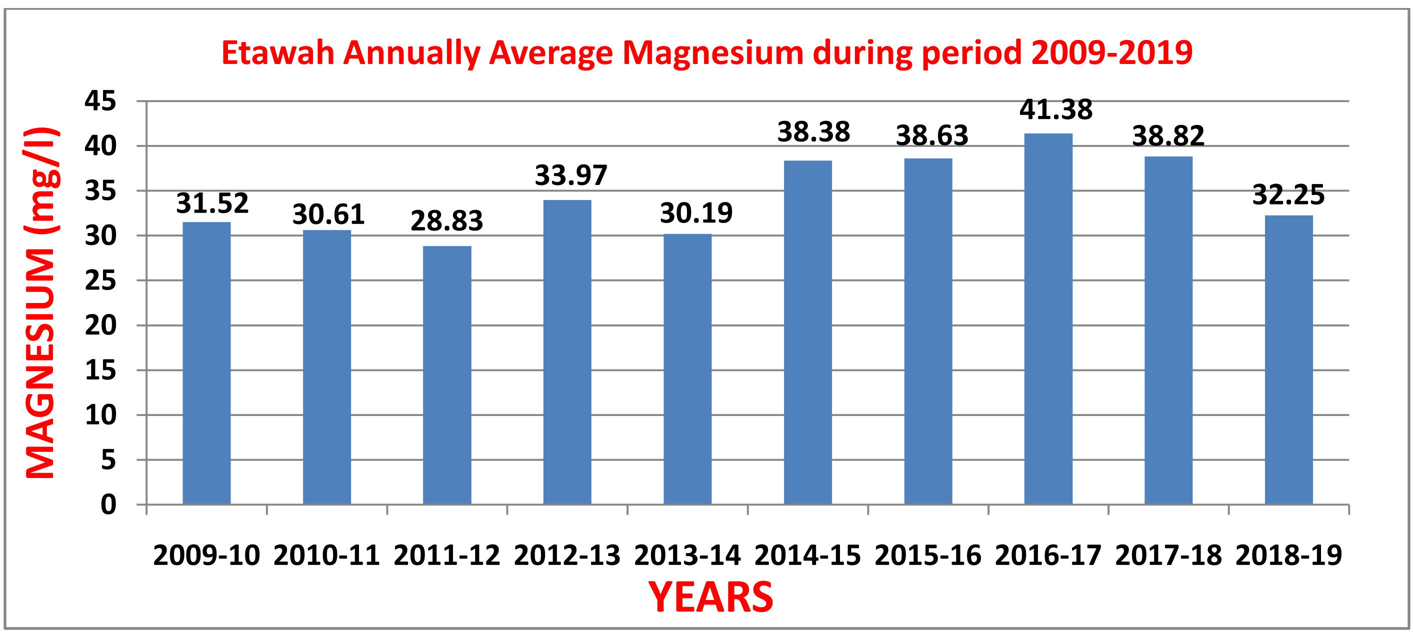
Magnesium limits 30 mg/lit.

Calculation:-

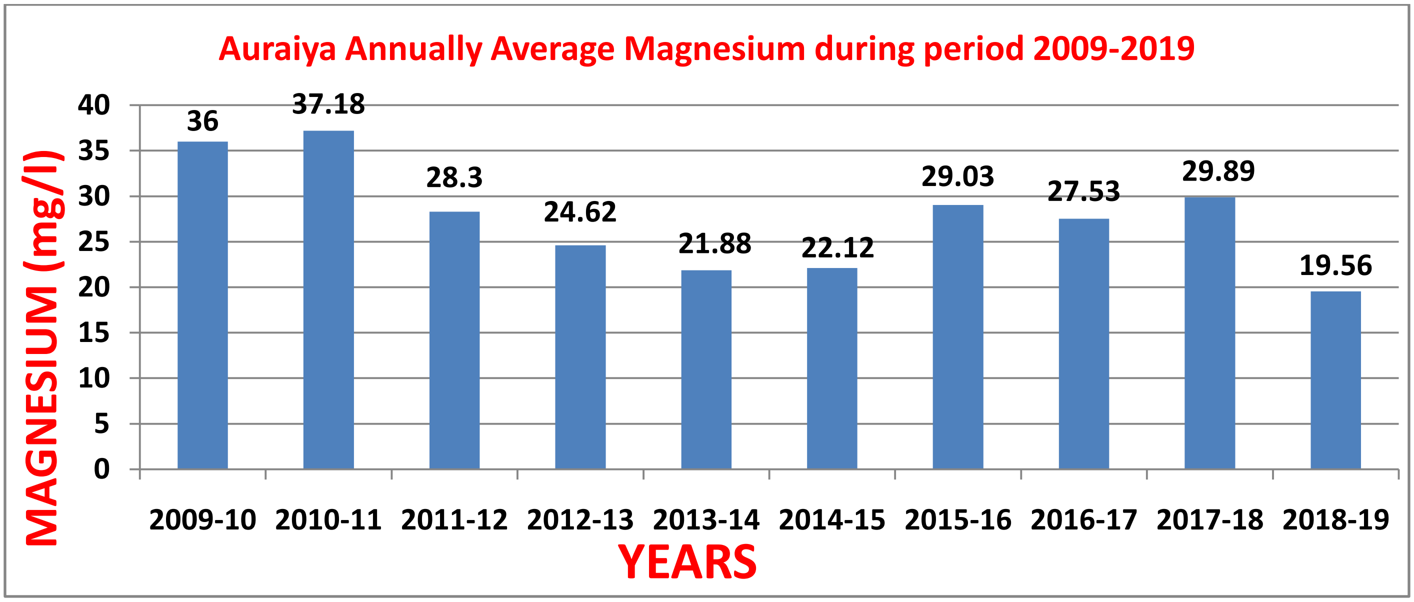
Magnesium= (TH as mg $CaCO_3$/L – CaH as $CaCO_3$/L)X0.24.



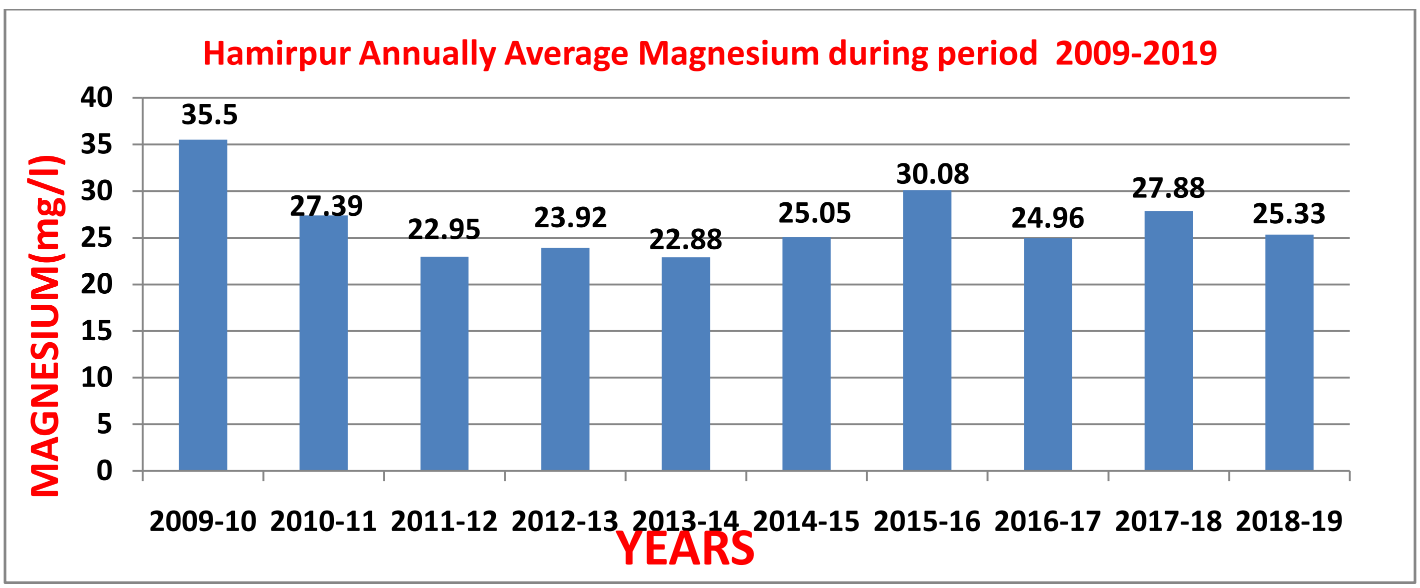
The Magnesium parameter at Poiyaghat Site has no trend.



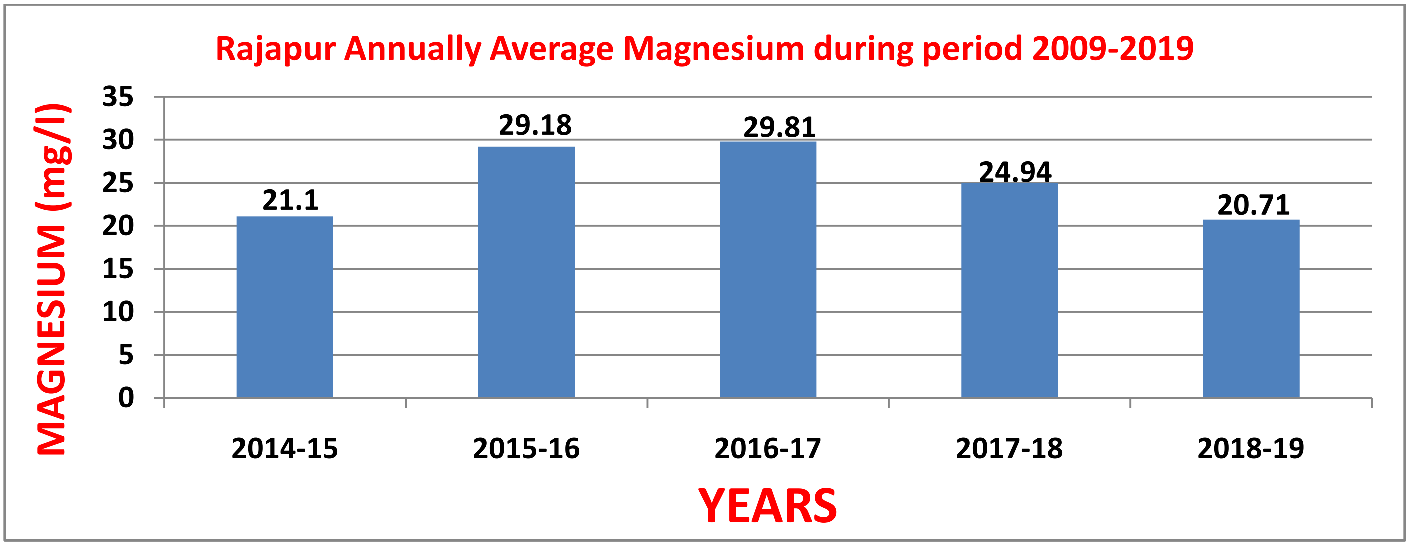
The Magnesium parameter at Etawah Site has no trend.



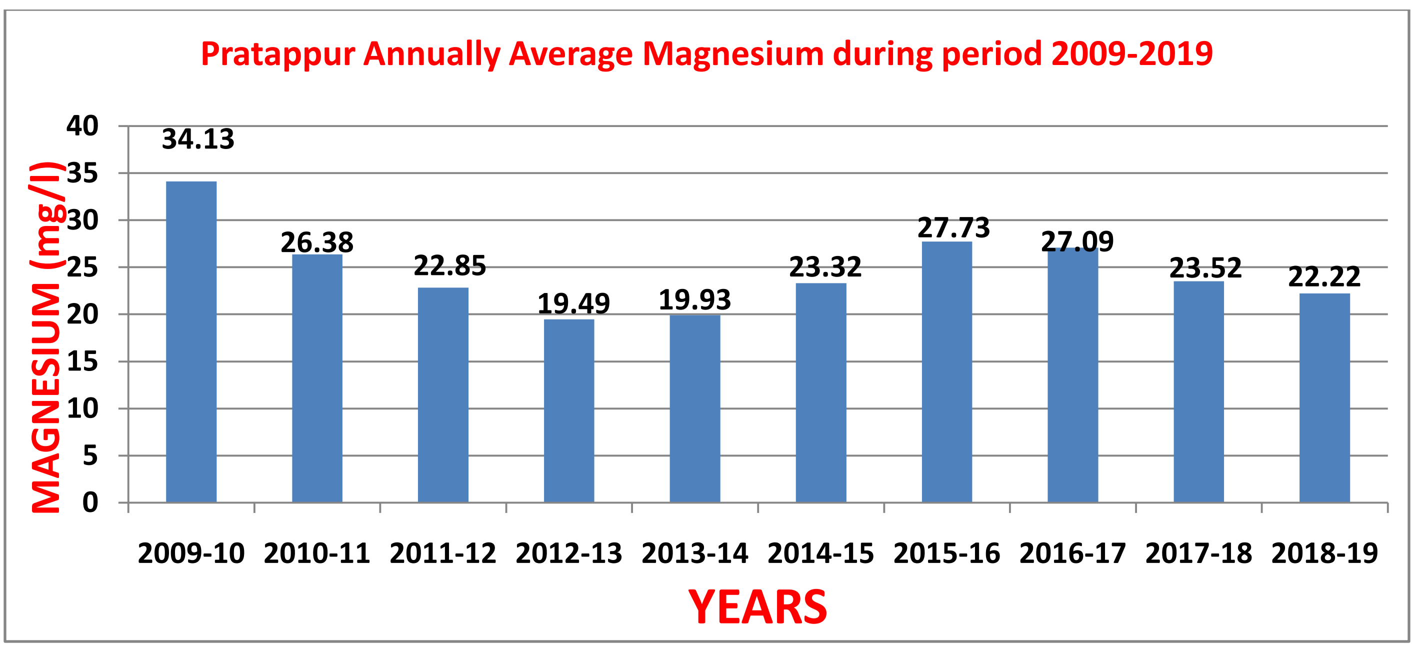
The Magnesium parameter at Auraiya Site has no trend.



The Magnesium parameter at Hamirpur Site has no trend.



The Magnesium parameter at Rajapur Site has no trend.



The Magnesium parameter at Pratappur Site has no trend.

SULPHATE

Principle:-

Sulfate ion (SO_4^{2-}) is precipitated in an acetic acid, medium with barium sulfate chloride (BaCl2) so as to form barium sulfate (BaSO4) crystals of uniform size. Light absorbance of the BaSO4 suspension is measured by a photometer and the SO_4^{-2} concentration of the reading with a standard curve.

Interference:-

Color or suspended matter in large amounts will interfere. Some suspended matter may be removed by filtration. Silica in excess of 500 mg/l will interfere and in waters containing large quantities of organic material it may not be possible to precipitate BaSO4 satisfactorily.

Apparatus:-

Nephelometric turbidity meter with sample cells. Altermatively

Magnetic stirrer

Stopwatch (timer with indication of seconds)

Reagents:-

Dissolbe 0.1479 gr of NaSO4 in distilled water make.

Buffer solution:-

Dissolve 30 gr magnesium chloride, MgCl2.6H20, 5 gr sodium acetate, CH3COONa. 3H20, 1gr potassium nitrate KNO3, and 20 ml acetic acid CH3COOH (99%) in ml distilled water and make up to 1000ml.

Procedure.

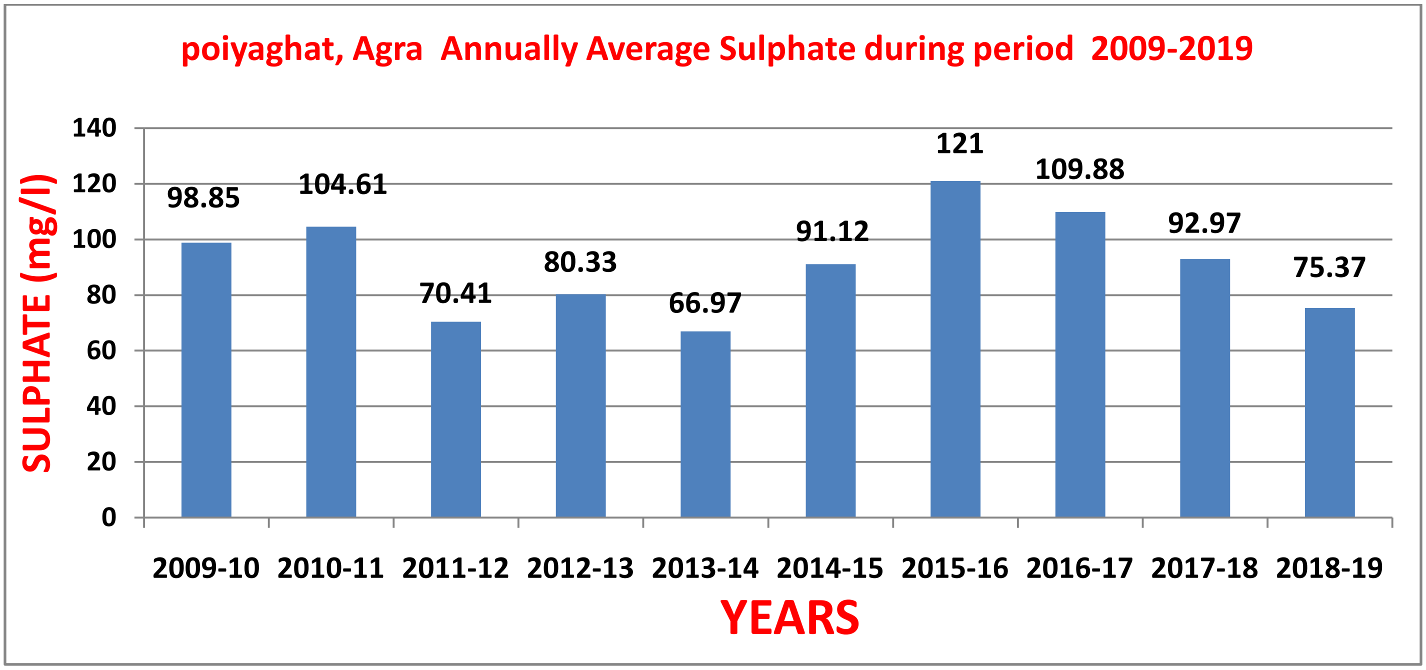
Standardize nephelometer following manufacture's instructions.

Formation of barium sulfate turbidity measure 100 ml sample or a suitable portion made up to 100 ml, into a 250 ml Erlenmeyer flask. Add 20ml buffer solution and mix in stirring apparatus. While stirring, add a spoonful of BaCl2 crystals and begin timing immediately stir for (60$\pm$2) s at constant speed.

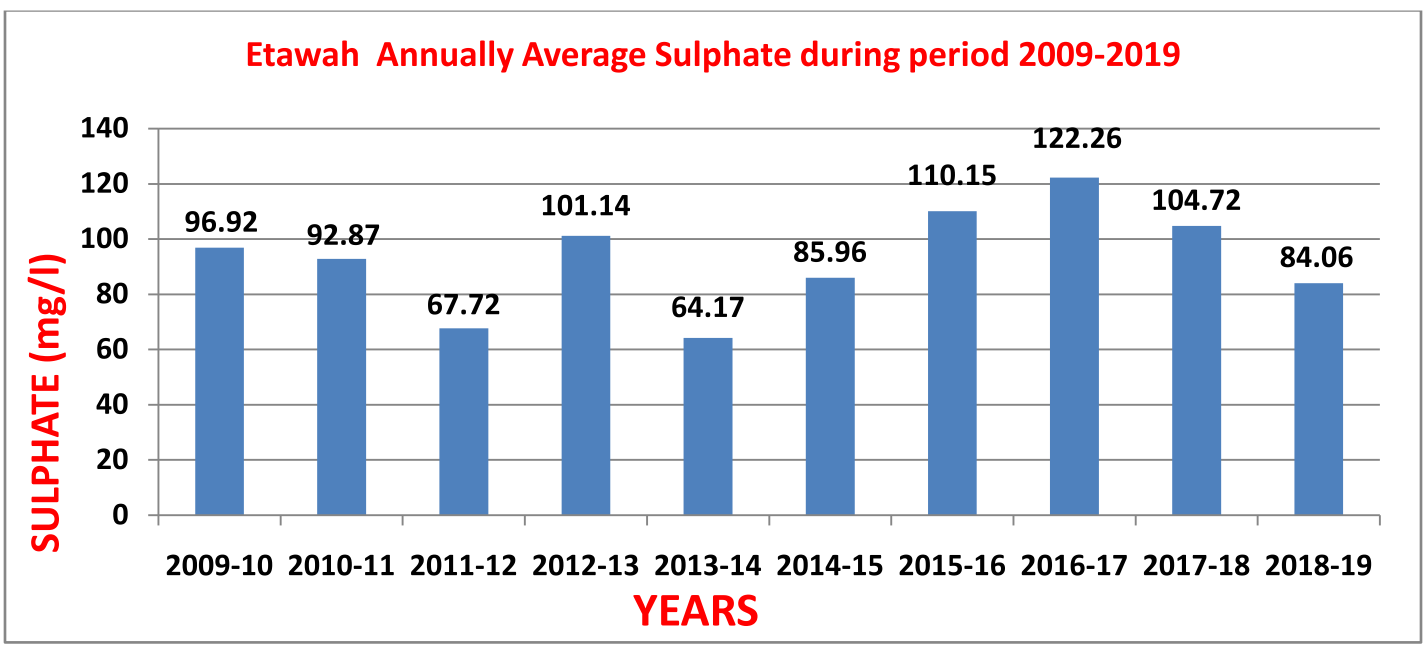
Measurement of Barium Sulfate turbidity:

After stirring period has ended, pour solution into absorption cell of photometer and measure turbidity at 5$\pm$0.5 min.

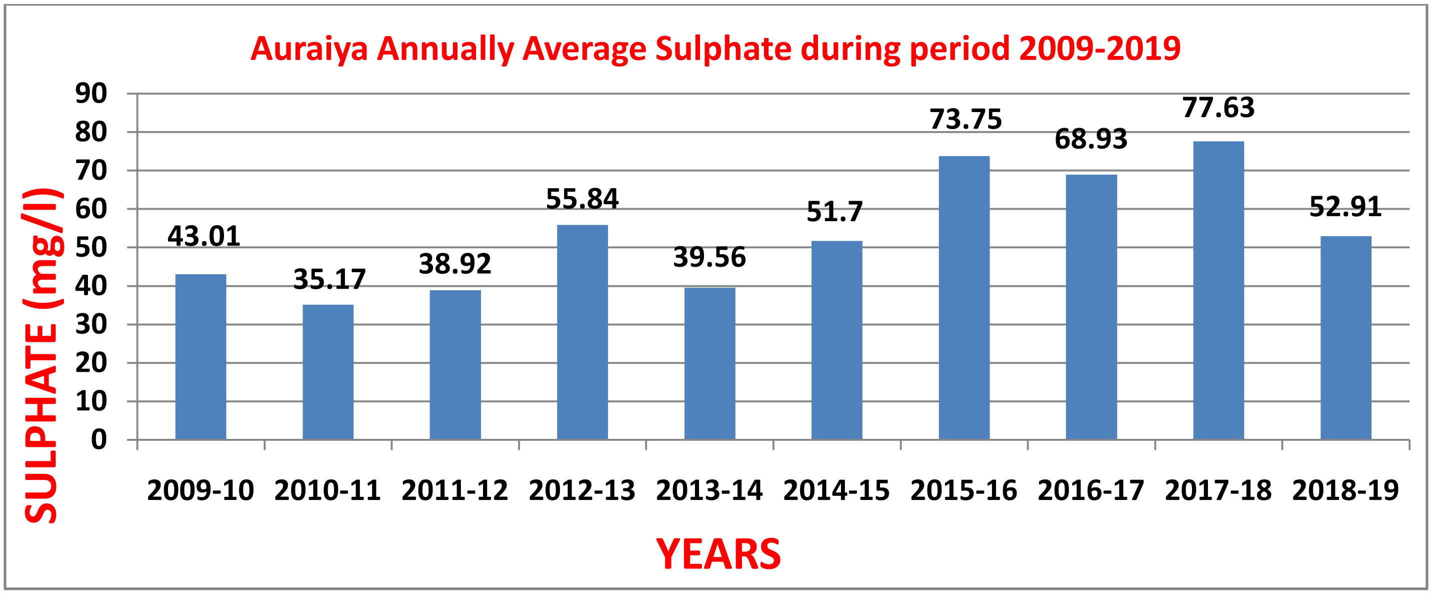
Sulphate Range 200 mg/lit.



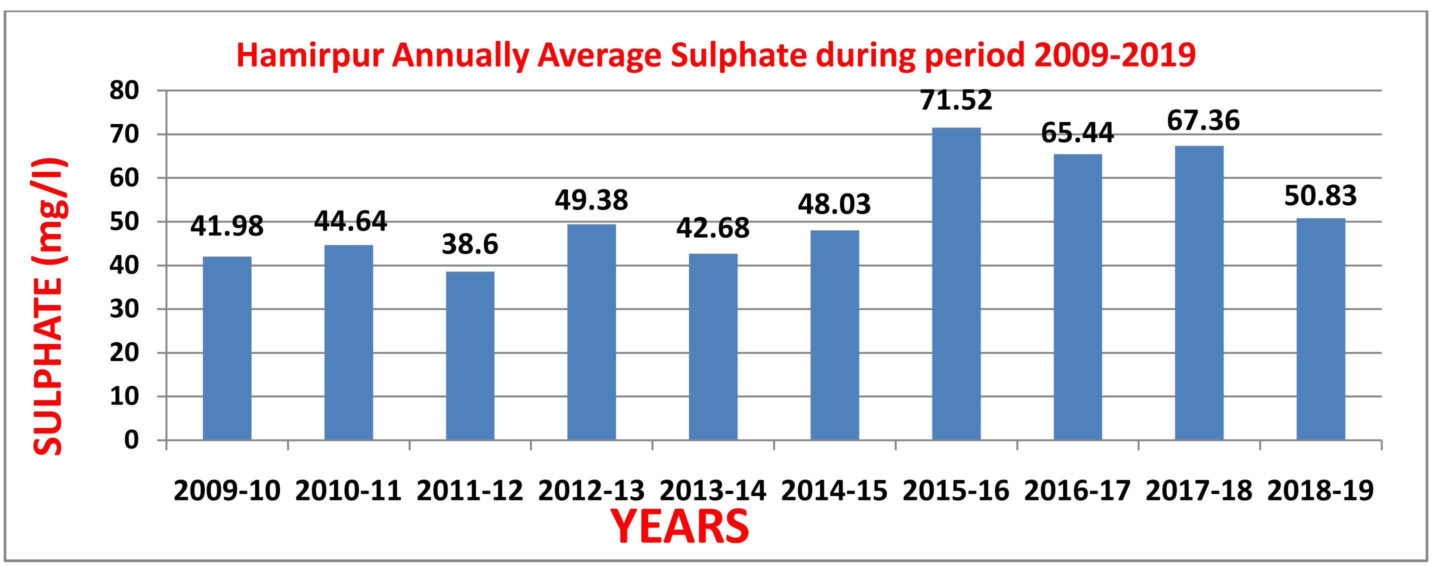
The Sulphate parameter at Poiyaghat Site has no trend.



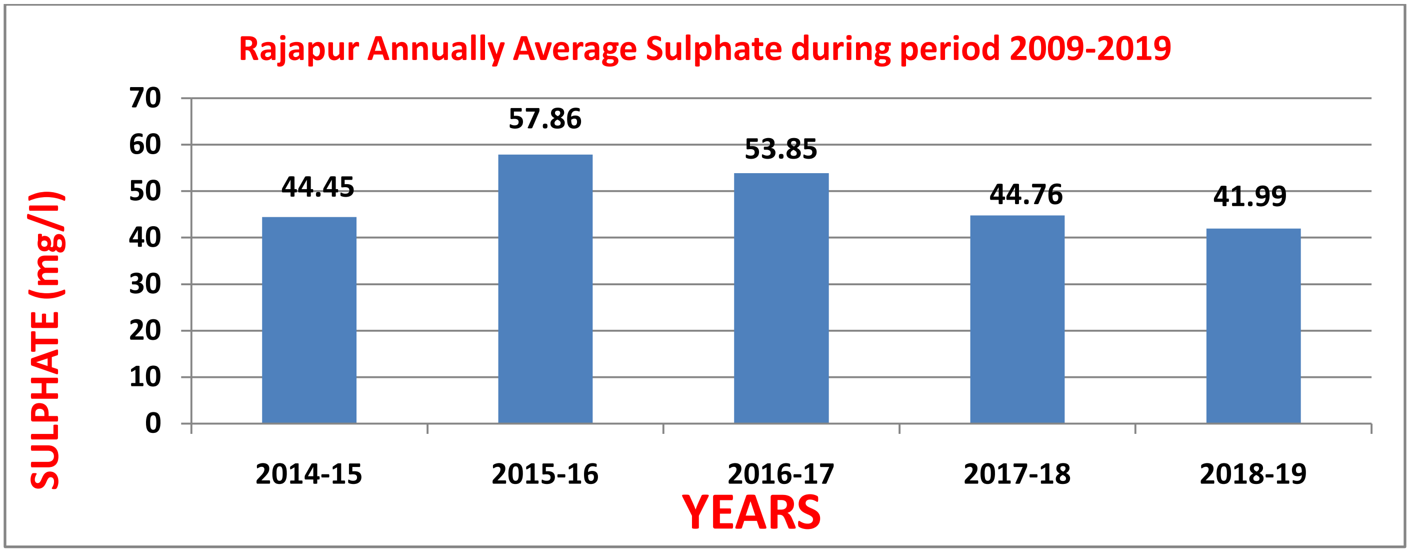
The Sulphate parameter at Etawah Site has no trend.



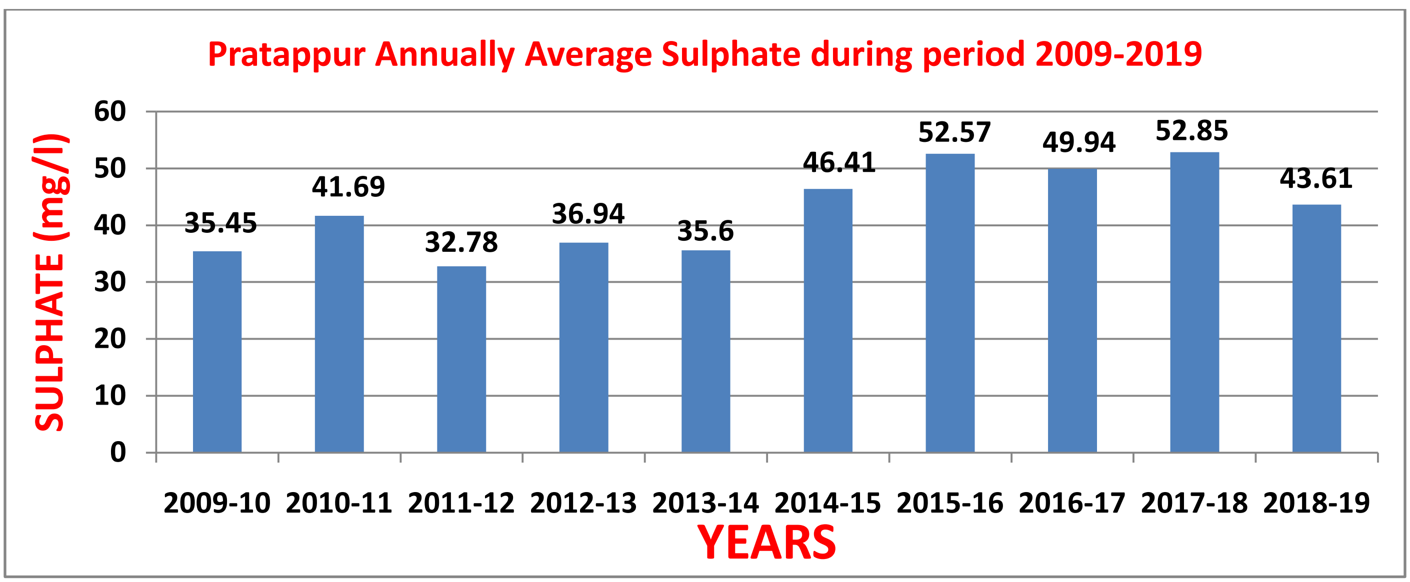
The Sulphate parameter at Auraiya Site has no trend.



The Sulphate parameter at Hamirpur Site has no trend.



The Sulphate parameter at Rajapur Site has no trend.



The Sulphate parameter at Pratappur Site has no trend.

FLAME EMISSION PHOTOMETRIC METHOD

SODIUM (Na)

Principle:

Trace amount of sodium can be determine by flame emission photometry at the wavelength of 598 nm. The sample is sprayed into a gas flame and excitation is carried out under carefully controlled and reproducible conditions. The desired special line is isolated by the use of interference filters or by a suitable slit arrangement in light-dispersing devices such as prisms or gratings. The intensity of light at 589nm is approximately proportional to the concentration of the element.

Interference:-

Operate in the lowest practical sodium concentration range.

Add radiation buffers to suppress ionization and anion interference. Among common anions capable of causing radiation interference are Cl^- ,SO_4^{-2} and HCO_3^- in relatively large amounts.

Remove burner clogging particulate matter from the sample by filtering through a quantitative filter paper of medium retentivencess.

Apparatus:-

a) Flame photometer, direct reading type.
b) Glassware rinse with 1+15 HNO3, followed by de-ionised distilled water.
c) Plastic bottles, to store all solutions.

Reagents:-

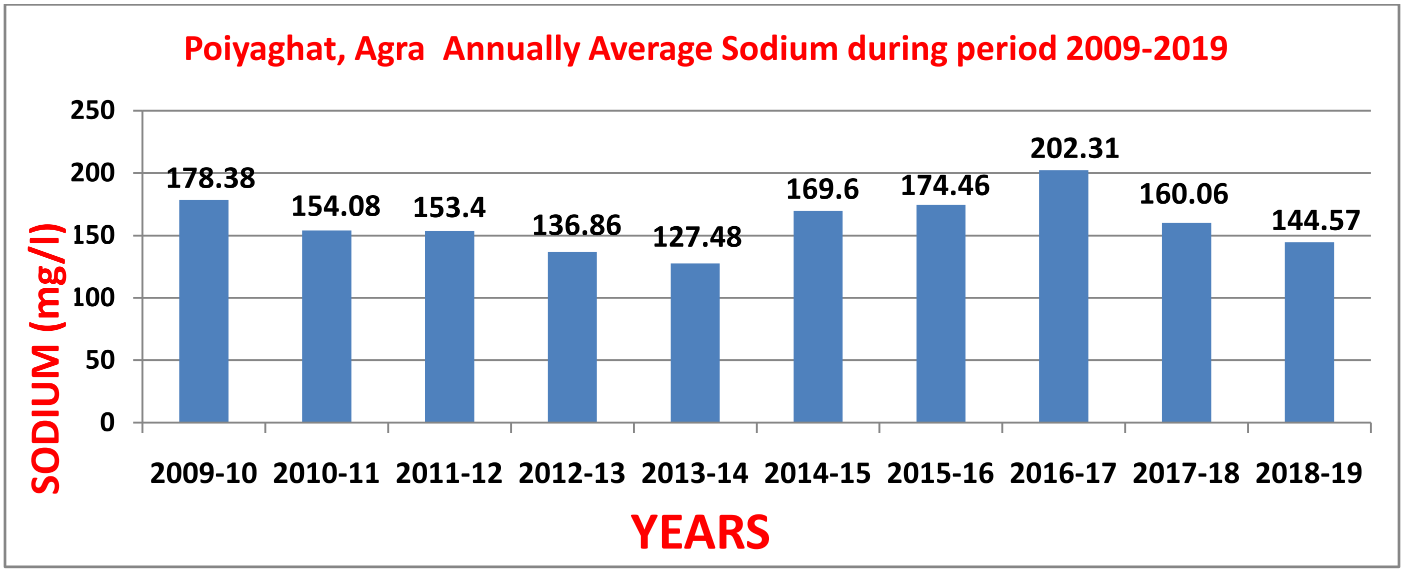
Stock sodium Solution:- weight 2.542 gr NaCl, dried at 140°C and cooled in desiccator, transfer to 1 lit. volumetric flask and make to 1 lit with water. 1ml= 1.00 mg Na.

Intermediate Sodium solution:-

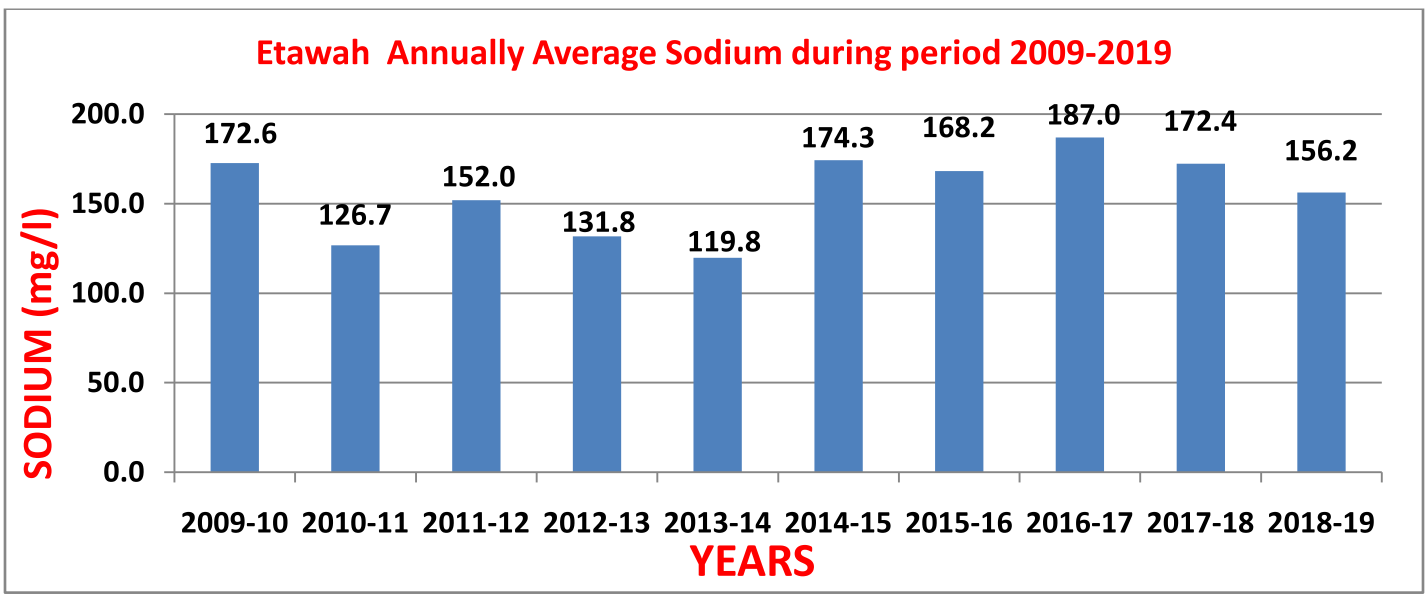
Dilute 10 ml stock sodium solution with water to 100ml; 1ml=0.1mg Na, prepare calibration curve in the range of 1 to 10 mg/lit.

Dilute 10 ml intermediate solution with water to 100 ml, 1ml=10µg Na, prepare calibration curve in the range of 0.1 to 1 mg/lit.

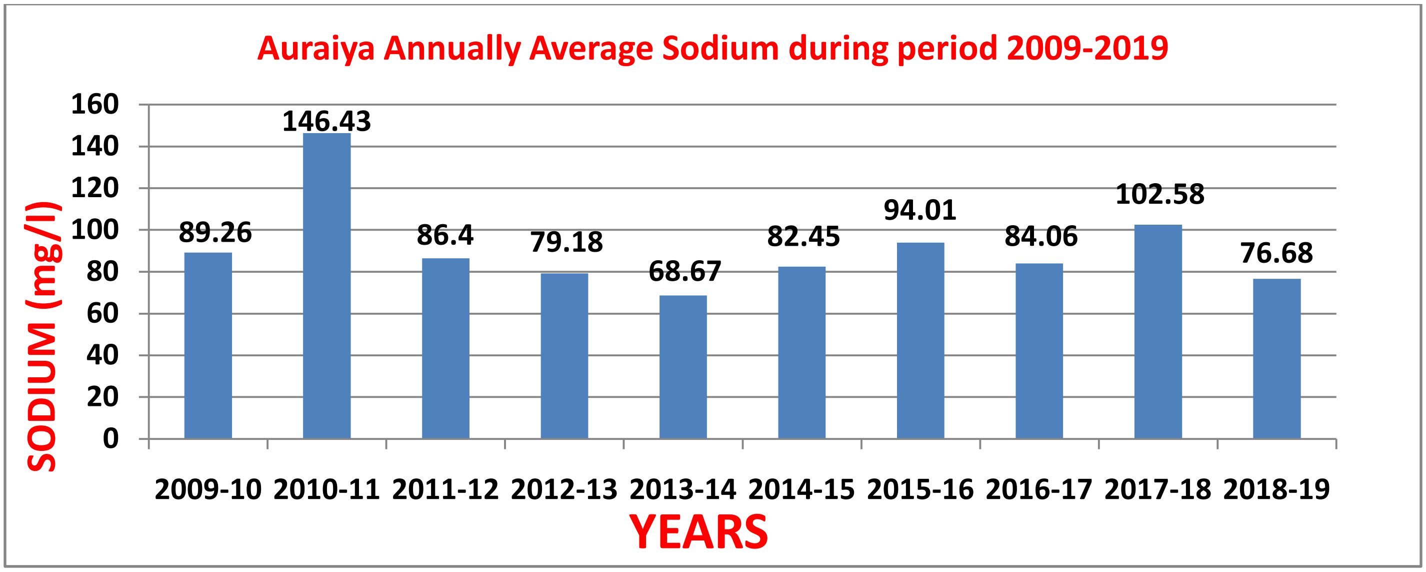
Procedure:- Follow instruction of flame photometer manufacturer for selecting proper photocell, wavelength, slit width adjustments, fuel gas and air pressure, steps for warm up, correcting for interference and flame background rinsing of burner sample ignition and emission intensity measurments.



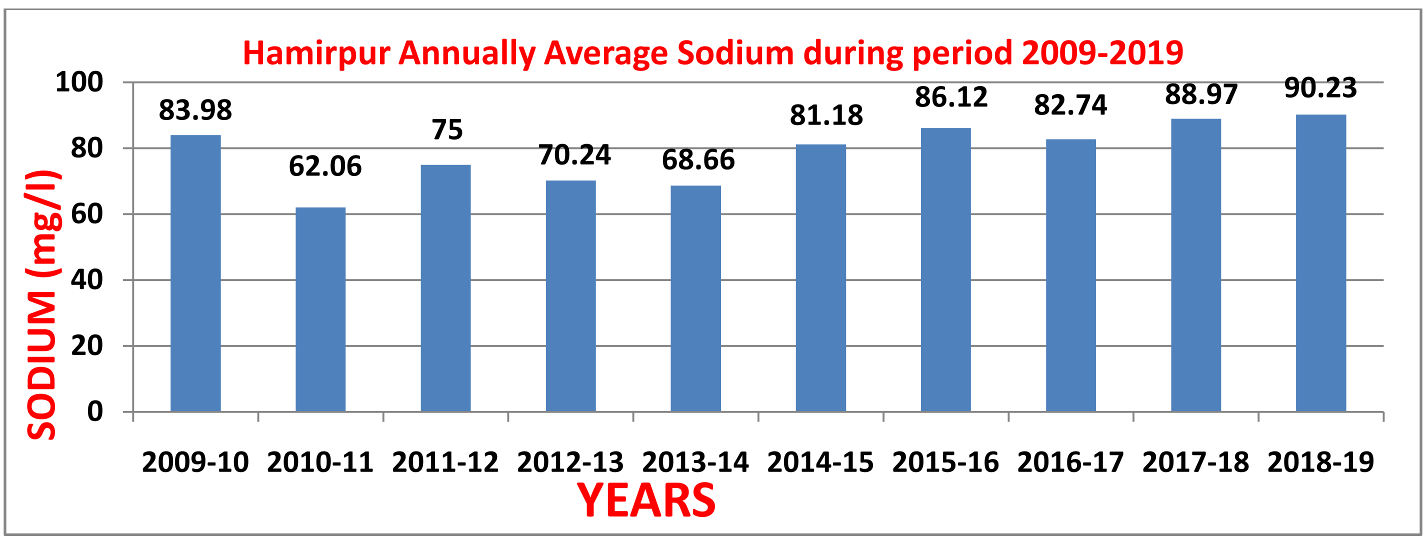
The Sodium parameter at Poiyaghat Site has no trend.



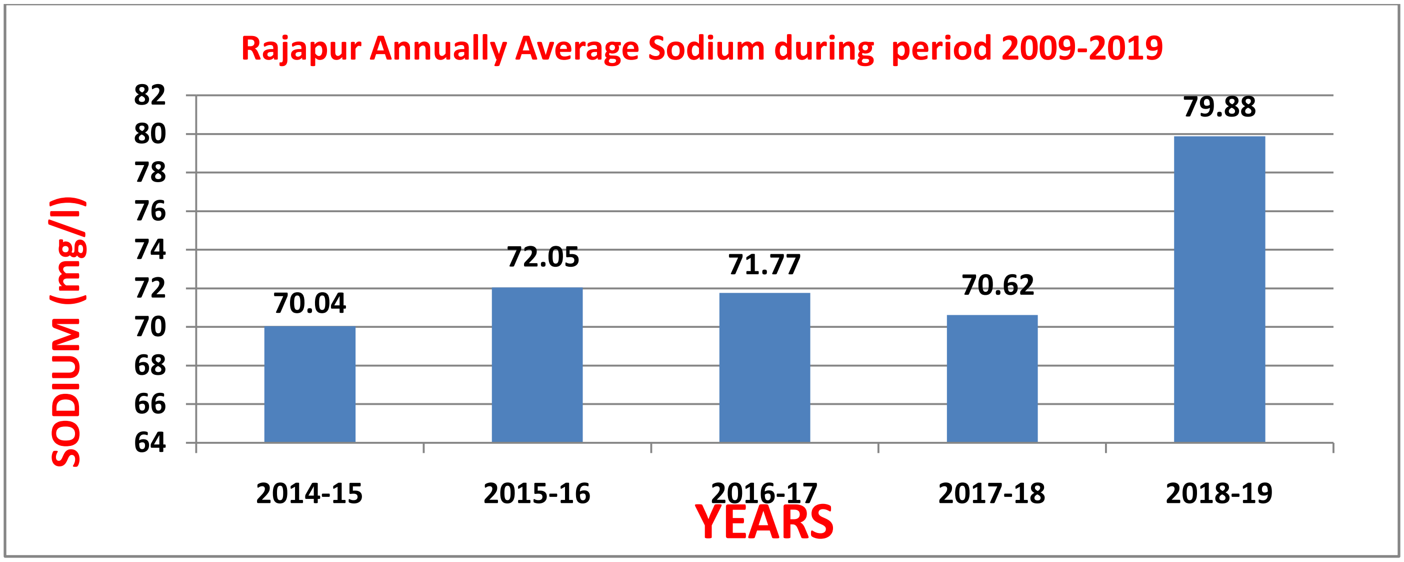
The Sodium parameter at Etawah Site has no trend.



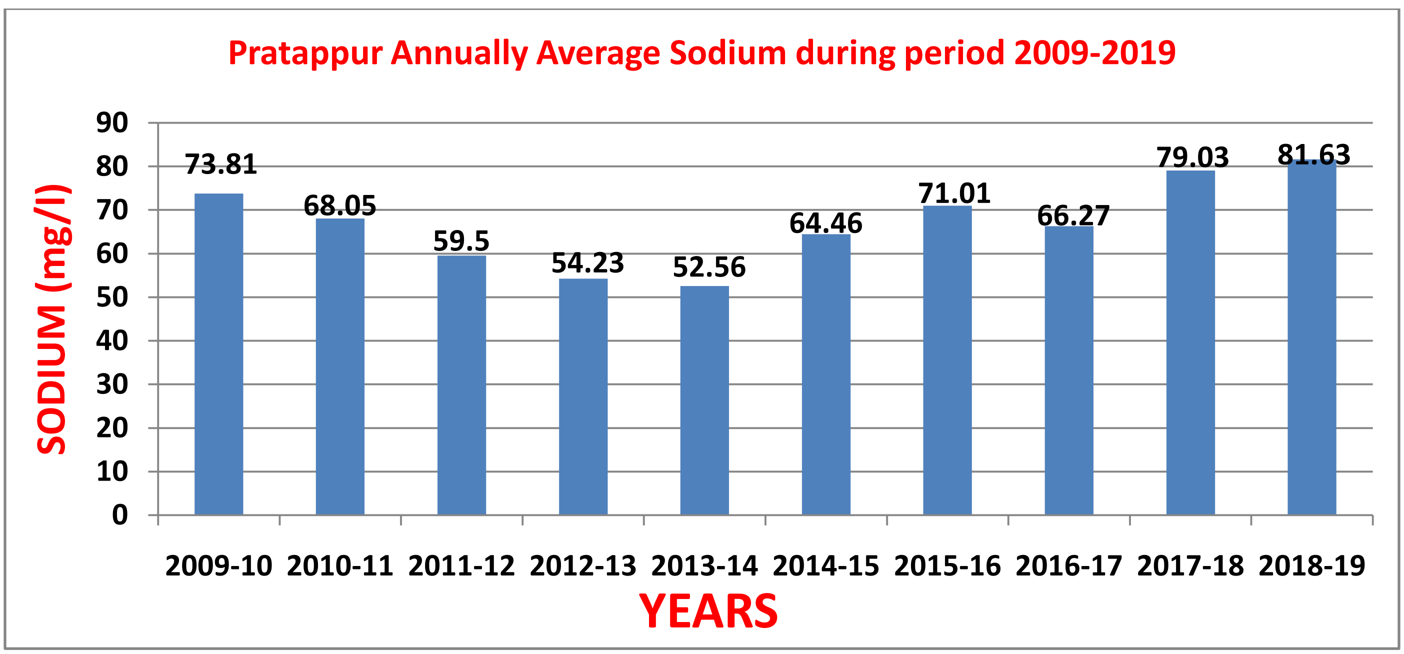
The Sodium parameter at Auraiya Site has no trend.



The Sodium parameter at Hamirpur Site has no trend.



The Sodium parameter at Rajapur Site has no trend.



The Sodium parameter at Pratappur Site has no trend.

POTASSIUM

Principle:-

Trace amounts of potassium can be determined in either a direct-reading or internal standard type of flame photometer at a wavelength of 766.5nm. because much of the information pertaining to sodium applies equally to the potassium determination of sodium before making a potassium determination.

Interference:-

Interference in the internal standard method may occur at sodium to potassium ratios of 5:1 or greater. Calcium may interfere if the calcium to potassium ratio is 10:1 or more. Magnesium begins to interfere when the magnesium to potassium ratio exceeds 100:1.

Apparatus:-

Flame photometer direct reading type.

Glassware rinse with 1+15 HNO_3, followed by de-ionised distilled water.

a) Plastic bottles, to store all solutions.

Reagents

Stock Potassium solution:

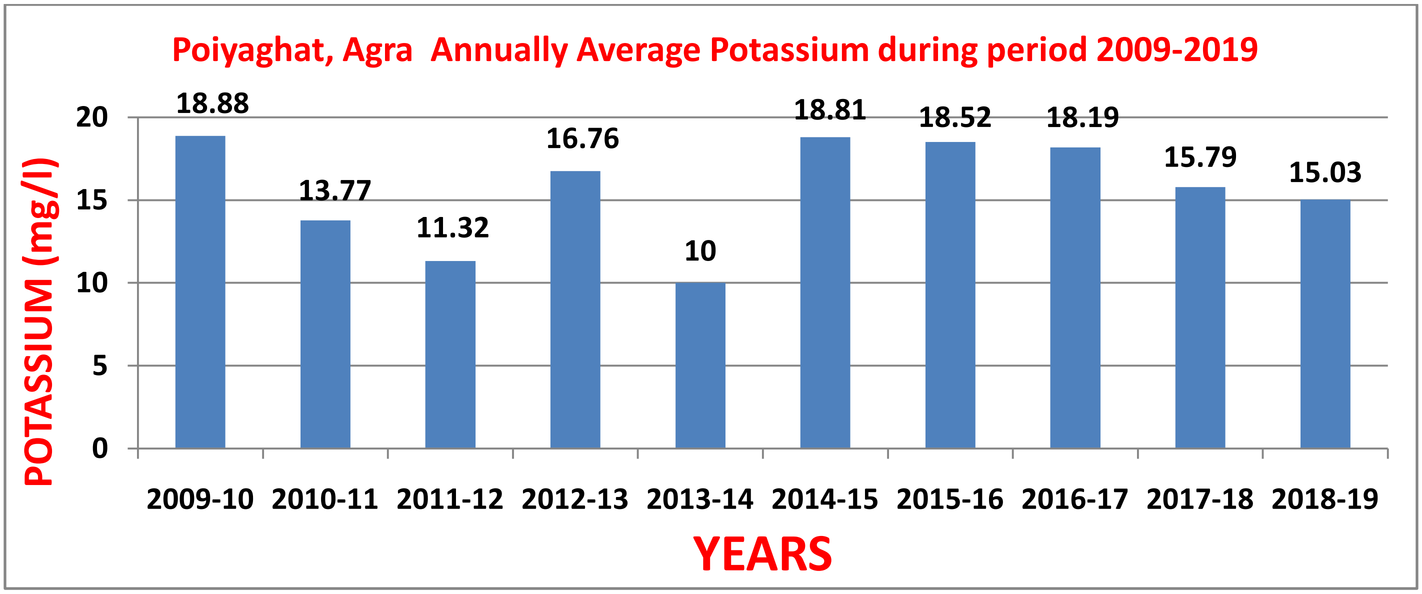
weight 1.907 gr KCl, dried at 110°C and cooled in desiccator, transfer to 1 lit. volumetric flask and make to 1 lit with water. 1ml= 1.00 mg K.

Intermediate Potassium solution:

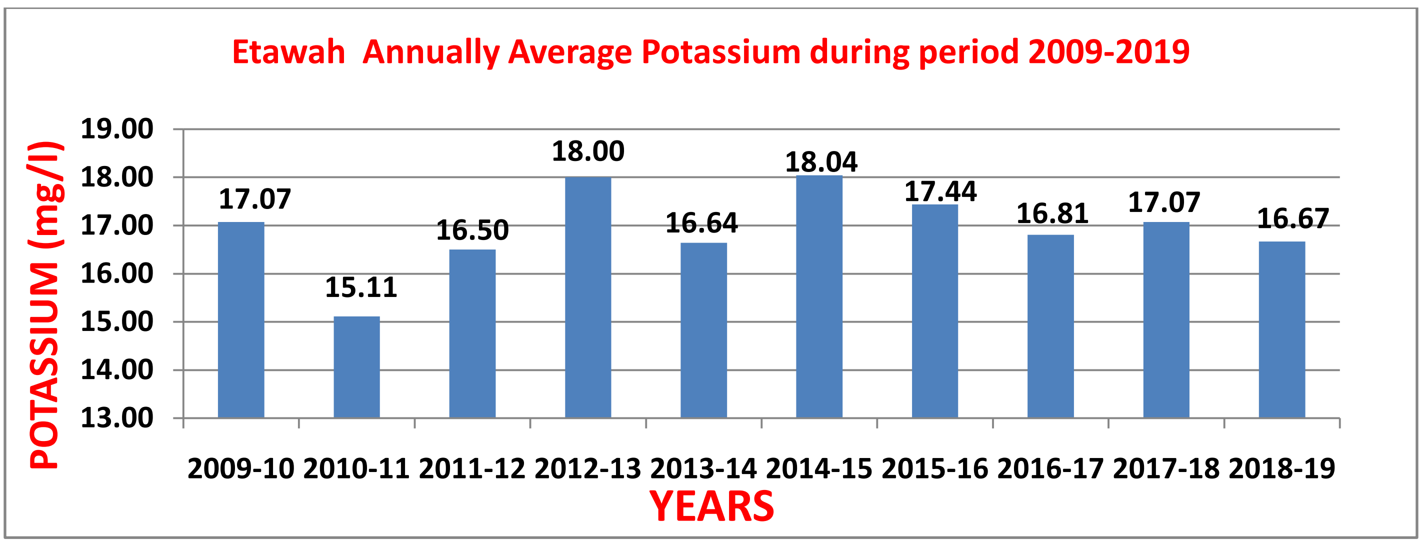
Dilute 10 ml stock potassium solution with water to 100ml; 1ml=0.1mg K, prepare calibration curve in the range of 1 to 10 mg/lit.

Dilute 10 ml intermediate solution with water to 100 ml, 1ml=10µg Na, prepare calibration curve in the range of 0.1 to 1 mg/lit.

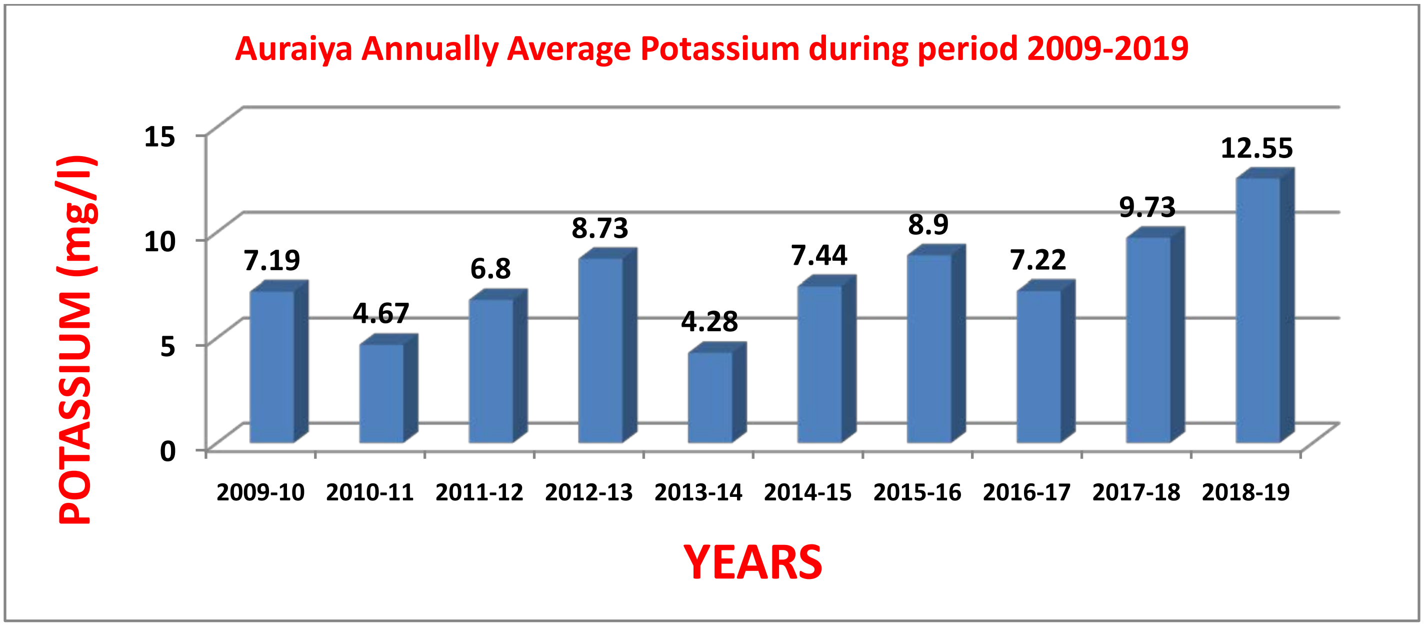
Procedure:- Follow instruction of flame photometer manufacturer for selecting proper photocell, wavelength, slit width adjustments, fuel gas and air pressure, steps for warm up, correcting for interference and flame background rinsing of burner sample ignition and emission intensity measurments.



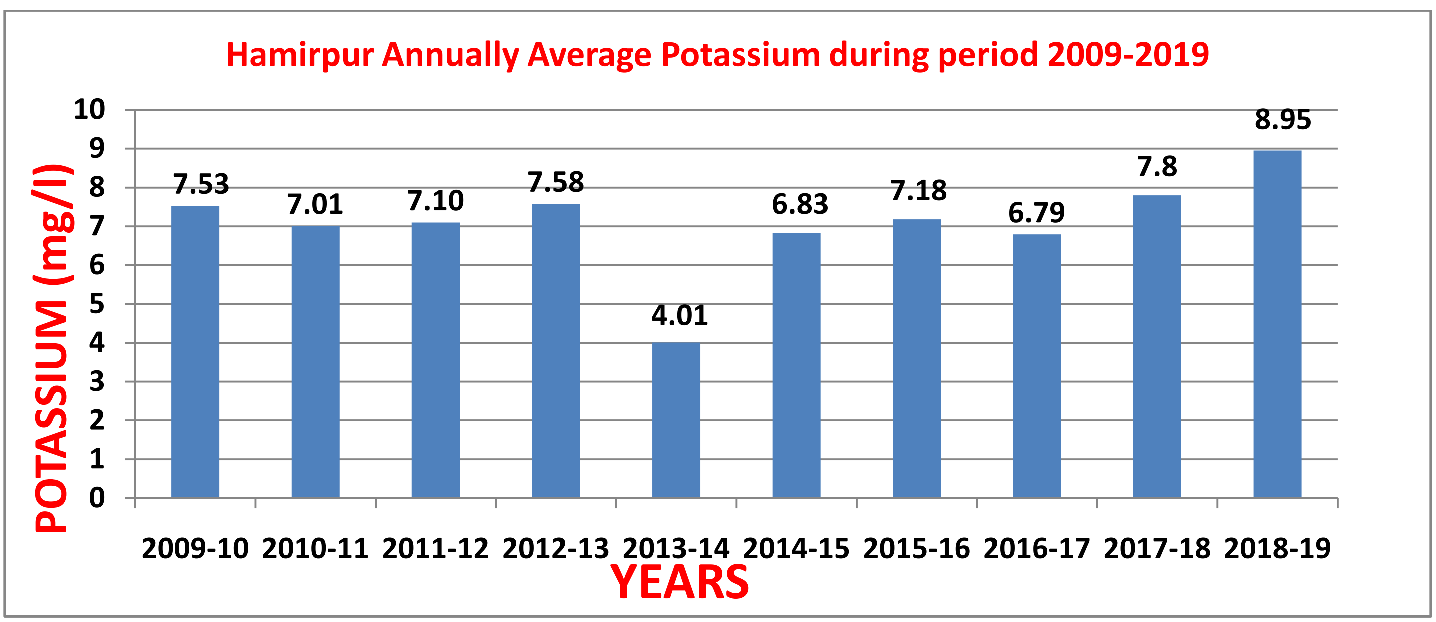
The Potassium parameter at Poiyaghat Site has no trend.



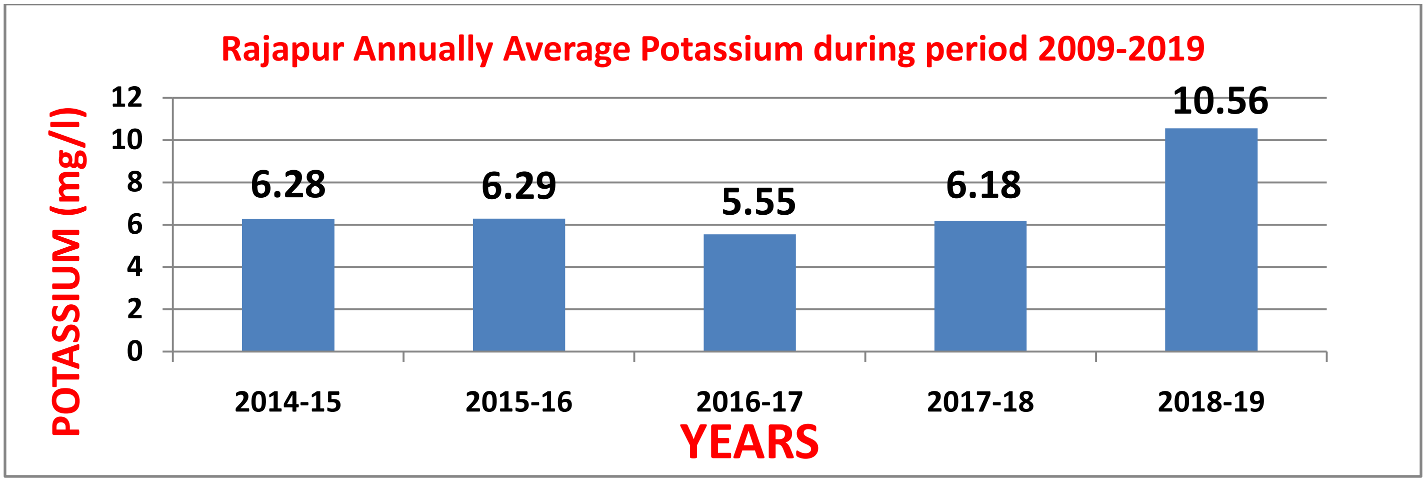
The Potassium parameter at Etawah Site has no trend.



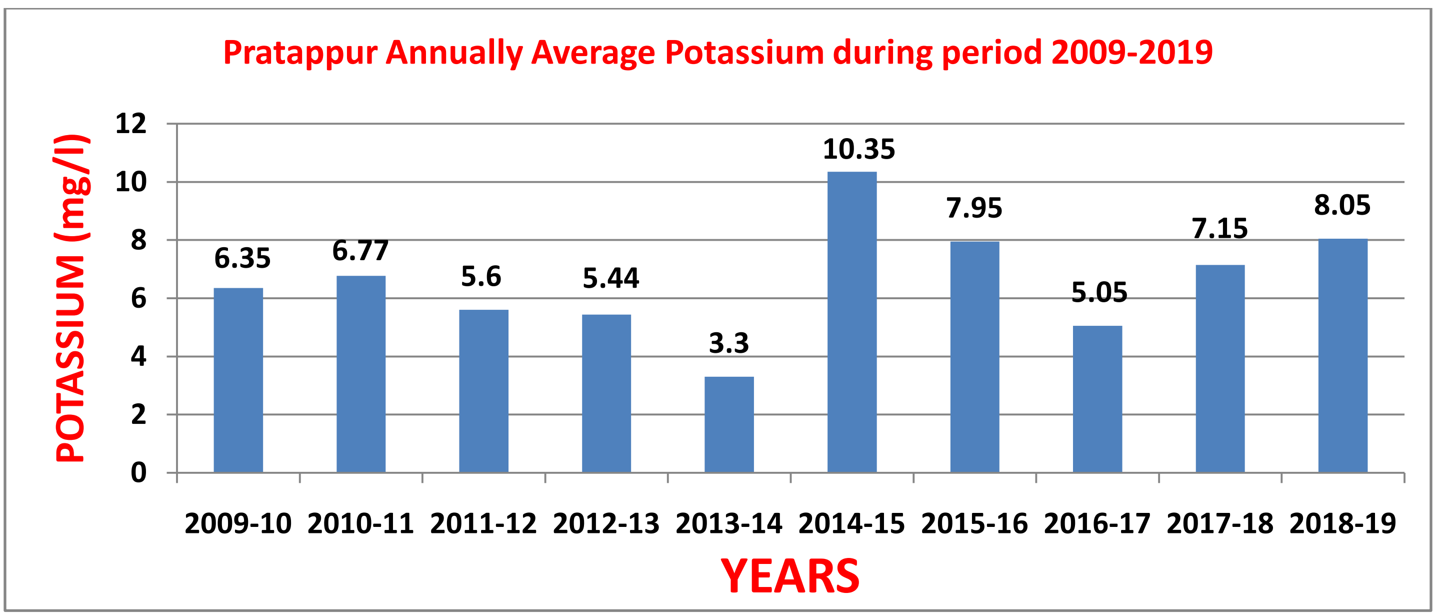
The Potassium parameter at Auraiya Site has no trend.



The Potassium parameter at Hamirpur Site has no trend.



The Potassium parameter at Rajapur Site has no trend.



The Potassium parameter at Pratappur Site has no trend.

CHLORIDE

Principle:-

In a neutral or slightly alkaline solution, potassium chromate can indicate the end point of the silver chloride is precipitated quantitatively before red silver chromate is formed.

Interference:-

Substance in amounts normally found in potable water will not interfere. Bromide, iodide, and cyanide register as equivalent chloride concentrations. Sulfide, thiosulfate, and sulfite ions interfere but can removed by treatment with hydrogen peroxide.

Reagents:-

Potassium Chromate indicator solution:-

Potassium chromate 50gr K_2CrO_4 in a little distilled water. add AgNO3 solution until a definite red precipitate is formed. Let stand 12 hours and filter and dilute 1 lit with distilled water.

Standard Silver Nitrate titrant, 0.0141M (0.0141N):-

Dissolve 2.395gr AgNO3 in distilled water and dilute to 1000ml. standardize against NaCl by the procedure in store in a brown bottle.

Standard Sodium Chloride 0.0141M (0.0141N):-

Dissolve 0.824gr NaCl (dried at 140°C) in distilled water and dilute to 100ml; 1.00 ml = 500 µg Cl^-.

Procedure:-

Directly titrant samples in the pH range 7 to 10. Adjust samples pH 7 to 10 with H2SO4 or NaOH if it is not in this range. For adjustment, preferably use a pH meter with a non - chloride type reference electrode. (if only a chloride type electrode is available, determine amount of acid or alkali needed for adjustment and discard this sample portion. Add 1.0 ml K2CrO4 indicator solution. Titrant to a pinkish yellow end point. Be consistent in end-point recognition.

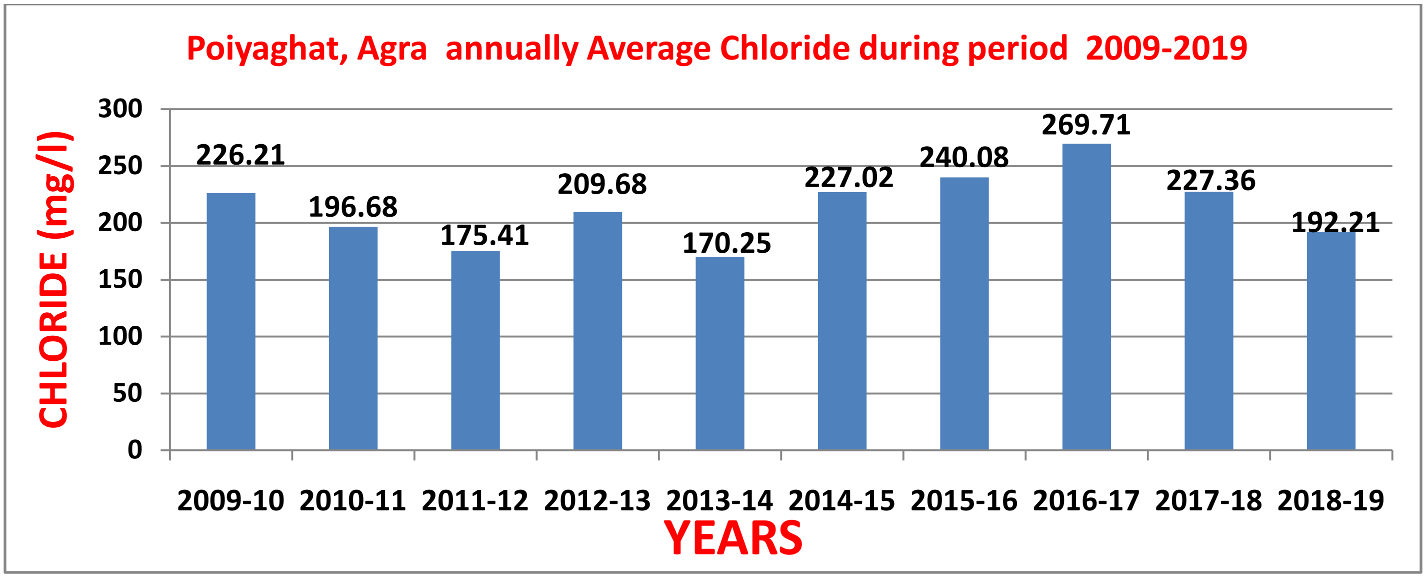
Calculation:-

mg Cl^{--}/L = (A – B) X N X 35.45/ ml sample.

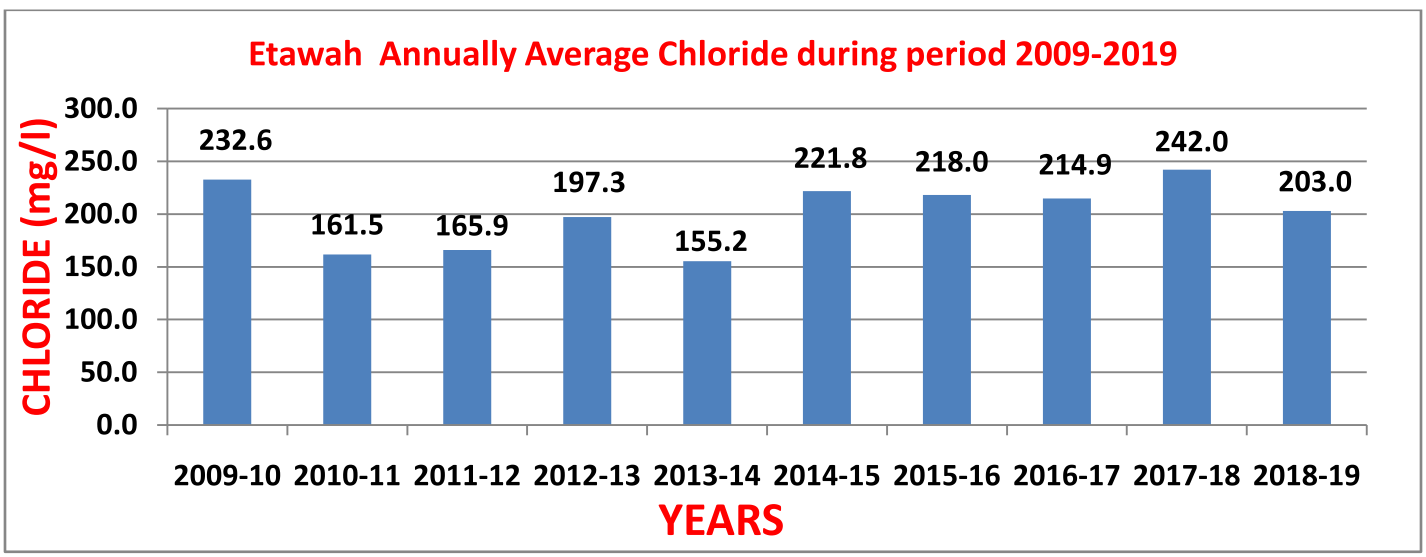
Where: A = ml titration for sample,

B = ml titration for blank

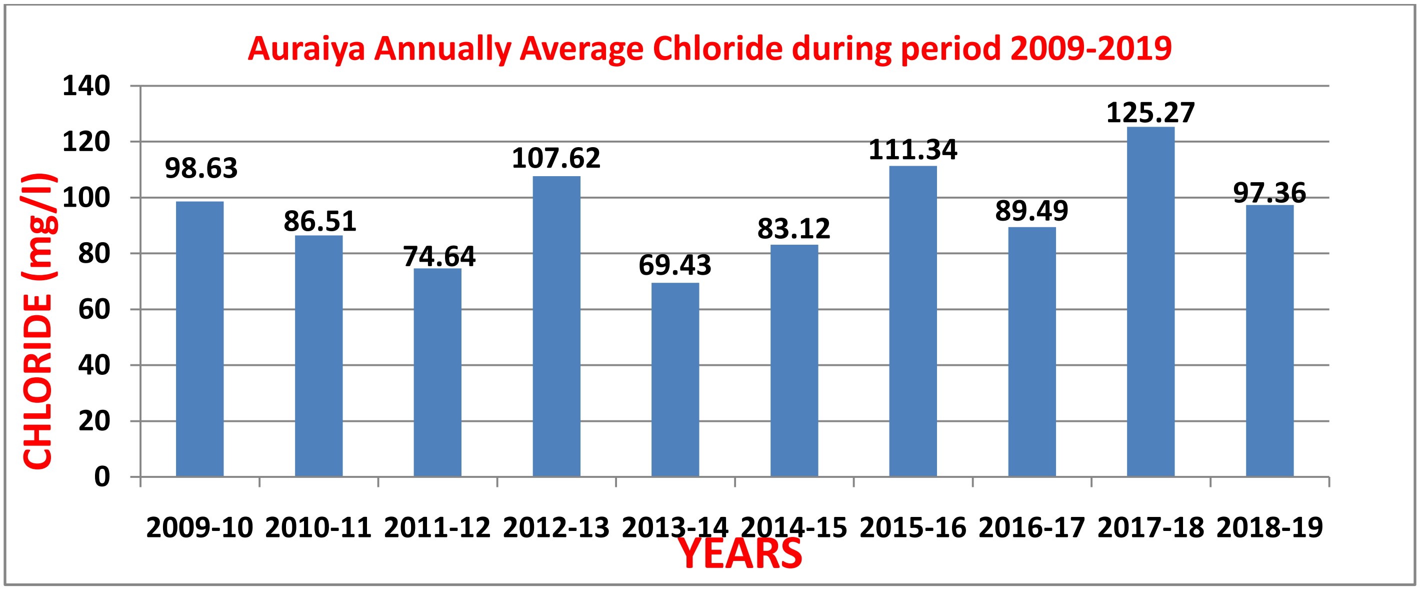
N = normality of AgNO3.



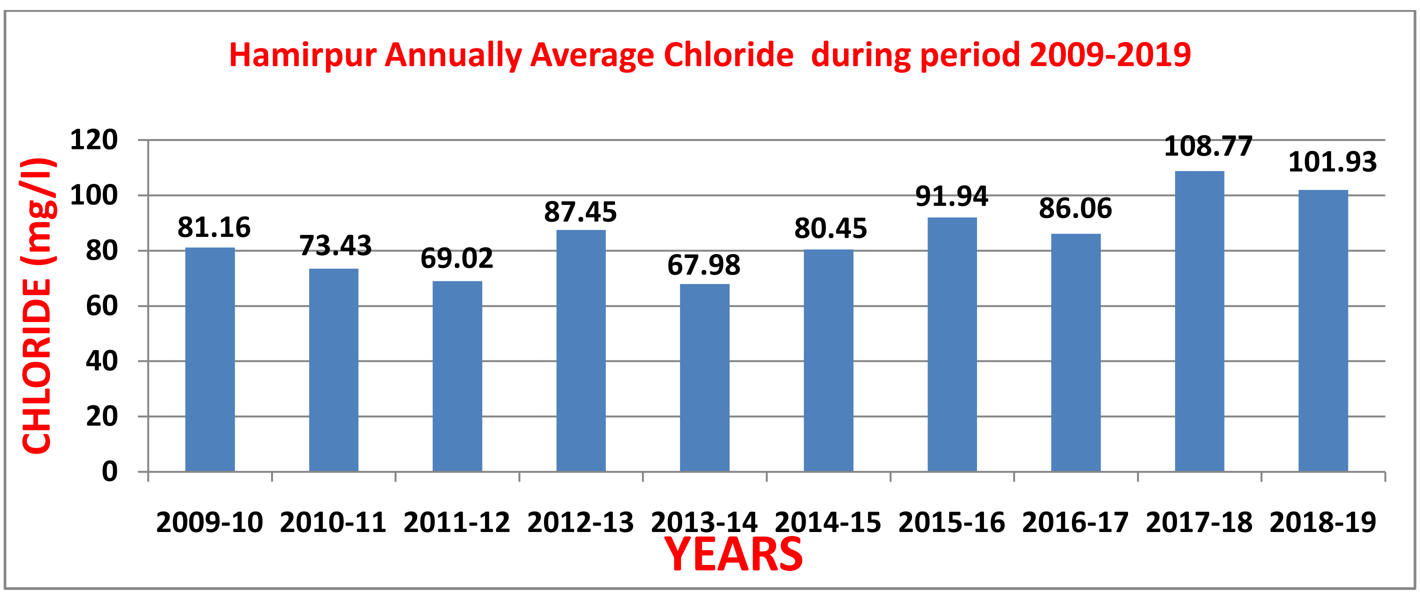
The Chloride parameter at Poiyaghat Site has no trend.



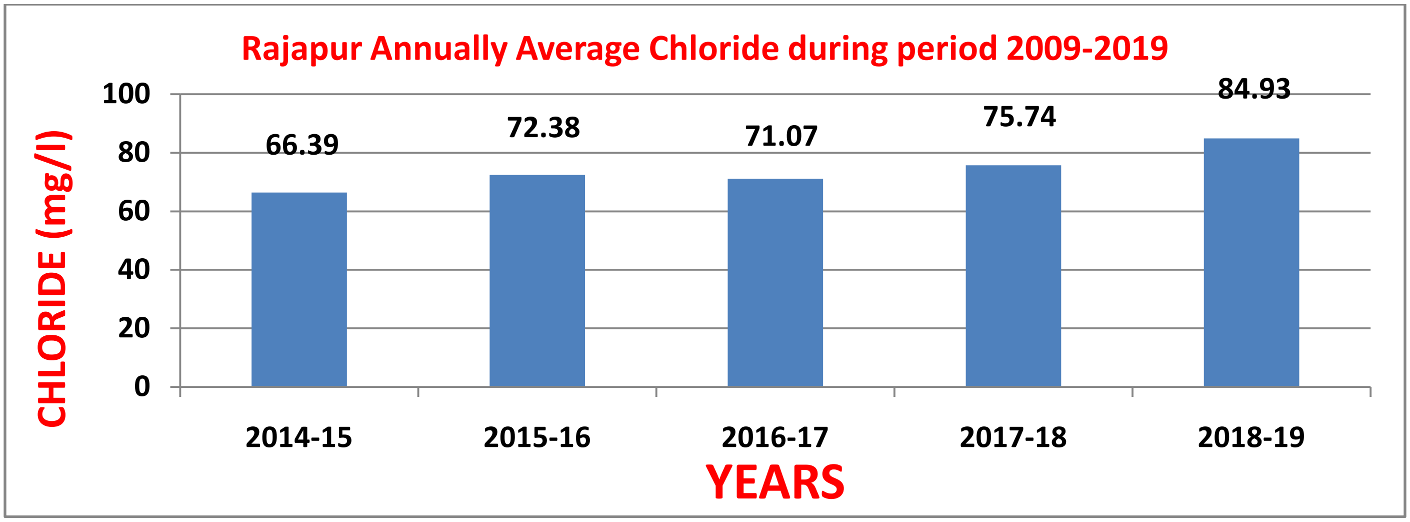
The Chloride parameter at Etawah Site has no trend.



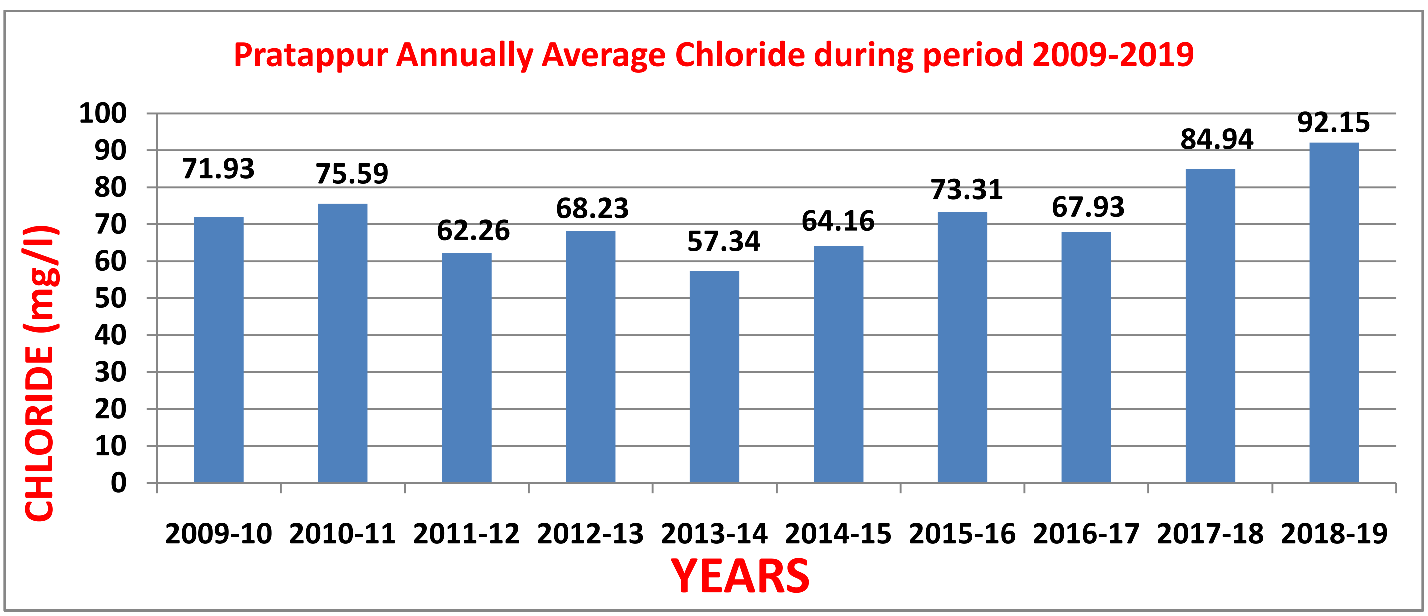
The Chloride parameter at Auraiya Site has no trend.



The Chloride parameter at Hamirpur Site has no trend.



The Chloride parameter at Rajapur Site has no trend.



The Chloride parameter at Pratappur Site has no trend.

TOTAL ALKALINITY

Principle:-

Hydroxyl ions present in a sample as a result of dissociation or hydrolysis of solutes react with additions of standard acid. Alkalinity thus depends on the end-point pH used. Alkalinity of sample can be estimated by titrating with standard sulphuric acid (0.02N) at room temperature using phenolphthalein and methyl orange indicator. Titration to decolourisation of phenolphthalein indicator will indicate complete neutralization of OH- and ½ of CO_3 while sharp change from yellow to orange of methyl orange indicator will indicate total alkalinity (complete neutralization of OH-, CO_3^{-2}, HCO_3^{-}).

END POINT:-

When alkalinity is due entirely to carbonate of bicarbonate content the pH at the equivalent point of the titration is determined by the concentration of depends, in turn on the total carbonate species originally present and any losses that may have occurred during titration.

Phenolphthalein alkalinity is the term traditionally used for the quantity measured by titration to pH 8.3 irrespective of the colored indicator, if any used in the determination phenolphthalein or metacresol purple may be used for alkalinity titration to pH 8.3 Bromcresol green or a mixed bromocresol green-methyl red indicator may be used for pH 4.5.

Reagents and standards.

Standard Sodium Carbonate:-

Dry 3 to 5 sodium carbonate, Na_2CO_3 at 250°C for 4 hours and cool in a desiccator. Accurately weigh 2.65±0.2 gr to the nearest mg dissolve in distilled water and make to 1L.

Standard H_2SO_4 approximately 0.1 N:

Dilute 2.8 ml concentration sulphuric acid to 1 L standardize against 40.0 ml 0.05N Na_2CO_3 with about 60 ml distilled water, in a beaker by titrating potentiometrically to pH 5. Lift out electrodes, rinse into the same beaker and boil gently for 3 to 5 min under a watch glass cover cool to room temperature rinse cover glass into beaker and finish titration to pH 4.3 calculation normality of sulphuric acid.

Normality, N = A X B/53.00XC

Where A= g Na_2CO_3 weighed into the 1 L-flask for the Na_2CO_3

B= ml Na_2CO_3 solution taken for standardization titration.

C= ml acid used in standardization titration.

Phenolphthalein indicator:

Dissolve 0.5 gr 500 ml 95% ethyl alcohol. Add 500 ml distilled water. Add dropwise 0.02N NaOH till faint pink colour appears (pH = 8.3).

Methyl Orange indicator:

Dissolve 0.5 gr and dilute to 1000 ml with CO2 free distilled water(pH 4.3-4.5).

Bromo-cresol green indicator:

Dissolve 0.1 gr bromocresol green, sodium salt, in 100 ml distilled water (pH 4.5).

Procedure:

Take 25 ml or 50 ml sample in conical flask and add 2-3 drops of phenolphthalein indicator.

If pink colour develops titrate with 0.02 N H_2SO_4 till it disappears or pH is 8.3.

Note the volume of H_2SO_4 required.

Add 2-3 drops methyl orange or bromo-cresol to the same flask and continue titration till yellow colour to orange.

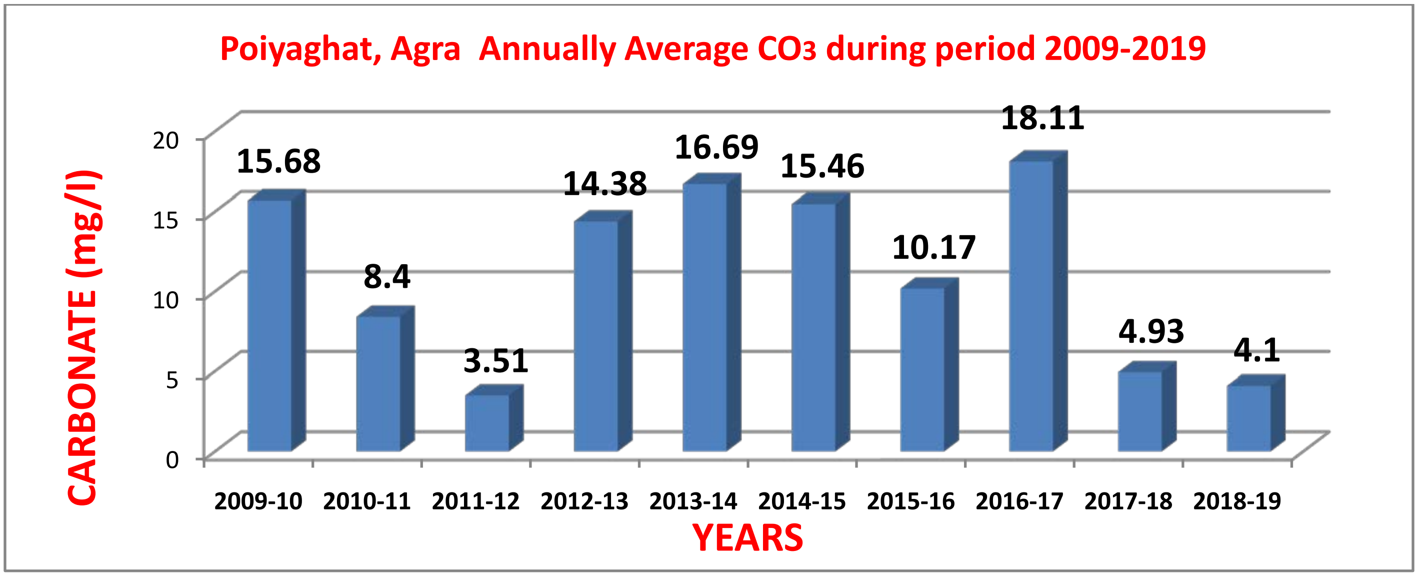
Not e the volumes of H_2SO_4 required.

Calculation:

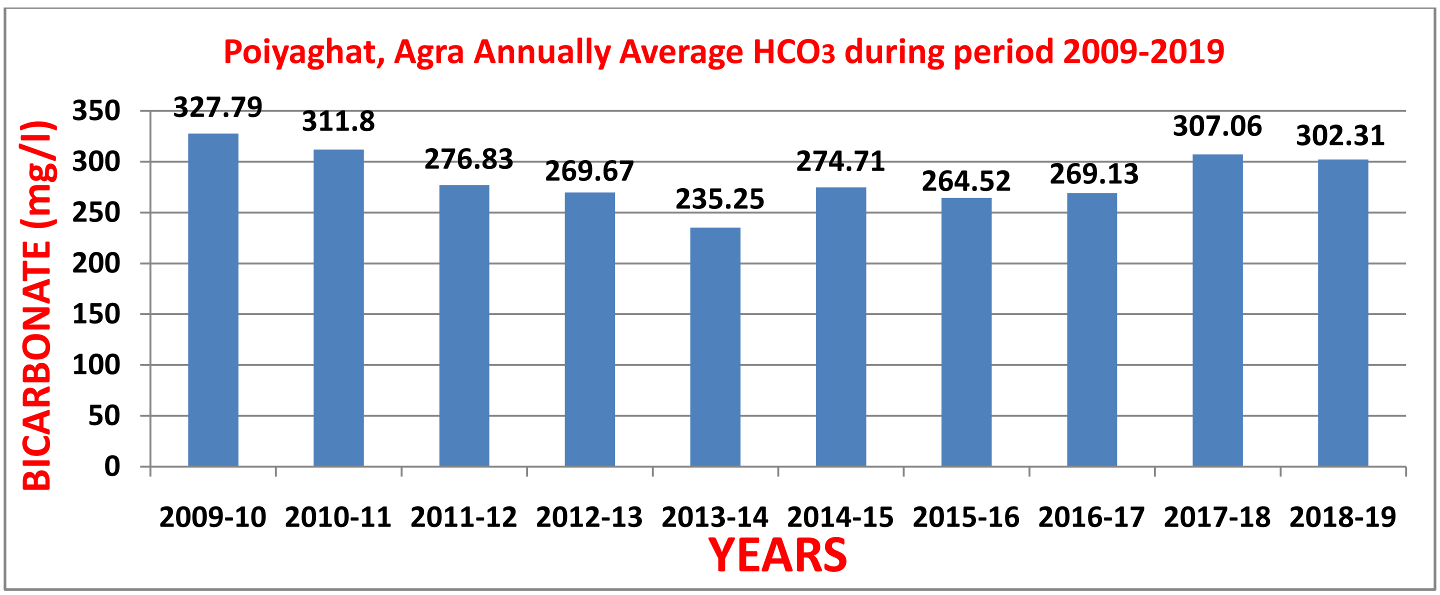
Factor for carbonate :- normality of H_2SO_4 X Eq. wt of Co_3^{-2} (30) X 1000/vol of sample taken.

Factor for bicarbonate :- normality of H_2SO_4 X Eq. wt of HCo_3^{-} (61) X 1000/vol of sample taken.

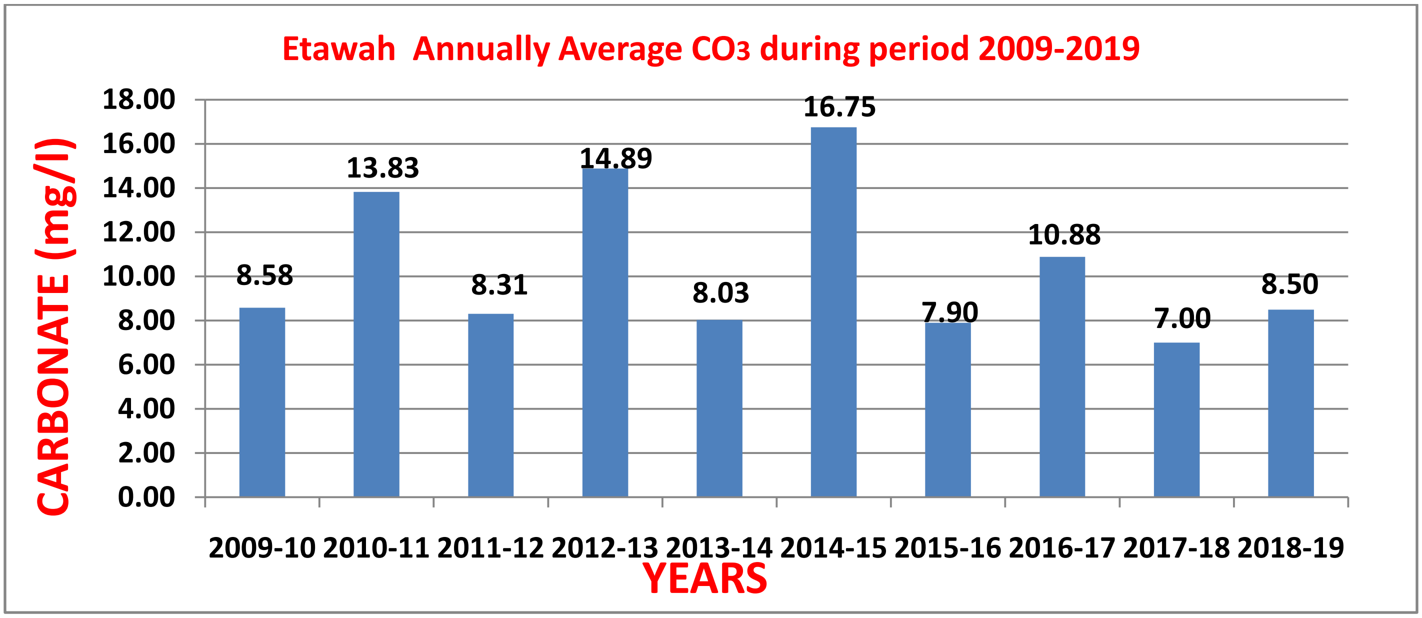
Factor for total alkalinity :- normality of H_2SO_4 X Eq. wt of $CaCO_3$(50) X 1000/vol of sample taken.



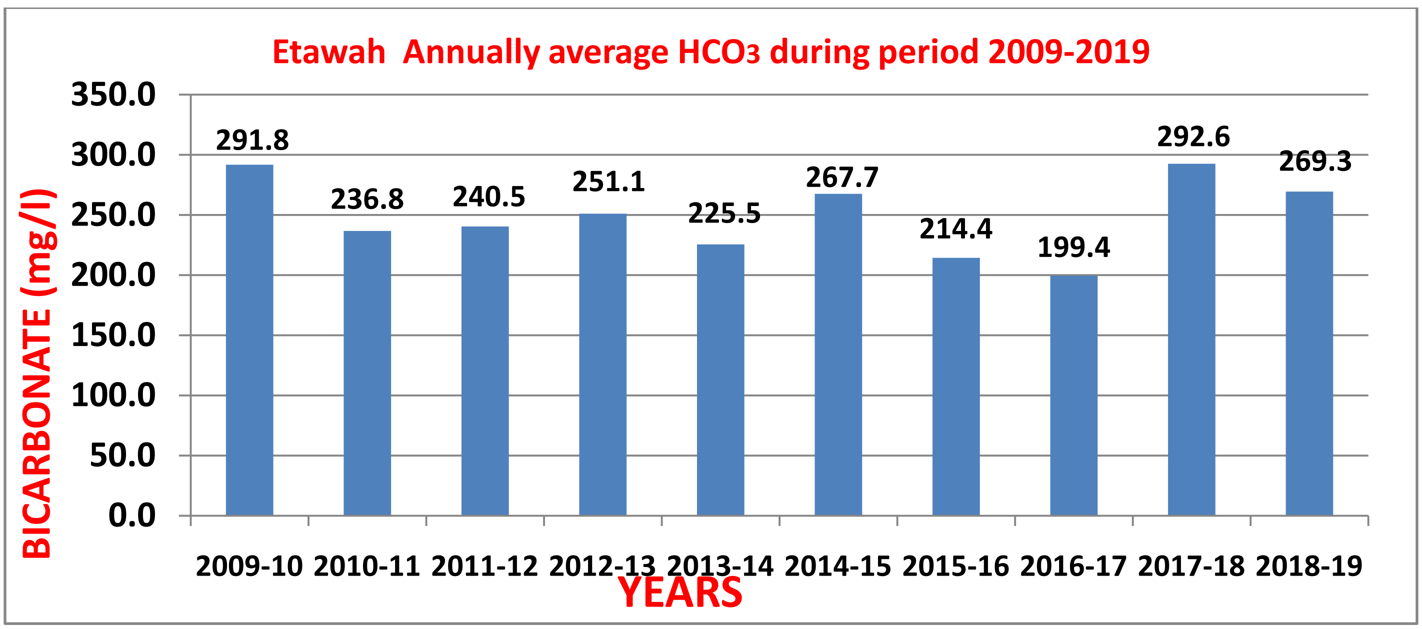
The Carbonate parameter at Poiyaghat Site has no trend.



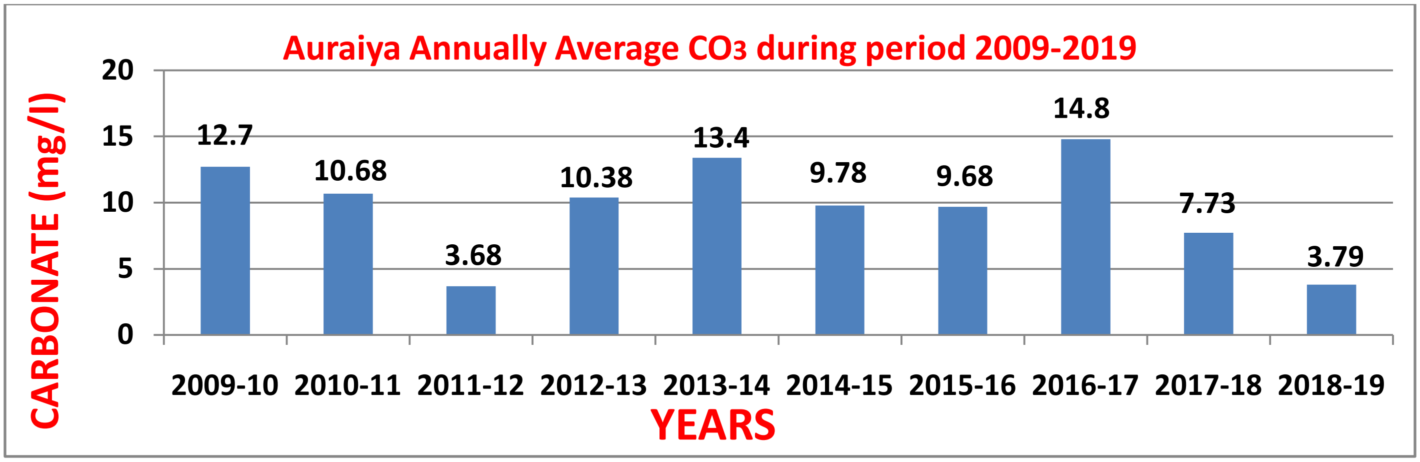
The Bicarbonate parameter at Poiyaghat Site has no trend.



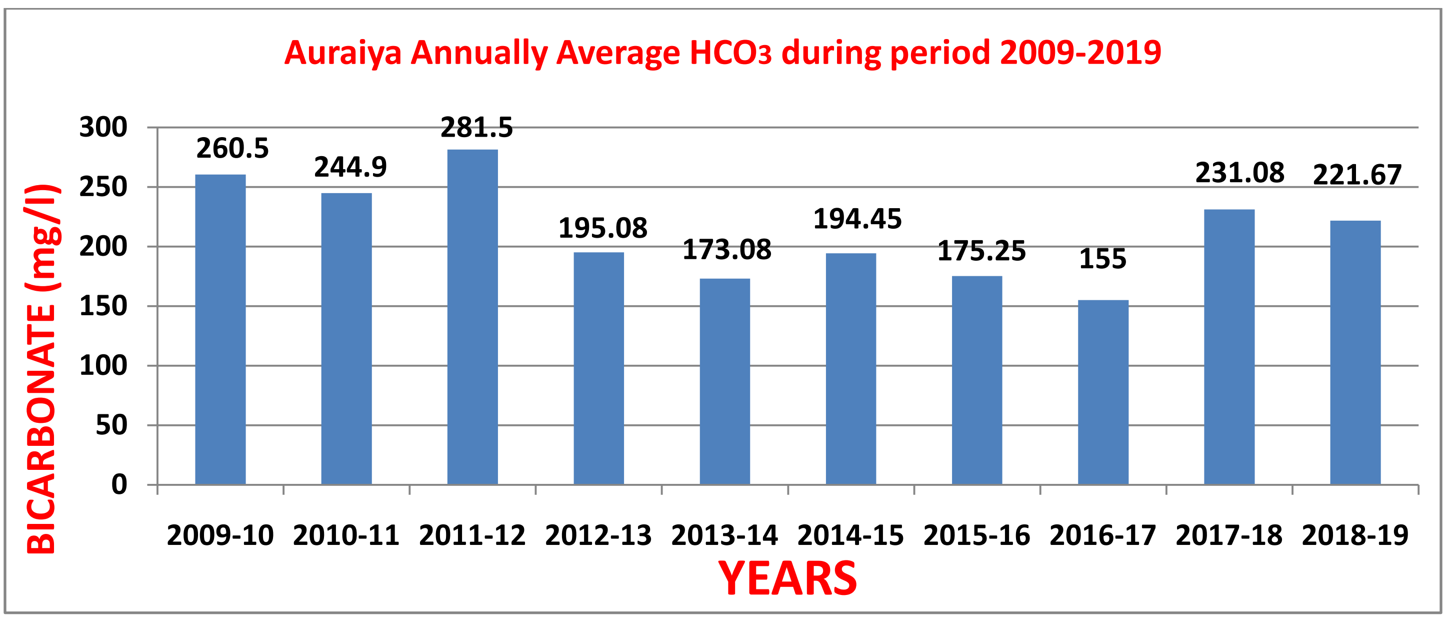
The Carbonate parameter at Etawah Site has no trend.



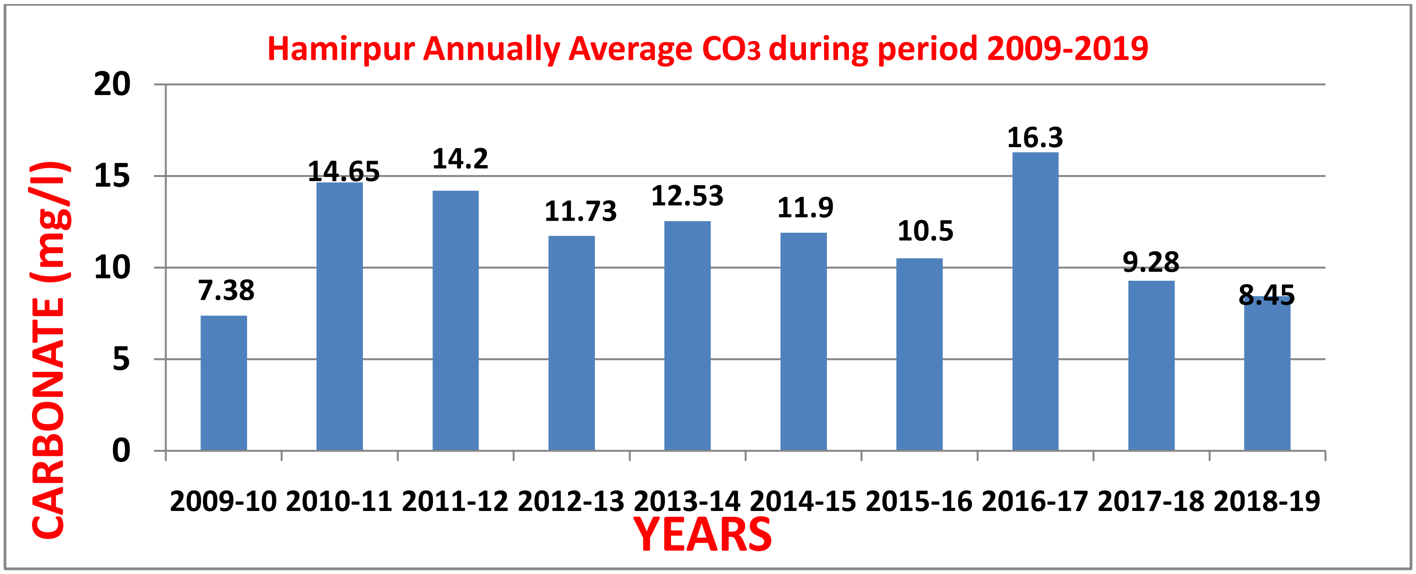
The Bicarbonate parameter at Etawah Site has no trend.



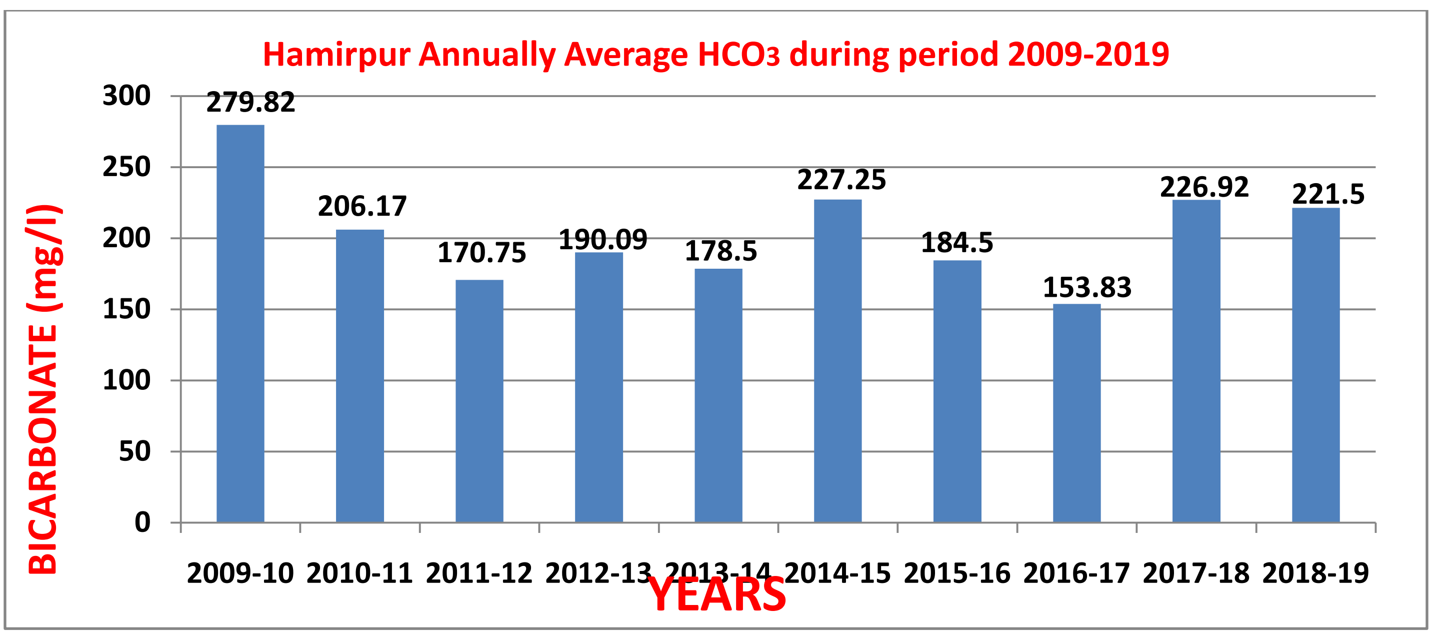
The Carbonate parameter at Auraiya Site has no trend.



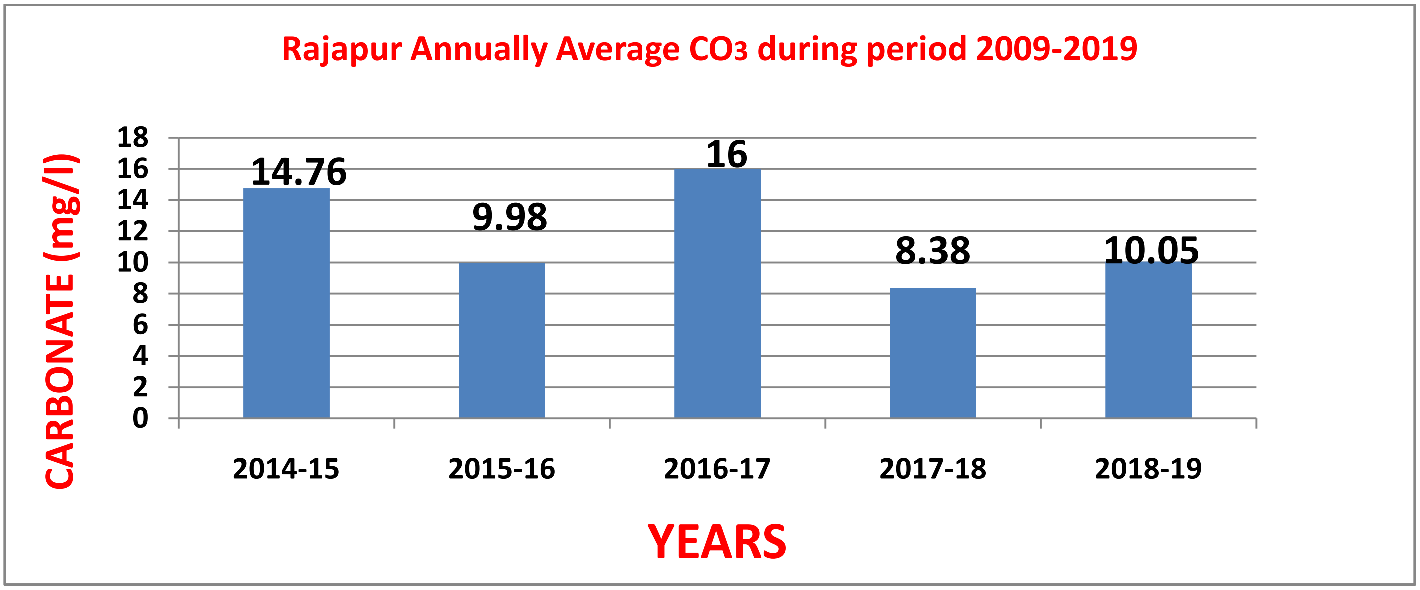
The Bicarbonate parameter at Auraiya Site has no trend.



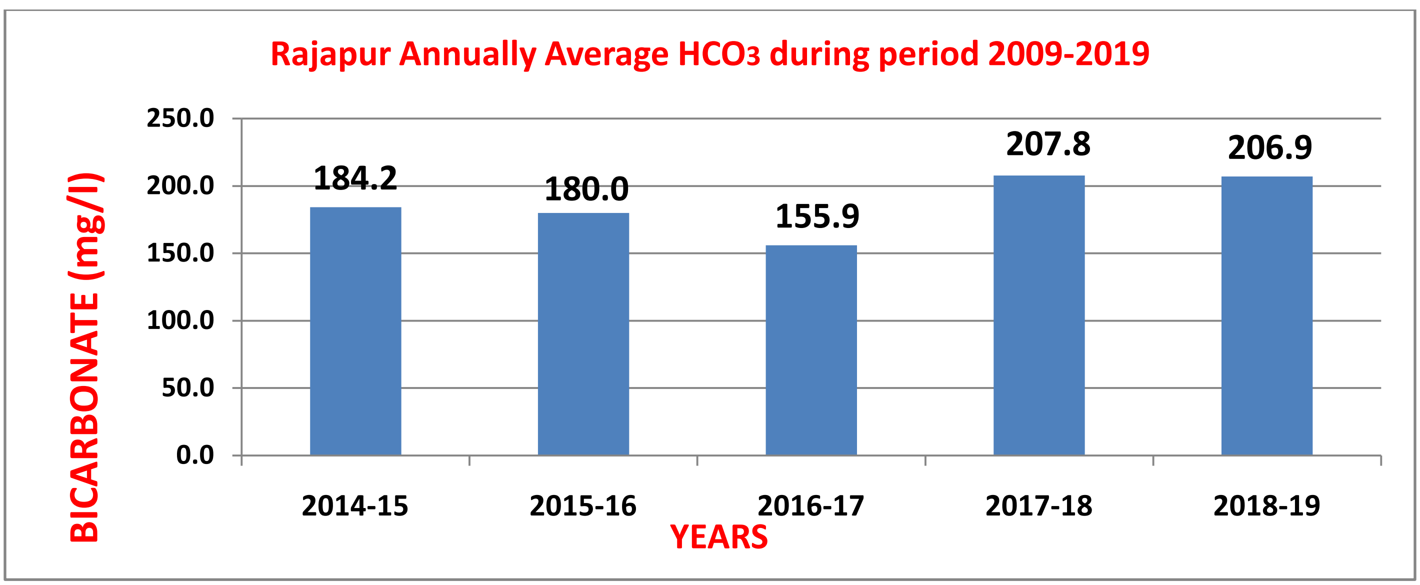
The Carbonate parameter at Hamirpur Site has no trend.



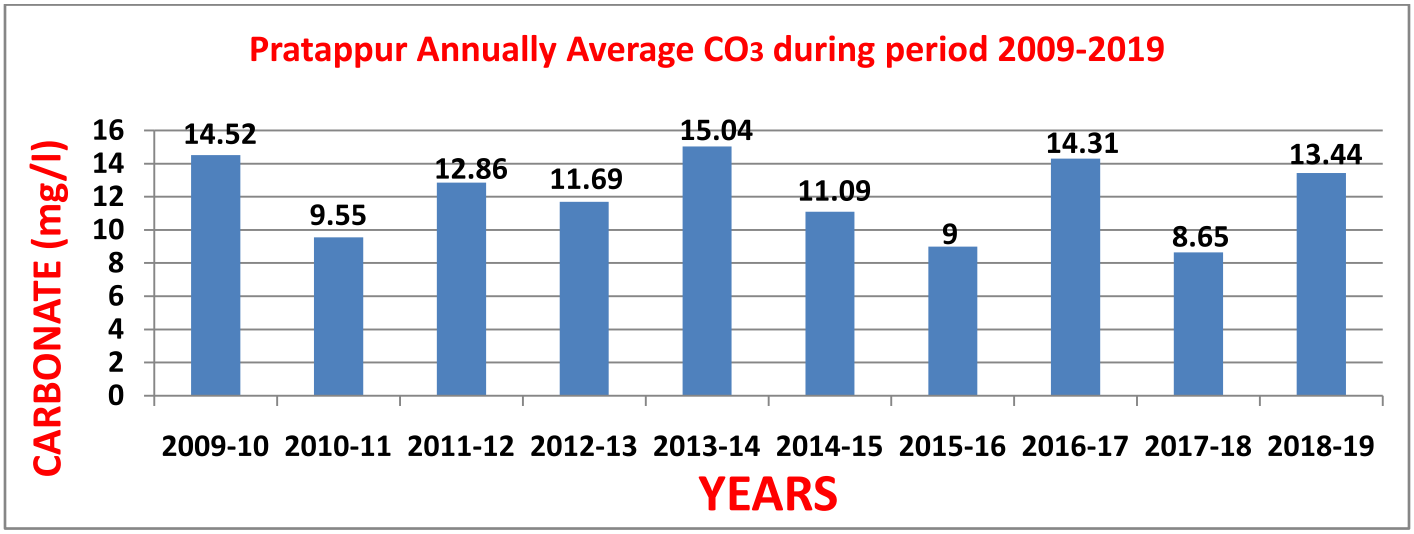
The Bicarbonate parameter at Hamirpur Site has no trend.



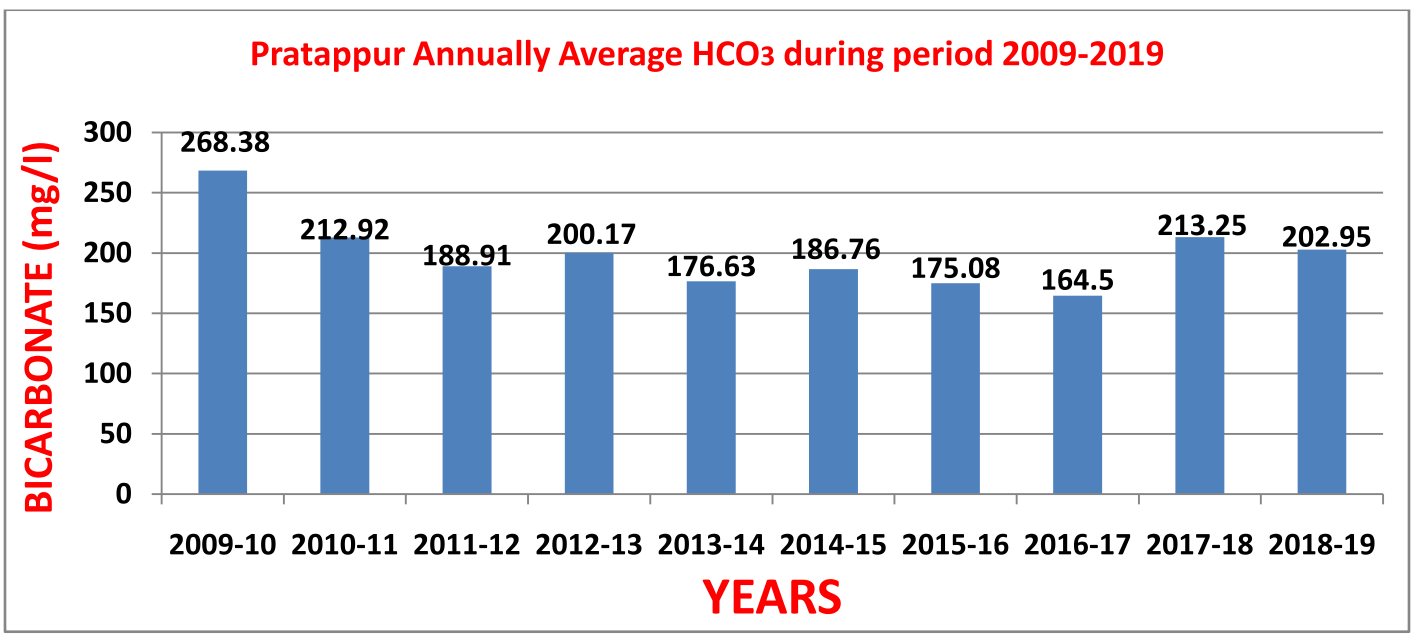
The Carbonate parameter at Rajapur Site has no trend.



The Bicarbonate parameter at Rajapur Site has no trend.



The Carbonate parameter at Pratapur Site has no trend.



The Bicarbonate parameter at Pratappur Site has no trend.

NITRATE

Principle:-

The nitrate ion electrode is a selective sensor that develops a potential across a thin porous, inert membrane that holds in place a water-immiscible liquid ion exchanger the electrode responds to nitrate ion activity between about 10-5 and 10-1 M (0.14 to 1400 mg NO_3^- N/L). the lower of detection is determined by the small but finite solubility of the liquid ion exchange.

Reagents:-

Dissolve 0.7218 gr previously dried and cooled potassium nitrate (KNO_3) in water and dilute to 1000 ml; 1 ml = 100µg NO_3-N.

Standard Nitrate solution:-

Dilute 1.0,10.0 and 50 ml stock solution to 100 ml to obtain standards of 1.0, 10 and 50 mg NO_3-N/L.

Buffer solution:-

Dissolve 17.32 gr $Al_2(SO_4)_3$. $18H_2O$, 3.43 gr Ag_2SO_4, 1.28 gr H_3BO_3, and 2.52 gr Sulfamic acid (H_2NSO_3H), in about 800 ml water. adjust to pH 3.0 by slowly adding 0.10N NaOH. Dilute to 1000 ml and store in dark in dark glass bottle.

Procedure:-

Transfer 10 ml of 1.0 mg NO_3-N/L standard to a 50 ml beaker, add 10 ml buffer and stir with magnetic stirring after mixing and immerse electrode start stirring again.

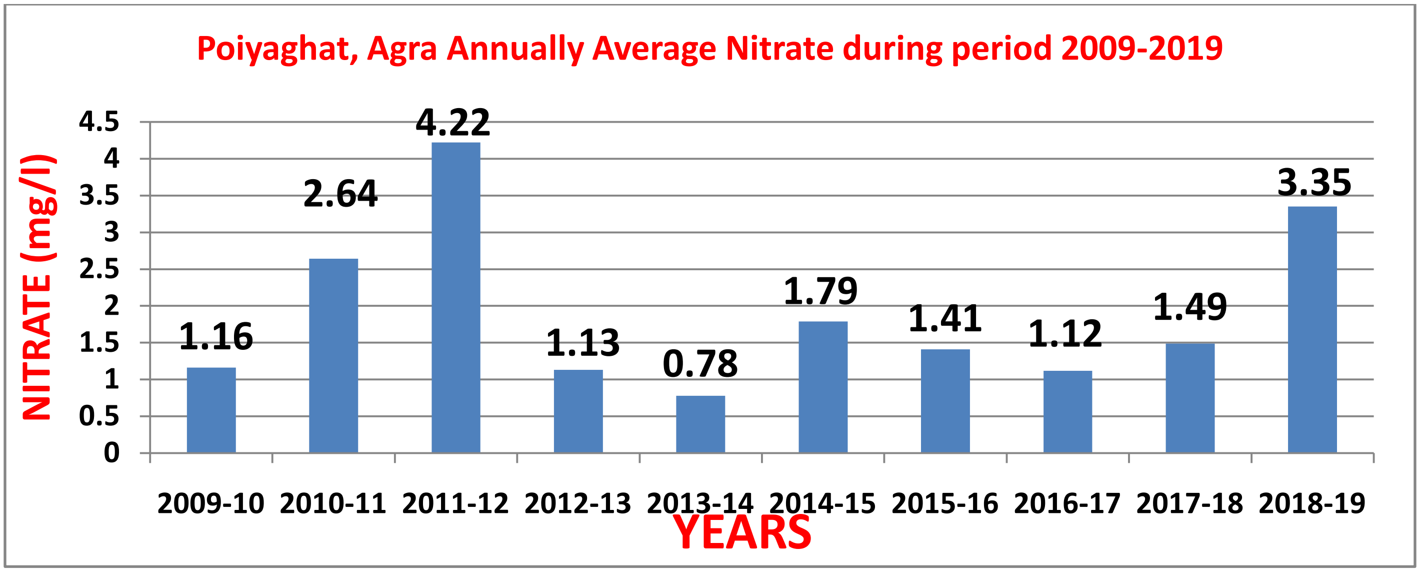
Take millivolt reading when stable (after about 1 min) repeat with 10 and 50 mg NO_3- N/L standards.

Plot on a semilogarithmic graph paper potential measurement of the standards in mV, on arithmetic scale, vs NO_3-N concentration on logarithmic scale. The calibration curve should be a straight line with a slope of + 57±3 decade at 25°C recalibration the probes and the instruments several times every day using the 10mg NO_3-N/L standards.

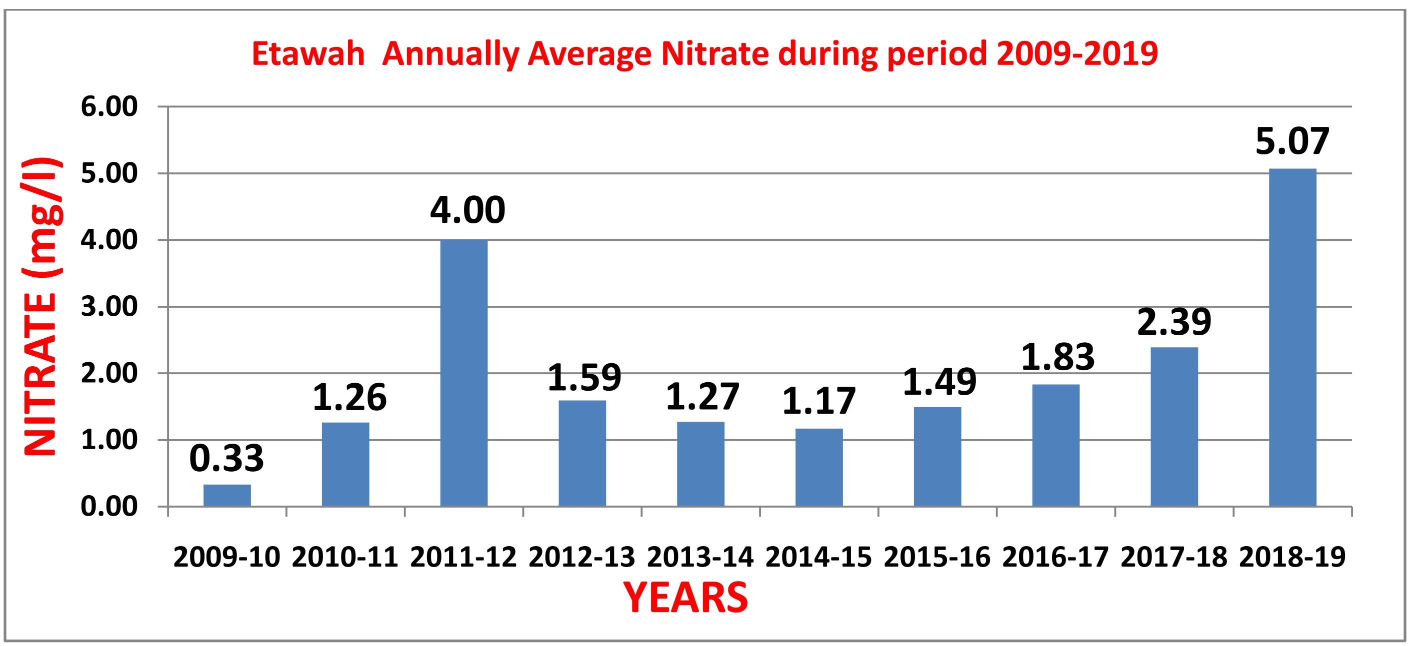
Transfer 10ml sample to a 50 ml beaker add 10 ml buffer and stir with magnetic stirrer stop stirring after mixing and immerse electrodes. Start stirring again take millivolt reading when stable (after about 1 min).

Calculation:-

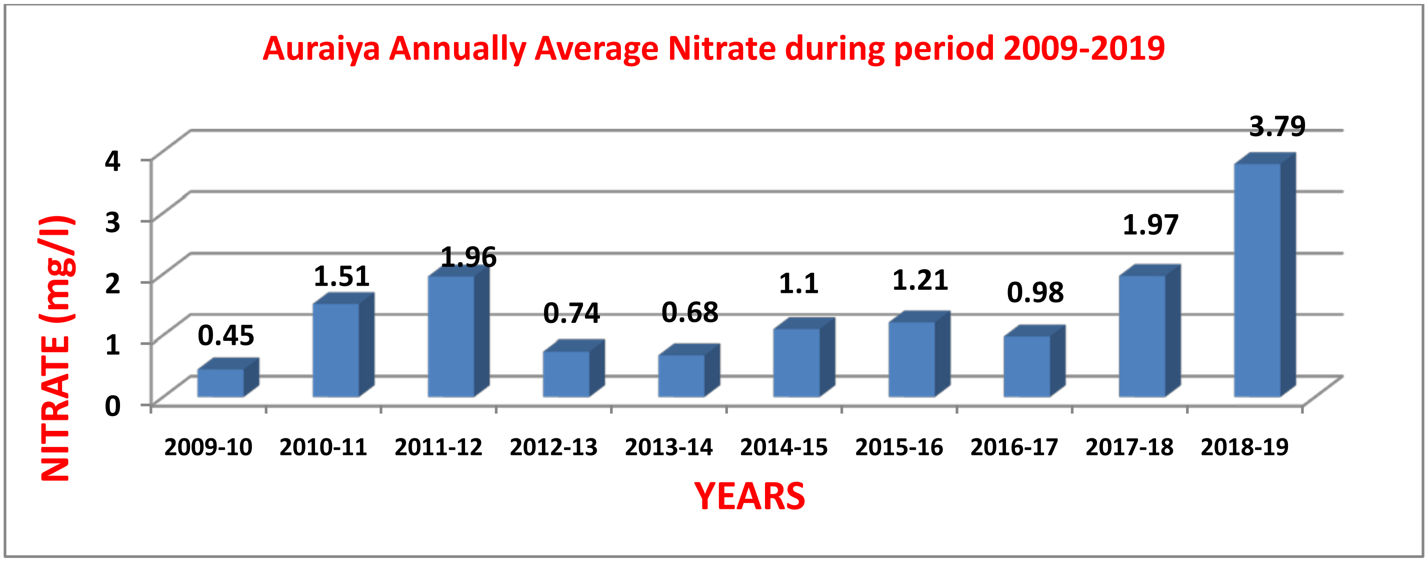
Read nitrate nitrogen concentration in the sample from the calibration curve or directly from the meter.



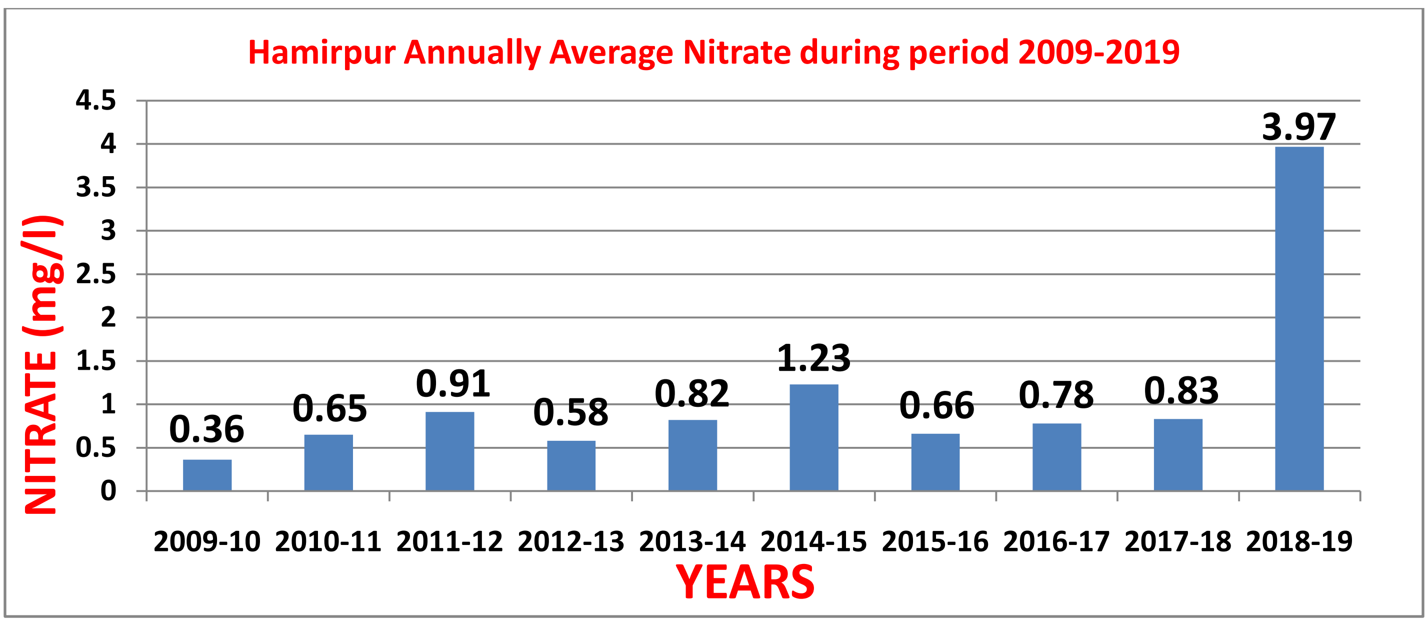
The Nitrate parameter at Poiyaghat Site has no trend.



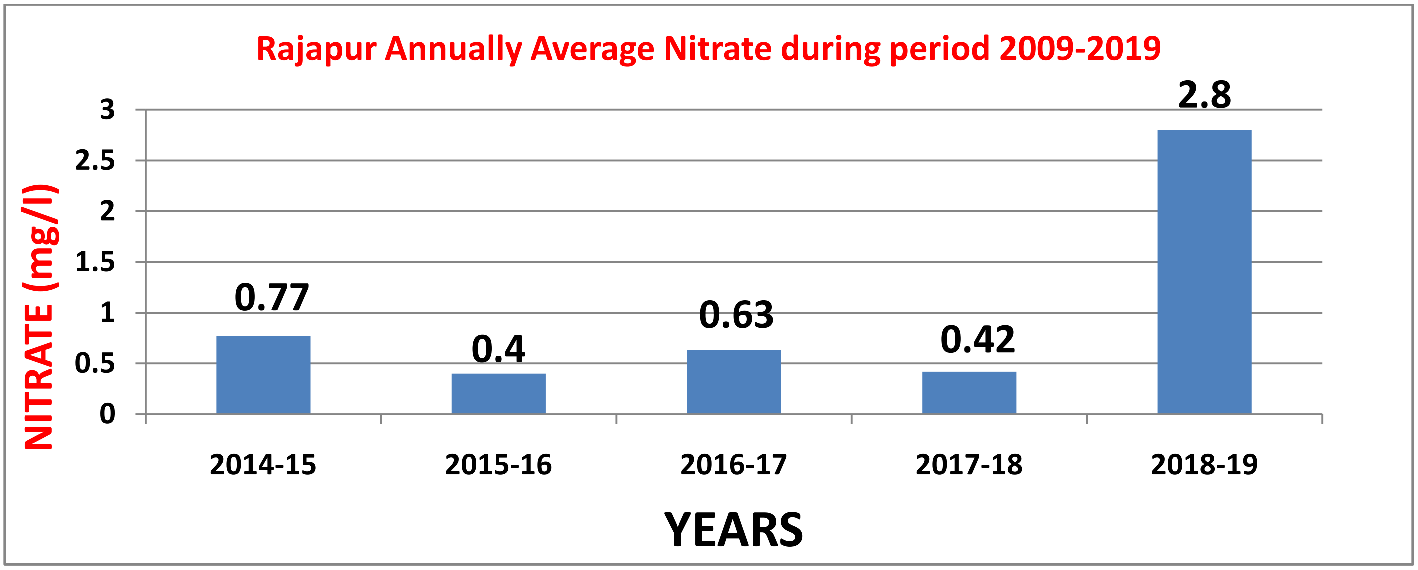
The Nitrate parameter at Etawah Site has no trend.



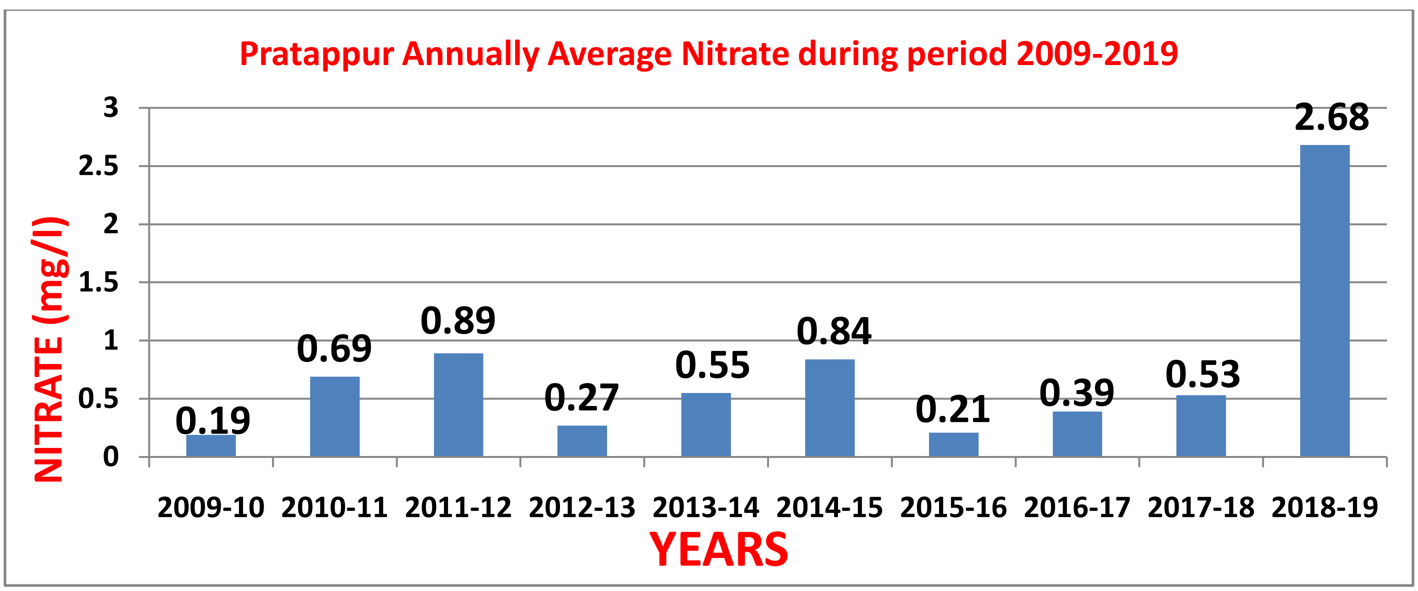
The Nitrate parameter at Auraiya Site has no trend.



The Nitrate parameter at Hamirpur Site has no trend.



The Nitrate parameter at Rajapur Site has no trend.



The Nitrate parameter at Pratappur Site has no trend.

Conclusion:

The analysis of water quality parameter has been done at the Sites Poiyaghat, Etawah, Auraiya, Hamirpur, Rajapur and Pratappur on Yamuna River. The pH, EC, Total Hardness, Calcium, Magnesium, Sulphate, Chloride, Nitrate, Sodium, Potassium, Carbonate and Bicarbonate are the major parameter which is analysed and found within permissible and acceptable limit. Also there is no trend found during last 10 years for any of the parameter analysed.

81438/2020/UYD-NEW DELHI

CHANGES IN WATER QUALITY OF RIVER YAMUNA (BETWEEN 2009-10 to 2019-20)

YAMUNA BASIN ORGANISATION

Central Water Commission

New Delhi

October 2020

CONTENTS

1.0 INTROODUCTON

The Yamuna River is one of the important and sacred rivers of India. It is the largest tributary of the River Ganga. It originates from Yamunotri glacier in the Mussoorie range of the lower Himalayas, and after traversing 1,376 km joins the river Ganga at Allahabad. The drainage area of the Yamuna basin is 366,220 sq km, which comprises part of seven states, viz. Uttarakhand, Himachal Pradesh, Uttar Pradesh, Haryana, Delhi, Rajasthan and Madhya Pradesh (Table 1).

Table 1 Details of catchment area and state of Yamuna river basin

State	Area in Yamuna basin (km²)	Area in major sub-basin (km²)					
		Hindon	Chambal	Sind	Betwa	Ken	Others
Uttarakhand	3,771 (1.1 %)	-	-	-	-	-	-
Himachal Pradesh	5,799 (1.7 %)	-	-	-	-	-	-
Uttar Pradesh	70,437 (20.4 %)	7,083 (100 %)	452 (0.32 %)	748 (2.89 %)	14,438 (30.12 %)	3,336 (13.66 %)	44,380 (44.06 %)
Haryana	21,265 (6.1 %)	-	-	-	-	-	21,265 (21.11 %)
Rajasthan	102,883 (29.7 %))	-	79,495 (56.87 %)	-	-	-	23,388 (23.22 %
Madhya Pradesh	140,208 (40.6 %)	-	59,838 (42.81 %)	25,131 (97.11 %)	33,502 (69.88 %)	21,090 (86.34 %)	647 (0.64 %)

The Yamuna River has four main tributaries in the Himalayan region; Rishi Ganga, Hanuman Ganga, Tons, and Giri. In the plains, the main tributaries are the Hindon, Chambal, Sind, Betwa and Ken (Fig. 1).

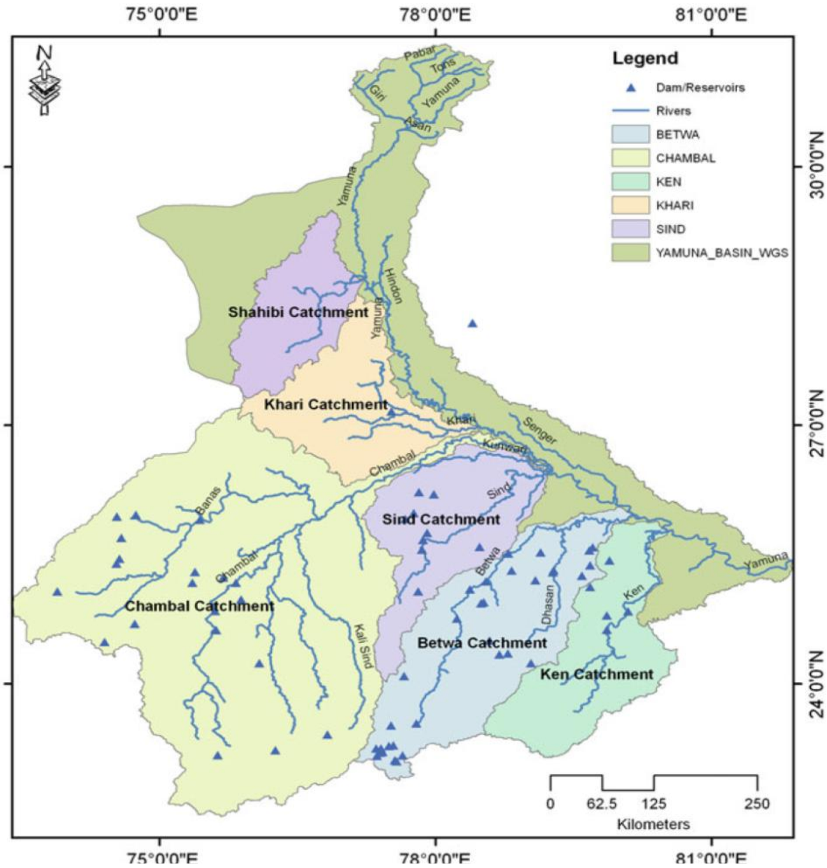


Figure : 1- Yamuna River Basin

The river water is generally used for irrigation, drinking and industries as well as for mass bathing, laundry, cattle bathing, and secretion of the cremation ash. The construction of diversion structures at regular intervals (Hathinikund, Wazirabad, Okhla, Gokul, etc.) for irrigation, domestic and industrial water supply, has largely modified the flow regime of the river. The inflow of wastewater either treated or partially treated in the river further aggravates the water quality problem of the river.

2.0 RIVER SEGMENTATION

The Yamuna is classified into 4 distinct segments due to characteristic Hydrological and Ecological conditions. The four independent segments are as follows:

Segment I:

This segment (length 172 km) is identified from Yamunotri and terminates at Hathnikund/Tajewala barrage. The major source of water in this segment is the melting of glaciers. The water flow in this segment terminates into Western Yamuna canal (WJC) and Eastern Yamuna Canal (EJC) for irrigation and drinking water purposes in command areas.

Segment II:

This segment (about 224 km) lies between Hathnikund barrage and Wazirabad barrage. The main source of water in this segment is ground water accrual. A few small tributaries also contribute water in this segment. The water is diverted in this segment from WJC through drain No. 2 to fulfil the raw water demand for drinking water supply to Delhi. The water segment is terminated into Wazirabad reservoir formed due to stagnation of water at Wazirabad barrage. The reservoir water is pumped to the various water works as raw water for treatment to meet the drinking water demand of the capital city. A little water is allowed to flow downstream of the Wazirabad barrage during lean seasons.

Segment III:

This 22 km segment of Yamuna River is located between the Wazirabad barrage and Okhla barrage. This segment receives water from seventeen sewage drains of Delhi and also from WJC and Upper Ganga Canal via Najafgarh drain and Hindon cut canal, respectively. Little contribution of Ganga water is also made in this segment by Surghat, where the Ganga and Yamuna water are provided for bathing purposes. This river segment also contribute water into Agra Canal, which is used to augment its flow for irrigation in the states of Haryana and Uttar Pradesh.

Segment IV:

This Segment of Yamuna River is about 958 km long initiate immediately downstream of the Okhla barrage and extends up to the confluence with Ganga River at Allahabad. The source of water in this segment are ground water accrual, its tributaries like Hindon, Chambal, Sind, Ken, Betwa, etc.

and waste water carrying drains of Delhi, Mathura-Vrindavan, Agra and Etawah. The water of this segment is used for drinking and industrial uses in Mathura and Agra. In Mathura, the Gokul barrage has been constructed to trap the Yamuna River water for drinking purposes. Due to low drinking water demand, only part of water is pumped out and the rest flows downstream. As the water demand will increase in future. It is likely that no water will be allowed to flow downstream like the Wazirabad and Okhla barrages. This may create further segmentation of segment IV into two segments of 154 and 804 km. With the construction of another barrage near Sikandara in Agra the river would be further segmented.

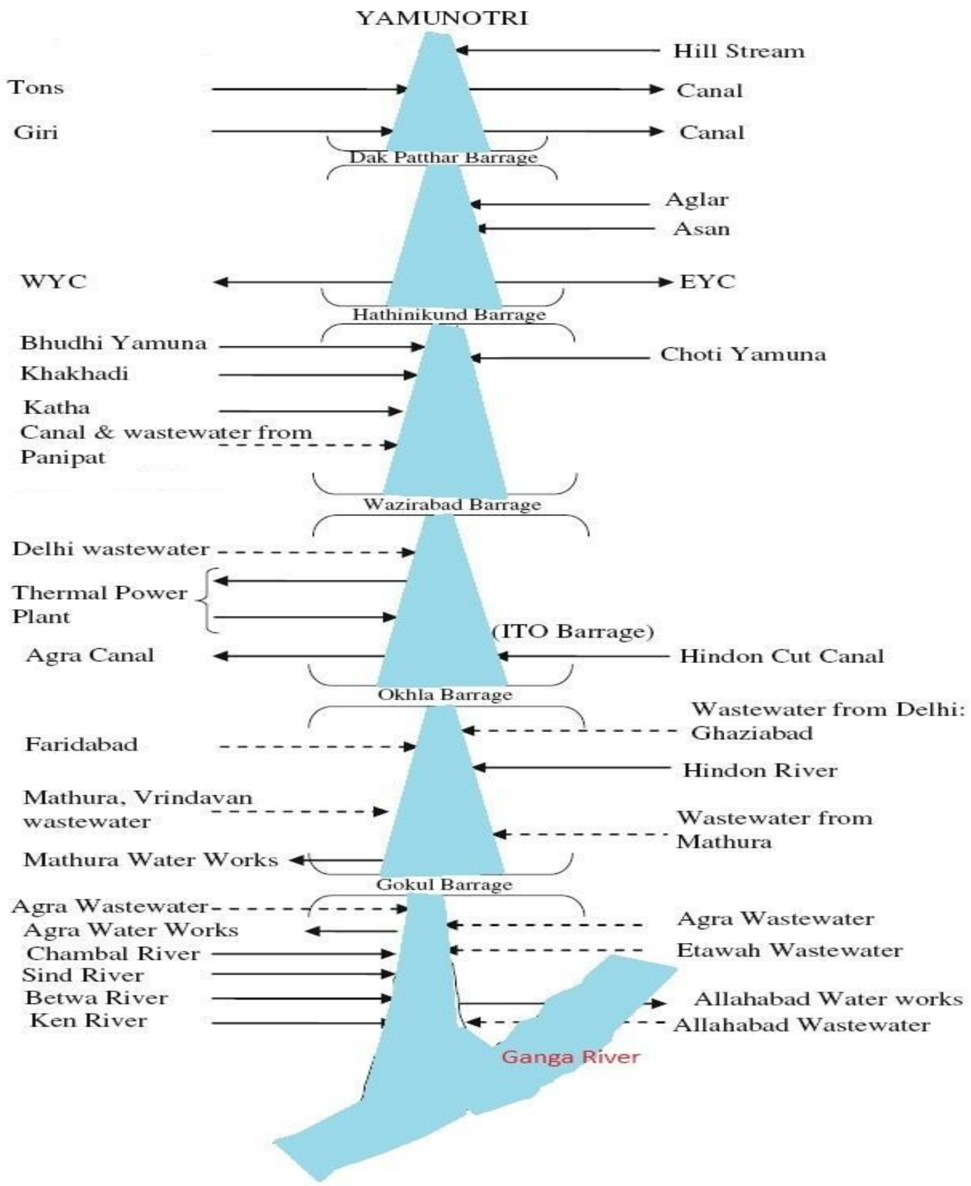


Fig. 9.1 Segmentation of the Yamuna River system

Figure : 2 – Segmentation of the Yamuna Basin System

3.0 CWC WATER QUALITY MONITORING NETWORK IN YAMUNA RIVER

Central Water Commission (CWC) is monitoring the quality of surface flowing water for the last five decades. Yamuna Basin Organisation, Central Water Commission, New Delhi is responsible for Hydrological Observations, flood forecasting and water quality monitoring of Yamuna river from its origin to its confluence with the river Ganga.

The river water quality monitoring is most essential aspect of restoring the water quality. One of the main objectives of the river water quality monitoring is to assess the suitability of river water for drinking purposes, irrigation, out- door bathing and propagation of wildlife, fisheries. The physical and chemical quality of river water is important in deciding its suitability for drinking purposes. As such the suitability of river water for potable uses with regard to its chemical quality has to be deciphered and defined on the basis of the some vital characteristics of the water

Water samples of River Yamuna are collected at 12 locations for physio-chemical and biological analysis. The samples are analyzed for time sensitive parameters at the sites and for other parameters, the analysis is done in the laboratory. The list of the water quality stations of CWC is given below in the Table 2.

Table 2. : The list of the Water Quality Stations on Yamuna River

S. No.	Water Quality Site	Distance from Yamunotri in KM	Latitude	Longitude	State	District
1	Paonta	141	30°26'03.74''	77°37'21.93''	Himachal Pradesh	Simaur
2	Kalanaur	196	30°04'04.20''	77°21'14.48''	Uttar Pradesh	Saharanpur
3	Mawi	295	29°22'56.94''	77°09'16.11''	Uttar Pradesh	Muzaffar Nagar
4	Palla	351	28°50'42.97''	77°12'45.32''	Delhi	North West Delhi
5	Delhi Rly Bridge	379	28°39'45.47''	77°14'56.07''	Delhi	North Delhi
6	Mohana	451	28°13'25.22''	77°27'22.59''	Haryana	Faridabad
7	Mathura	578	27°30'14.84''	77°41'14.04''	Uttar Pradesh	Mathura
8	Agra (P.G.)	637	27°15'17.02''	78°01'24.11''	Uttar Pradesh	Agra
9	Etawah	767	26°44'47.90''	78°59'12.40''	Uttar Pradesh	Etawah
10	Auraiya	830	26°25'44.61''	79°28'41.04''	Uttar Pradesh	Auraiya
11	Hamirpur	950	25°57'36.67''	80°09'13.97''	Uttar Pradesh	Hamirpur
12	Pratappur	1205	25°17'58''	81°33'56''	Uttar Pradesh	Allahabad

4.0 WATER QUALITY PARAMETERS AND PROCEDURES

The time sensitive parameters which are analyzed at the sites are as follows:			
S. No.	PARAMETER	PROCEDURE	EQUIPMENT
1	Odour	Smell	-
2	Colour	Visual comparison	Colour disc
3	Temperature	Contact	Thermometer
4	pH	Contact	pH meter
5	Electrical Conductivity	Contact	Conductivity meter
6	Dissolved Oxygen	Titration (Winkler Method)	Glass apparatus
Apart from the above time sensitive parameters, following parameters are analysed in Laboratory of CWC			
S. No.	PARAMETER	PROCEDURE	EQUIPMENT
1	pH*	Electromotive force	pH Meter
2	EC*	Electromotive force	EC Meter
3	Calcium	Titration	Digital Burette
4	Magnesium	Titration	Digital Burette
5	Total Hardness	Titration	Digital Burette
6	Potassium	Flame emission	Flame photometer
7	Sodium	Flame emission	Flame photometer
8	Ammonia	Colour development	Spectrophotometer
9	Boron	Colour development	Spectrophotometer
10	Total Alkalinity	Titration	Digital Burette
11	Carbonate	Titration	Digital Burette
12	Bi-carbonate	Titration	Digital Burette
13	Chloride	Titration	Digital Burette
14	Sulphate	Turbidity	Nephelometer
15	Nitrate	Colour development	Spectrophotometer
16	Nitrate	Colour development	Spectrophotometer
17	Silicate	Colour development	Spectrophotometer
18	Phosphate	Colour development	Spectrophotometer
19	Fluoride	Colour development	Spectrophotometer
20	Arsenic**	Atomic Absorption	AAS
21	Copper	Atomic Absorption	AAS
22	Cadmium**	Atomic Absorption	AAS
23	Chromium**	Atomic Absorption	AAS
24	Lead**	Atomic Absorption	AAS
25	Iron**	Atomic Absorption	AAS
26	Mercury**	Atomic Absorption	AAS
27	Zinc**	Atomic Absorption	AAS
28	B. O. D.	Incubation	B. O. D. incubator
29	Total Coliform	MPN Method	Incubator & Bio Safety Cabinet
30	Fecal Coliform	MPN Method	Incubator & Bio Safety Cabinet

* pH and EC are also observed at Level I laboratory

** Trace & Toxic metals analysed in NRWQL, New Delhi'

5.0 FACTOR AFFECTING WATER QUALITY OF YAMUNA RIVER

Rapidly increasing population, rising standards of living and exponential growth of industrialization and urbanization have exposed the river Yamuna to various forms of degradation. The deterioration in the water quality impacts the people immediately. Yamuna River, in some stretches, particularly during lean seasons has become unfit for drinking, bathing and fish culture. There are four problem areas that are affecting the water quality of river Yamuna:

- Inadequate flow of water in the river, needed to maintain ecological flow, dilute and assimilate waste, particularly during the lean season
- Growing quantum of untreated sewage discharged from cities along the river
- Point-source pollution from industries discharging waste into the river.
- Municipal and industrial solid waste.

1. Inadequate flow of water in the river:

The water availability in the Yamuna River is not enough to meet environmental demands during the months of December to June except from the Etawah to Allahabad stretch. This stretch has no major industrial and domestic influence. Also, this stretch receives good quality water from four major tributaries, such as Chambal, Sind, Betwa and Ken.

2. Pollution Load Generation from Domestic Waste:

In the Yamuna basin there are two important sources of wastewater, i.e., domestic sewage from urban centers and industrial effluents from different categories of industries. As per the studies carried out by the Central Pollution Control Board, the domestic wastewater is the predominant source of pollution of the Yamuna River. Every human activity result in the generation of waste though the nature and quantities of such wastes may vary in a wide range from activity to activity. Rural and urban areas are very much distinct from each other in terms of activities as well as the provision of infrastructure, particularly water supply and sanitation (CPCB).

It is revealed that out of the 16 towns along the river, 10 including Delhi and downstream towns discharge their wastewater directly into the river. Three towns upstream of Delhi in Haryana, i.e., Karnal, Panipat and Sonepat discharge their wastewater into drains leading to the Yamuna after traversing a distance of 20–45 km. Yamunanagar discharges its wastewater into Western Yamuna Canal. The two towns in U.P. upstream of Delhi, i.e., Saharanpur and Muzaffarnagar discharge their wastewater into Hindon and Kali Rivers respectively. Delhi contributes highest load into the river. Table 3 is showing the major polluting sources of Yamuna River (CPCB, Reports).

Table 3: Major polluting sources of Yamuna River

Cities/towns	Bank	Volume of WW, MLD	Treatment capacity MLD
Yamunanagar	R	45	35
Saharanpur	L	45	38
Muzaffarnagar	L	40	32.5
Karnal	R	60	48
Panipat	R	60	45
Sonepat	R	45	30
Delhi	R/L	3, 800	2,330
Gurgaon	R	45	30
Faridabad	R	140	115
Ghaziabad	L	150	126
Noida	L	90	70
Vrindavan	R	5	4.5
Mathura	R	35	28
Agra	R	190	90
Etawah	R	13	10
Allahabad	L	223	89
Total		4, 986	3,121

Source: CPCB

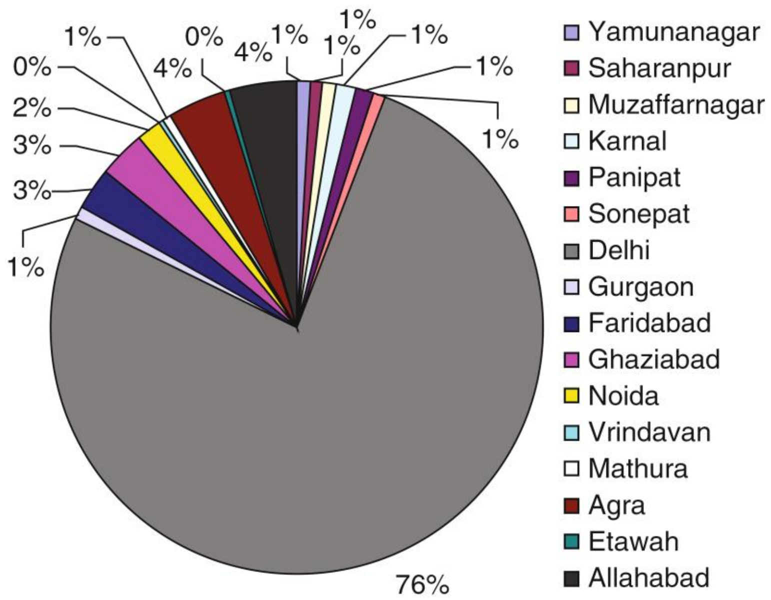


Figure 3: Town share of wastewater generation along the Yamuna River

The CPCB has been regularly monitoring the drains in Delhi. The average values of monitoring results of drains are presented in Table 4. It is clear from the table that the Najafgarh Drain along with the supplementary drain, carries maximum pollution load to the Yamuna River followed by the Shahdara drain. The two drains together contribute about 55% by load and 72% by volume of waste water.

Table 4: Discharge and BOD loads in different drains of Delhi

S.No.	Name of Drain	Avg. Flow (MLD)	Avg. BOD Load (TPD)	% BOD Load
1	Najafgarh Drain	1938.38	133.82	50.63
2	Shahdara Drain	500.97	61.44	23.25
3	Waste water input into abandoned Agra Canal	117.93	21.54	8.15
4	Barapulla Drain	151.77	10.46	3.96
5	Tuglakabad Drain	22.1	3.42	1.29
6	Delhi Gate (Power House) Drain	39.02	3.43	1.30
7	Sen Nursing Home Drain	31.53	4.69	1.77
8	Abu Fazal Drain	28.94	0.88	0.33
9	ISBT + Mori Gate Drain	37.94	2.67	1.01
10	SaritaVihar Drain	35.68	7.73	2.92
11	Maharani Bagh Drain	30.16	3.51	1.33
12	Jaitpur Drain	19.58	3.07	1.16
13	Molar Bandh Drain	22.17	2.36	0.89
14	Kailash Nagar Drain	9	2.7	1.02
15	Tonga Stand Drain	4.46	0.59	0.22
16	Shastri Park Drain	5.76	0.75	0.28
17	Drain No.14	6.54	0.07	0.03
18	Magazine Road Drain	4.32	0.3	0.11
19	Civil Mill Drain	11.14	0.67	0.25
20	Metcalf House Drain	3.45	0.11	0.04
21	Sweeper Colony Drain	5.4	0.1	0.04
22	Khyber Pass Drain	NF	NF	
Total		**3026.24 MLD**	**264.31 TPD**	
Note: NF- No Flow				

Source: Central Pollution Control Board, Delhi (2019)

3. Pollution Load Generation from Industrial Sources

There are a large number of large, medium and small scale industries in the NCT of Delhi. A major fraction of these industrial units are located within the 28 major industrial areas and thus, act as another source of concentrated generation of pollutants. Most of the large and many small and medium scale industries have their own effluent treatment systems, but in the absence of relevant information regarding the extent of treatment provided by the industries, it is difficult to consider pollution reduction due to treatment. The name of industrial areas with their respective sewerage zone is provided in Table 5.

There are 15 common effluent treatment plants planned for the 28 industrial areas as shown in Table 5. Some of them are installed and working. However, the performance of these treatment plants is not satisfactory due to various reasons, including the nature of wastes, non-existence of pre-treatment needed in many industries, etc. (CPCB, Reports).

S.No.	Sewerage Zone	Industrial Area	Industrial Discharge (MLD)	% Industrial Discharge (MLD)
1	Okhla	Okhla Industrial Area	12	25.9
		Okhla Industrial Estate	10	21.6
		Okhla Industrial Factories	7.5	16.2
		Friends Colony Industrial Estate	3	6.5
		Mohan Co-operative Industrial Estate	13.8	29.8
		Sub Total	**46.3**	
2	Keshopur	Rohtak Road	14	19.9
		Karampura Industrial Estate	9.09	12.9
		Mayapuri Industrial Estate	12	17.1
		Najafgarh Road Industrial Estate(60%)	7.2	10.2
		Kirti Nagar Industrial Estate	8	11.4
		Tilak Nagar Industrial Estate	8	11.4
		Naraina Industrial Estate	10.56	15.0
		Mangolpuri Industrial Estate(40%)	1.5	2.1
		Sub total	**70.35**	
3	Rithala	MangolpuriIndustrial Estate(60%)	2.4	2.8
		Najafgarh Road Industrial Estate(40%)	4.8	5.6
		Anand Parbat Industrial Estate	8	9.4
		Lawerence Road Estate	2	2.3
		Badli Industrial Estate	1.53	1.8
		Udyognagar Industrial Estate	3.21	3.8
		Rajasthan Udyognagar Industrial Estat	10	11.7
		SMA Industrial Estate	12	14.0
		Narela Industrial Estate(90%)	10	11.7
		Wazirpur Industrial Estate	20	23.4
		GT karnal Road Industrial Estate	4	4.7
		SSI Industrial Estate	3.5	4.1
		DSIDC Nagloi Industrial Estate	4	4.7
		Sub Total	**85.44**	
4	Coronation Pillar	Azadpur Industrial Estate	1.94	78.2
		Narela Industrial Estate(10%)	0.54	21.8
		Sub Total	**2.48**	
5	Shahdara	Jhilmil Industrial Estate	7	51.9
		Patparganj Industrial Estate	3	22.2
		Shahdara Industrial Estate	3.5	25.9
		Sub Total	**13.5**	

Table 5: Sewerage zone wise generation of Industrial Pollution Load

6.0 WATER QUALITY STANDARDS

The river water quality monitoring is most essential aspect of restoring the water quality. One of the main objectives of the river water quality monitoring is to assess the suitability of river water for drinking purposes, irrigation, out- door bathing and Propagation of wildlife, fisheries. The physical and chemical quality of river water is important in deciding its suitability for drinking purposes. As such the suitability of river water for potable uses with regard to its chemical quality has to be deciphered and defined on the basis of the some vital characteristics of the water.

Bureau of Indian Standards (BIS) formally known as Indian Standards Institution (ISI) vide its document IS 2296:1992 has recommended the quality standards for designated best uses and these have been used for finding the suitability of river water. On this basis of classification, the natural river water of India has been categorized as Class – A: Drinking Water Source without conventional treatment but after disinfection; Class – B: Outdoor bathing (Organised); Class – C: Drinking water source after conventional treatment and disinfection; Class – D: Propagation of Wild life and Fisheries; Class – E: Irrigation, Industrial Cooling, Controlled Waste disposal.

River water quality is very important aspect in India. The physic-chemical parameters like pH, electrical conductance (TDS), Chloride, Fluoride, Nitrate, Sulphate, Boron, Total hardness, Dissolved Oxygen and Bio-chemical Oxygen demand are main constituents defining the quality of river water in surface water. Therefore, presence of these parameters in river water beyond the permissible limit has been considered as river water quality hotspots.

Actually every river stretch has a distinct water use as some is used for irrigation, other for mass bathing and still others for drinking. The best use classification is essential for maintaining the quality of river water of the particular stretch. The whole concept was unique, as not even many technically advanced countries possess such detailed user based river atlas. To evolve a methodology for hot spot in Indian River, in respect of biochemical oxygen demand, the BIS 2296:1992 / Central Pollution Control Boards classification has been considered for evaluating the hot spot in rivers. In this classification we shall consider the class – B for Outdoor bathing. In India, CPCB has identified water quality requirements in terms of a few chemical characteristics, known as primary water quality criteria. Further, Bureau of Indian Standards has also recommended water quality parameter for different uses in the standard IS 2296:1992.

Table 6: Water Quality Standards in India (Source IS: 2296; 1992)

S. No	Characteristics	Designated best use				
		A	B	C	D	E
1	**Dissolved Oxygen (DO) mg/l. min**	6	5	4	4	-
2	**Biochemical Oxygen demand (BOD) mg/l.max**	2	3	3	-	-
3	**Total coliform organisms MPN /100 ml.max**	50	500	5.000	-	-
4	**pH value**	6.5-8.5	6.5-8.5	6.0-9.0	6.5-8.5	6.0-8.5
5	**Colour. Hazen units. max**	10	300	300	-	-
6	**Odour**	Un-objectionable			-	-
7	**Taste**	Tasteless	-	-	-	-
8	**Total dissolved solids. mg/l. max.**	500	-	1500	-	2100
9	**Total hardness (as $CaCO_3$),mg/l.max**	200	-	-	-	-
10	**Calcium hardness (as $CaCO_3$), mg/l.max**	200	-	-	-	-
11	**Magnesium hardness (as $CaCO_3$), mg/l.max.**	200	-	-	-	-
12	**Copper (as Cu).mg/l.max**	1.5	-	1.5	-	-
13	**Iron (as Fe). Mg/l max.**	0.3	-	0.5	-	-
14	**Manganese (as Mn).mg/l.max**	0.5	-	-	-	-
15	**Chloride (as Cl). mg/l.max**	250	-	600	-	600
16	**Sulphates (as SO_4). mg/l. max**	400	-	400	-	1.000
17	**Nitrate (as NO_3). mg/l. max**	20	-	50	-	-
18	**Fluorides (as F). mg/l. max**	1.5	1.5	1.5	-	-
19	**Phenolic compounds (as C_2H_5OH). mg/l. max**	0.002	0.005	0.005	-	-
20	**Mercury (as Hg). mg/l.max.**	0.001	-	-	-	-
21	**Cadmium (as Cd).mg/l.max**	0.01	-	0.01	-	-
22	**Selenium (as Se).mg/l.max**	0.01	-	0.05	-	-
23	**Arsenic (as As).mg/l.max**	0.05	0.2	0.2	-	-
24	**Cyanide (as Pb).mg/l.max**	0.05	0.05	0.05	-	-
25	**Lead (as Pb).mg/l.max**	0.1	-	0.1	-	-
26	**Zinc (as Zn).mg/l.max**	15	-	15	-	-
27	**Chromium (as Cr^{6+}).mg/l.max**	0.05	-	0.05	-	-
28	**Anionic detergents (sa MBAS). mg/l.max**	0.2	1	1	-	-
29	**Barium (as Ba).mg/l.max**	1	-	-	-	-
30	**Free Ammonia (as N)). Mg/l.max**	-	-	-	1.2	-
31	**Electrical Conductivity. Micromhos/cm. max.**	-	-	-	-	2250
32	**Sodium absorption ratio. max**	-	-	-	-	26
33	**Boron. Mg/l. max**	-	-	-	-	2

Class – A: Drinking Water Source without conventional treatment but after disinfection
Class – B: Outdoor bathing (Organised)
Class – C: Drinking water source after conventional treatment and disinfection
Class – D: Propagation of Wild life and Fisheries
Class – E: Irrigation, Industrial Cooling, Controlled Waste disposal

7.0 STATUS OF IMPORTANT WATER QUALITY PARAMETERS OF RIVER YAMUNA

Water quality is one of the fundamental constraints important for drinking, bathing and irrigation and is regularly monitored by the Central Water Commission (CWC) for major river systems and tributaries of major rivers, respectively. The water quality data during the past 10 years (2009-10 & 2019-20) were compiled for twelve monitoring locations at Yamuna River. For all the locations, seasonal variations in pH, Total Dissolved solids, Dissolved Oxygen, Biochemical oxygen demand, Total Alkalinity, Total Hardness, Fluoride, Chloride, % sodium and Sulphate have been analyzed and depicted in Fig. 4 to 13. It is clear from figure that the water quality of the river has gradually shown similar trends of deterioration throughout the 10 years period. The entire stretch of Yamuna River from origin to confluence with Ganga River is highly used for various human activities. The accumulated results of these activities are the low flow availability in the river during the lean period and water pollution. During the course of travel, Yamuna River receives a lot of pollutants of various kinds.

7.1 pH

BIS (Bureau of Indian Standard) have recommended a limit of 6.5 – 9.0 of pH in Class C - Drinking water source with conventional treatment followed by disinfections. pH is a general physico-chemical parameter and indicates the fate of chemical constituents. During the period of the study, the average values of pH observed during monsoon and non-monsoon period in the River Yamuna stretch at Poanta to Pratappur and the permissible range for Class C (normally adopted for River Waters) are given in the following figure 4 below.). During the period from 2009-10 to 2019-20 the pH is varying from 8.0 to 7.8 on average basis in monsoon season while in non-monsoon season variation is from pH 8.4 to 8.30 on average basis in segment 1 of 172 km at Ponta site and in segment II of 224 km it is lowering further at Kalanaur, Mawi and Palla in both monsoon and non- monsoon but within the range of 6.5 to 9.0 i.e. class 'C' water. While in segment III of 22 km it is lowers further and touches 7.5 in monsoon and 7.9 in non-monsoon. In segment IV just after Okhla barrage up to Partappur pH is increasing at Mohana and Mathura but again decreasing at Agra and after Agra pH is increasing and becoming 8.0 in monsoon and 8.3 in non -monsoon season. So in all segment from I to IV the pH is within range and water is fit for 'C' type and safe for drinking from pH point of view.

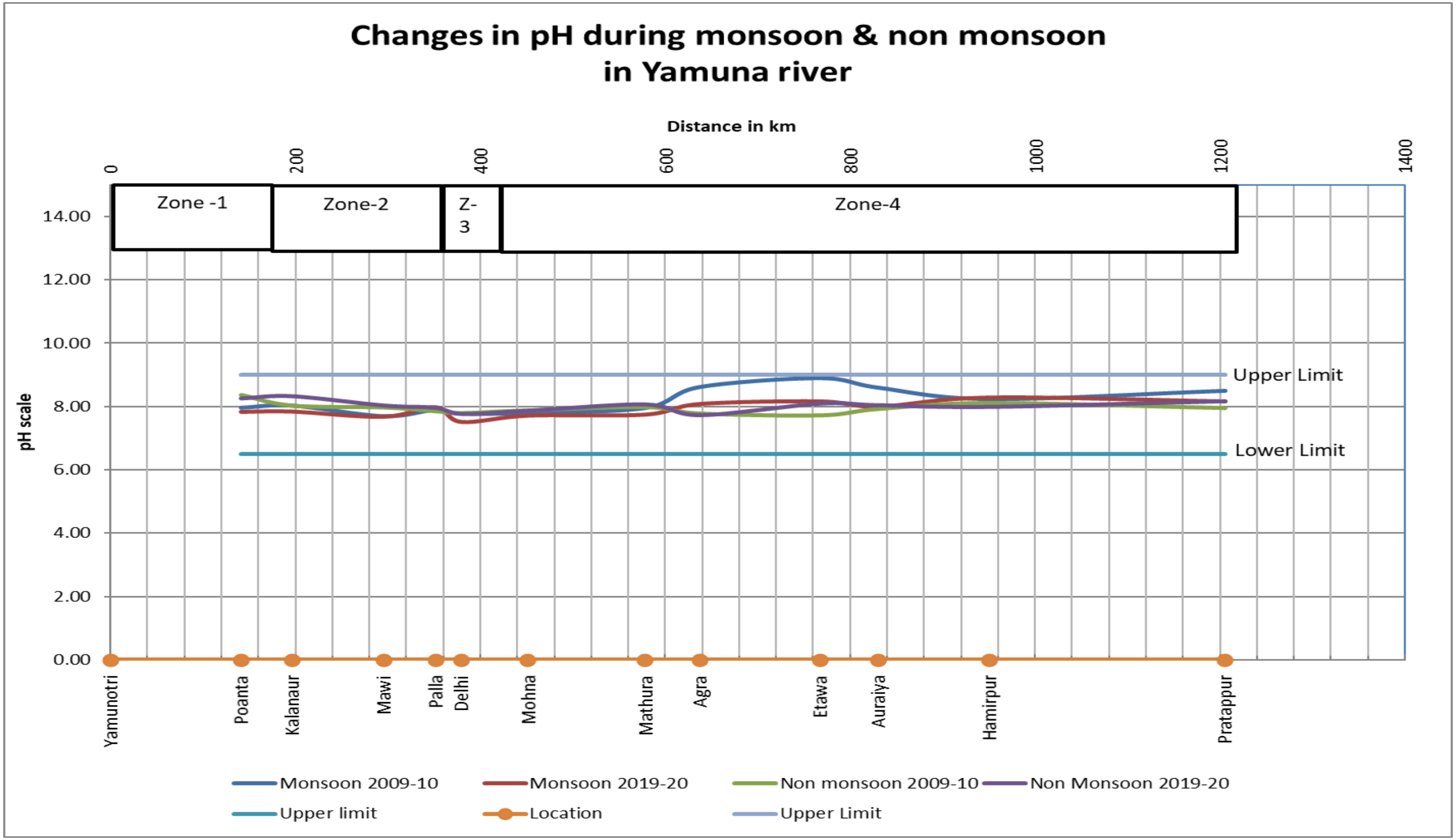


Figure : 4 – pH variation during (2009-10 & 2019-20) in Yamuna River

7.2 ELECTRICAL CONDUCTIVITY

Electrical conductivity is the measure of the ability of a solution to conduct an electric current and is sometimes referred to as “specific conductance.” This electrical conductivity is due to the anions and cations in the solution. Electrical conductivity depends on the ionic strength of the water. There are no BIS limits for conductivity of drinking water; however, as per quality survey made by UNESCO/WHO, the electrical conductivity of most fresh and finished waters is in the range of 5-50 µmhos/cm. The BIS (Bureau of Indian Standard) IS: 2296; 1992 prescribed limit of conductivity is 2250 µmhos/cm for Class E - Irrigation/Agriculture purpose. During the period between 2009-10 and 2019-20 Conductivity was at its maximum level in the entire river stretch during non-monsoon seasons and decreasing in monsoon season significantly after getting dilution during monsoon seasons.

During the period of the study, the average values of electrical conductivity observed during monsoon and non-monsoon period (2009-10 & 2019-20) in the River Yamuna stretch at Poanta to Pratappur are given in the following figure:

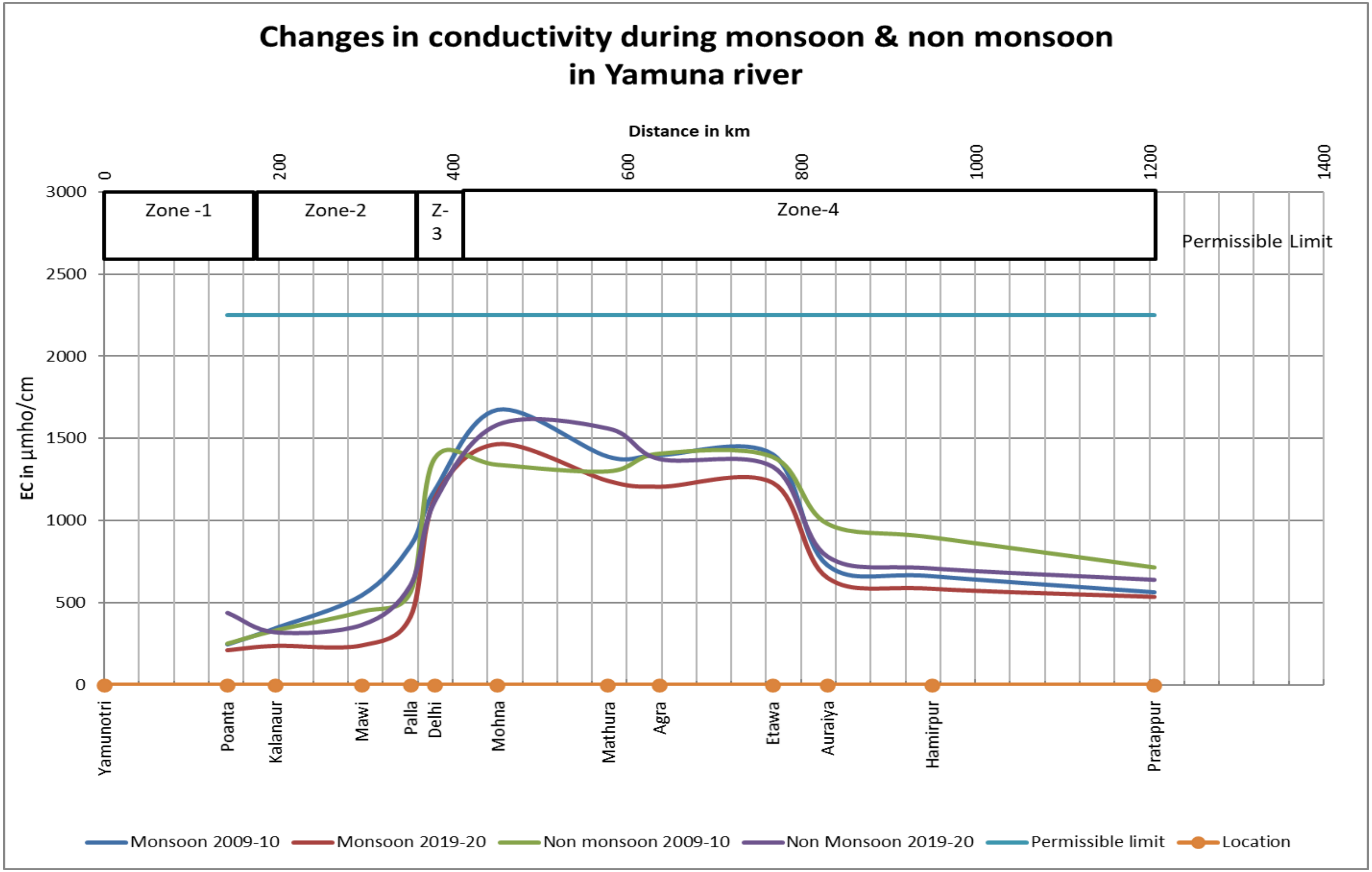


Figure : 5 – Electrical Conductivity variation during (2009-10 & 2019-20) in Yamuna River

From above graph it is clear that change in conductivity is sharp in segment III of 22 km stretch but in segment I the change is not so significant in both monsoon and non-monsoon season. But in all segment i.e. from segment I to segment IV the electrical conductivity is not crossing the limit of 2250 μmhos/cm in both seasons.

7.3 HARDNESS

BIS 2296:1992 has set the limit of total hardness for Class A - Drinking water source without conventional treatment but after disinfections is 200 mg/L. Since the parameter can be addressed adequately during treatment, hence it does not have a prescribed value for Class C. Therefore, the reference value of Class A is taken for analysis here.

During the period of the study, the average values of total hardness observed during monsoon and non-monsoon period in the River Yamuna stretch at Poanta to Pratappur are given in the following figure 6.

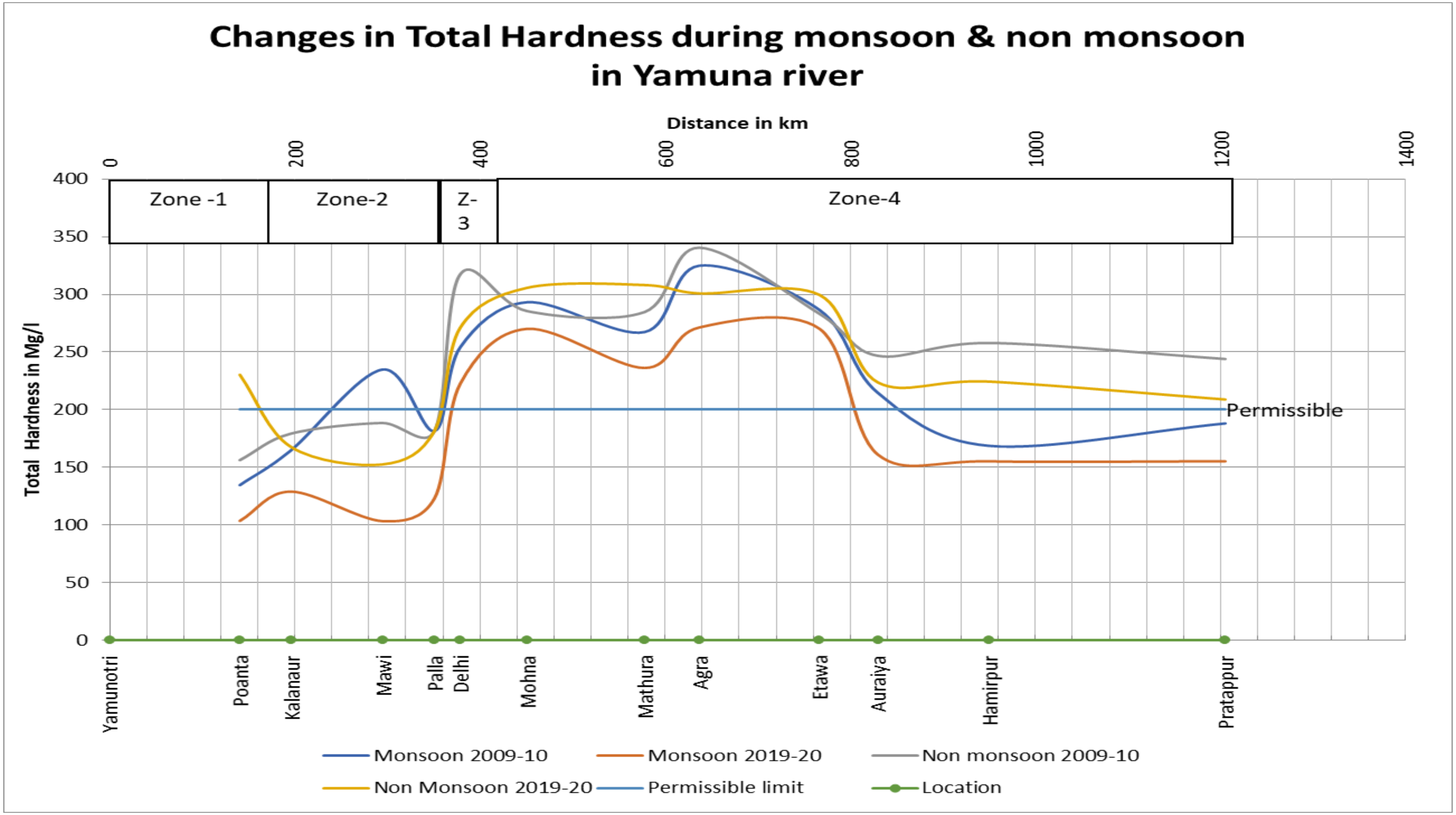


Figure: 6 – Total Hardness variation during (2009-10 & 2019-20) in Yamuna River

During the period between 2009-10 to 2019-20 in segment I the hardness is nearly 150 mg/L in both seasons. In segment II the value is 190 mg/L up to Palla in in both seasons. But in segment III it is 240 mg/L in monsoon and 340mg /L in non-monsoon. In Segment IV the value is high 340mg/L in monsoon and 350 mg/L in non-monsoon at Agra site. After Agra site the hardness is declining in both seasons up to Partapur.

7.4 DISSOLVED OXYGEN (DO)

The presence of dissolved oxygen (DO) is essential to maintain the biological life and to keep proper balance of various populations of aquatic species thus making the water bodies healthy. BIS 2296:1992 has set the limit of dissolved oxygen for Class B – out door bathing is 5 mg/litre. For Class C and Class D - Drinking water source without conventional treatment but after disinfections and Propagation of Wild life and Fisheries are 4 mg/litre.

During the period of the study, the average values of dissolved oxygen observed during monsoon and non-monsoon period (2009-10 & 2019-20) in the River Yamuna stretch at Poanta to Pratappur are given in the following figure 7.

Yamuna River receives significantly high amounts of organic matter, which generally originate from domestic sources. For biodegradation, this organic waste requires oxygen, causing a significant depletion of dissolved oxygen in the river water. The oxygen depletion not only affects biotic community of the river but also affects its self-purification capacity. This problem is critical in the river stretch between Delhi and its confluence with Chambal River. In the Delhi stretch, the load of organic matter is so high that it consumes the entire dissolved oxygen available in river water.

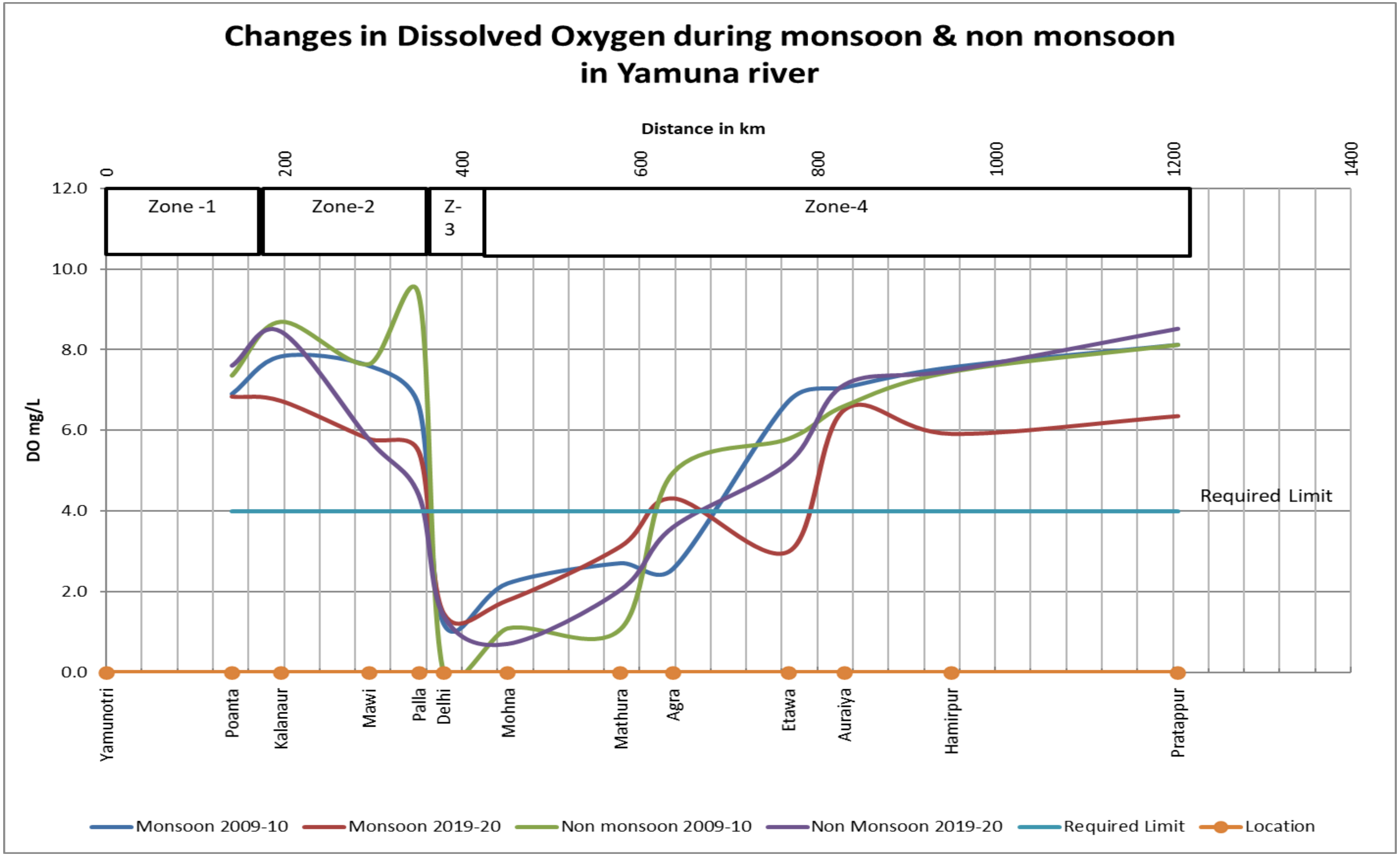


Figure : 7 – Dissolved Oxygen variation during (2009-10 & 2019-20) in Yamuna River

During the period between 2009-10 to 2019-20 the DO in segment I is 7.0 mg/L in monsoon and nearly 8.0 mg/L in non-monsoon seasons. In segment II DO is decreasing from 7.0mg/L to 5.5 mg/L in monsoon and in non-monsoon the value is 8.0mg/L to 4.5 mg/L. In 2009-10 the DO was near 1.0mg/L at Delhi site in monsoon seasons and 0.0 mg/l in Non-Monsoon but in monsoon the DO is little improved and become 2.0mg/L in 2019-20 in Delhi-segment III. In segment IV after Agra site DO is improving in both seasons during the period between 2009-10 and 2019-20.

7.5 BIO-CHEMICAL OXYGEN DEMAND (BOD)

As is well known, BOD is the indicative of organic load, which is primarily due to sewage load in the rivers. BIS 2296:1992 has set the limit of BOD for Class C - Drinking water source without conventional treatment but after disinfections is 3 mg/L.

During the period of the study, the average values of BOD observed during monsoon and non-monsoon period in the River Yamuna stretch at Poanta to Pratappur are given in the following figure 8. The spatial trend of the bio-chemical oxygen demand (BOD) during the year 2009-10 & 2019-20 (season wise) of all 12 water quality stations of Yamuna River are given below in figure.

The BOD is nearly 1 mg/litre in segment I at Poanta site means water is pure during the period of 2009-10 and 2019-20 I while in segment II the BOD varying but it is below 5mg/litre in both seasons. But in Segment III there is a marked increase in value of BOD between Delhi Railway Bridge and Agra. This shows major mixing of sewage and allied activities such as open defecation, cattle wallowing, disposal of animal carcass and unburnt bodies, in the intervening stretch. Our studies show that Najafgarh drain is a major source of organic pollution in the river in this stretch. Further due to low velocities in river Yamuna, the diffusion of atmospheric oxygen also slows down resulting in a deeper drag on the dissolved oxygen. Mohana the nearest city is about 50 km downstream of Delhi and there is no rivers/rivulets joining Yamuna in between. As stated, the drain that joins Yamuna and carries the waste water from East Delhi and Noida is highly polluted and very rich in organic load and coliform population. The river here also shows strong eutrophic conditions but there is not many fish present in this reach due to high pollution load that generally decrease the dissolved oxygen levels enabling only harder fish to survive in such environment. But in segment IV the BOD value in both seasons is decreasing after Agra site during the period 2009-10 and 2019-20.

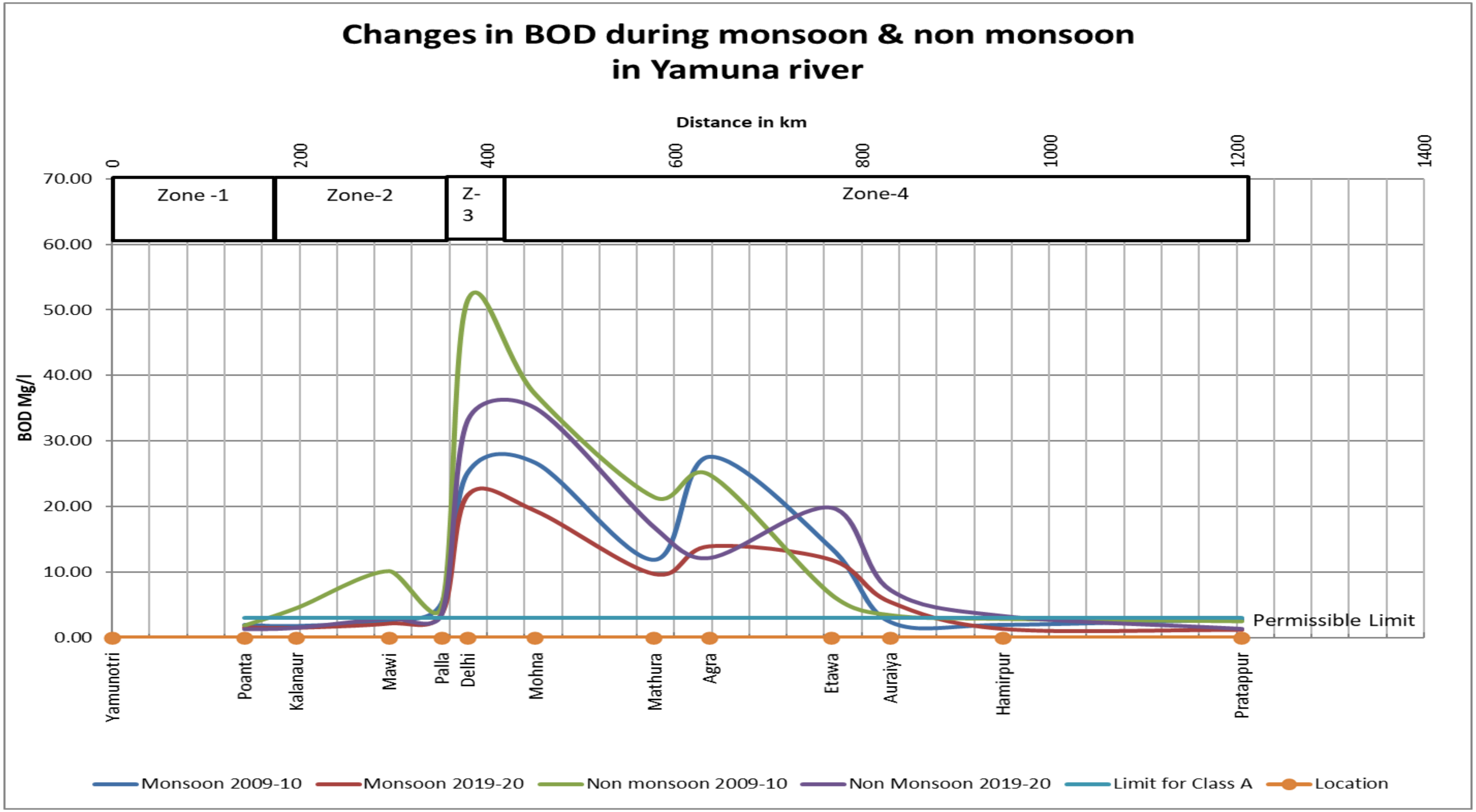


Figure : 8– BOD variation during (2009-10 & 2019-20) in Yamuna River

7.6 TOTAL DISSOLVED SOLIDS (TDS)

Sudden increase in the content of TDS can often indicate pollution by an extraneous source. Harmful hazardous and lethal heavy metals are also found in the form of dissolved solids. The BIS (Bureau of Indian Standard) 2296:1992 has recommended the TDS value Class A - Drinking water source without conventional treatment followed by disinfections is 500 mg/L.

During the period of the study, the average values of TDS observed during monsoon and non-monsoon period in the River Yamuna at Poanta to Pratappur are given in the following figure 9.

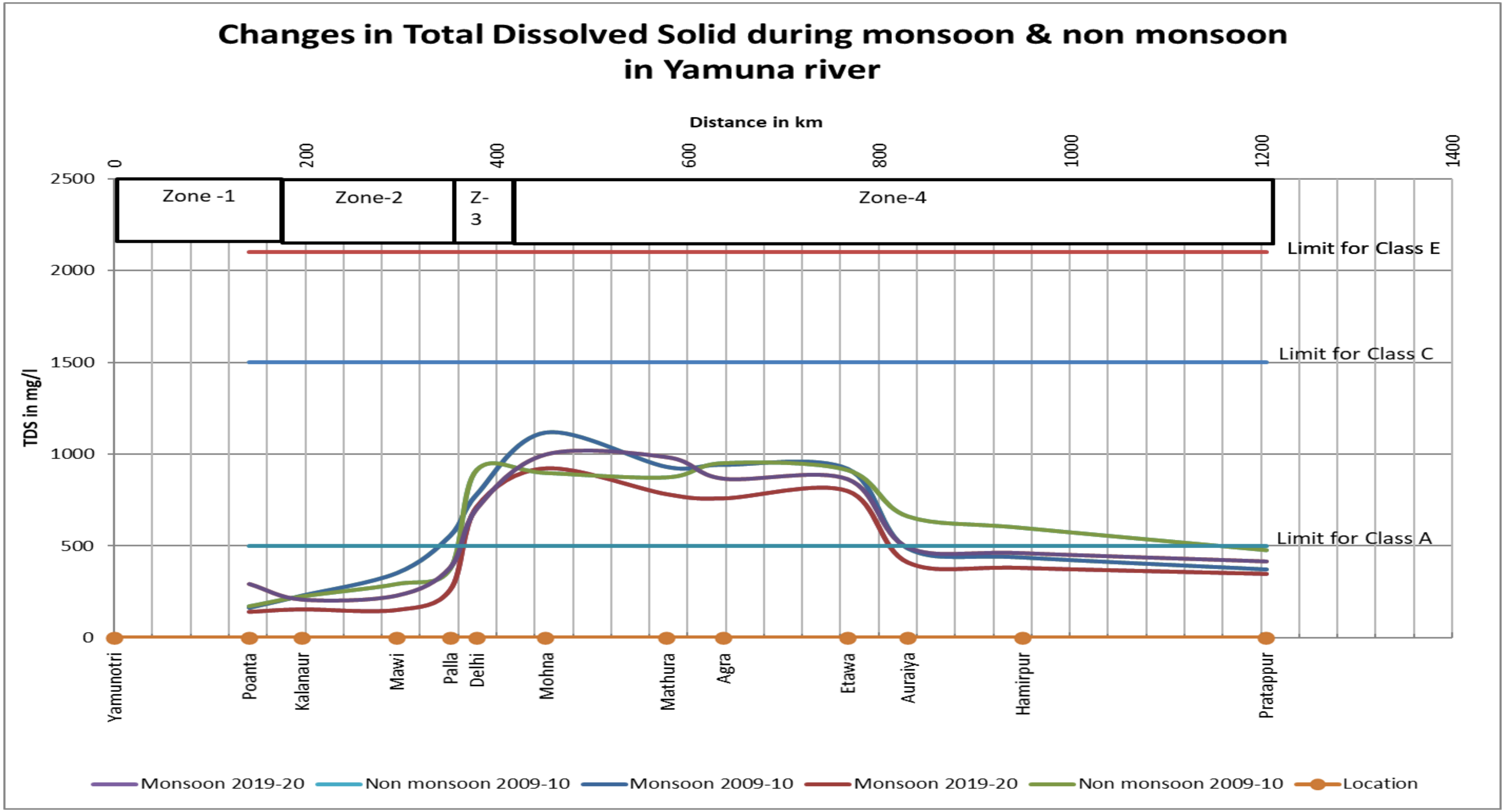


Figure : 9– TDS variation during (2009-10 & 2019-20) in Yamuna River

In segment I at Ponta site the TDS is below 200mg/L in monsoon and between 200 to 400mg/L . In segment II TDS is below 200mg/L up to Palla. After Palla site in segment III TDS is increasing sharply indicating more dissolved ions in both seasons. The TDS is 1200mg/L in monsoon and 1000m/L in non-monsoon season. While in segment IV after Agra site its value is decreasing up to Partapur.

7.7 CHLORIDE:

The BIS (Bureau of Indian Standard) 2296:1992 has recommended the Chloride value Class A - Drinking water source without conventional treatment followed by disinfections is 250 mg/L.

During the period of the study, the average values of Chloride observed during monsoon and non-monsoon period in the River Yamuna at Poanta to Pratappur are given in the following figure.

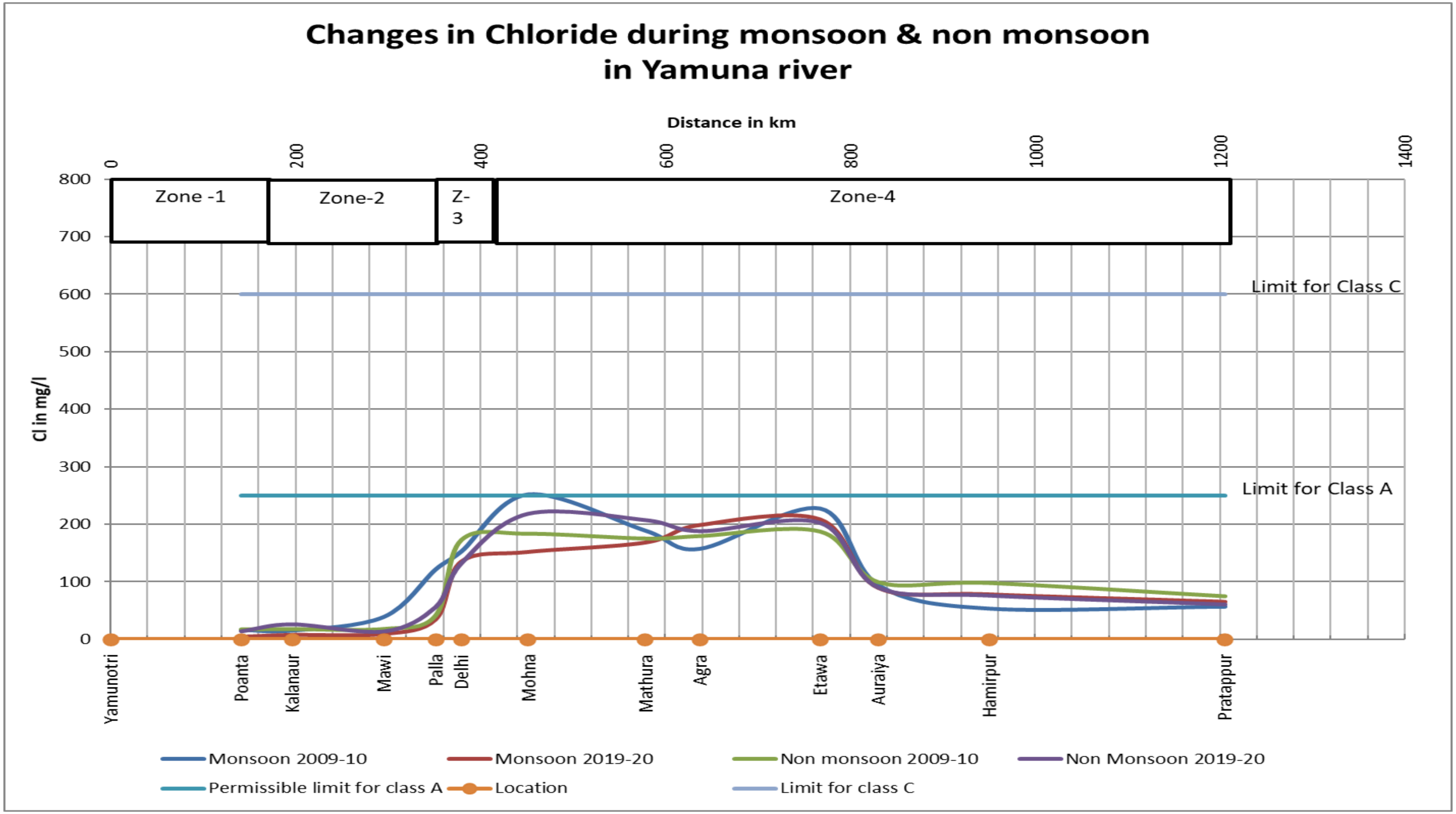


Figure : 10 – Chloride variation during (2009-10 & 2019-20) in Yamuna River

In segment I the chloride is below 50 mg/L in both seasons. The BIS limit is 250 mg/L for class “A” water, so chloride is well below the limit in this segment. In segment II its value is between 25mg/L and 50 mg/L in both seasons i.e. below the permissible limit for class “A” water. In segment III too the chloride concentration is below the permissible limit for class “A” water. The chloride concentration is not above the permissible limit for class “A” water in entire stretch of Yamuna.

7.8 FLUORIDE:

The BIS (Bureau of Indian Standard) 2296:1992 has recommended the Fluoride value Class A - Drinking water source without conventional treatment followed by disinfections is 1.5 mg/L.

During the period of the study, the average values of Fluoride observed during monsoon and non-monsoon period in the River Yamuna at Poanta to Pratappur are given in the following figure.

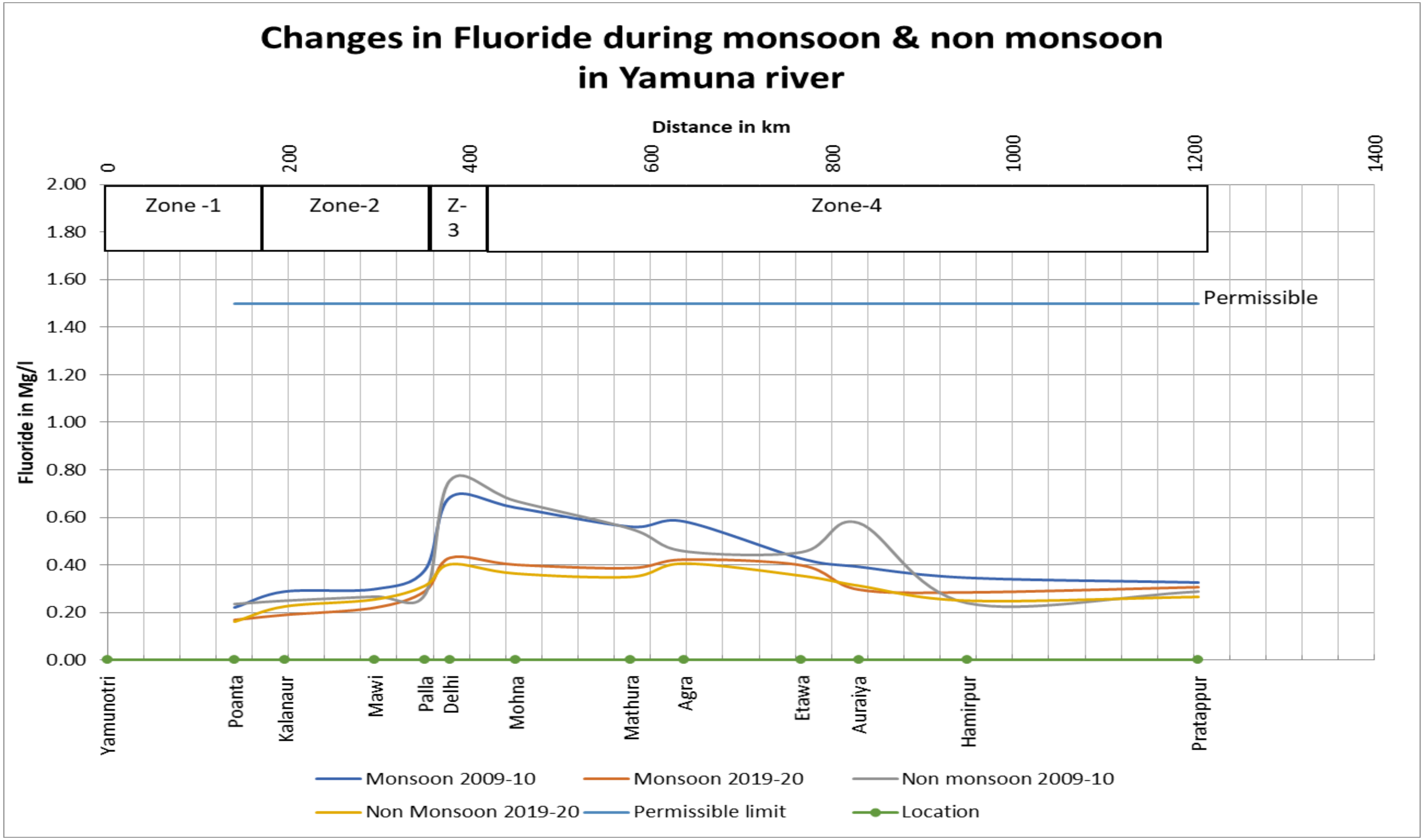


Figure : 11 – Fluoride variation during (2009-10 & 2019-20) in Yamuna River

In segment I Fluoride is below 0.20 mg/L While in segment II the fluoride value is rising but below 0.30 mg/L. The permissible limit is 1.50 mg/L for class “A” water. In entire stretch of Yamuna river the fluoride value is below the limit of 1.50mg/L

7.9 SULPHATE:

The BIS (Bureau of Indian Standard) 2296:1992 has recommended the Sulphate value Class A - Drinking water source without conventional treatment followed by disinfections is 400 mg/L.

During the period of the study, the average values of Sulphate observed during monsoon and non-monsoon period in the River Yamuna at Poanta to Pratappur are given in the following figure. In segment I the sulphate is below 40mg/L. In segment II it value is rising up to 100mg/L in monsoon and 80 mg/L in non-monsoon. In segment III it is below 80 mg/L. In segment IV the sulphate is higher than 100 mg/L up to Agra. After Agra site the sulphate concentration is lowering.

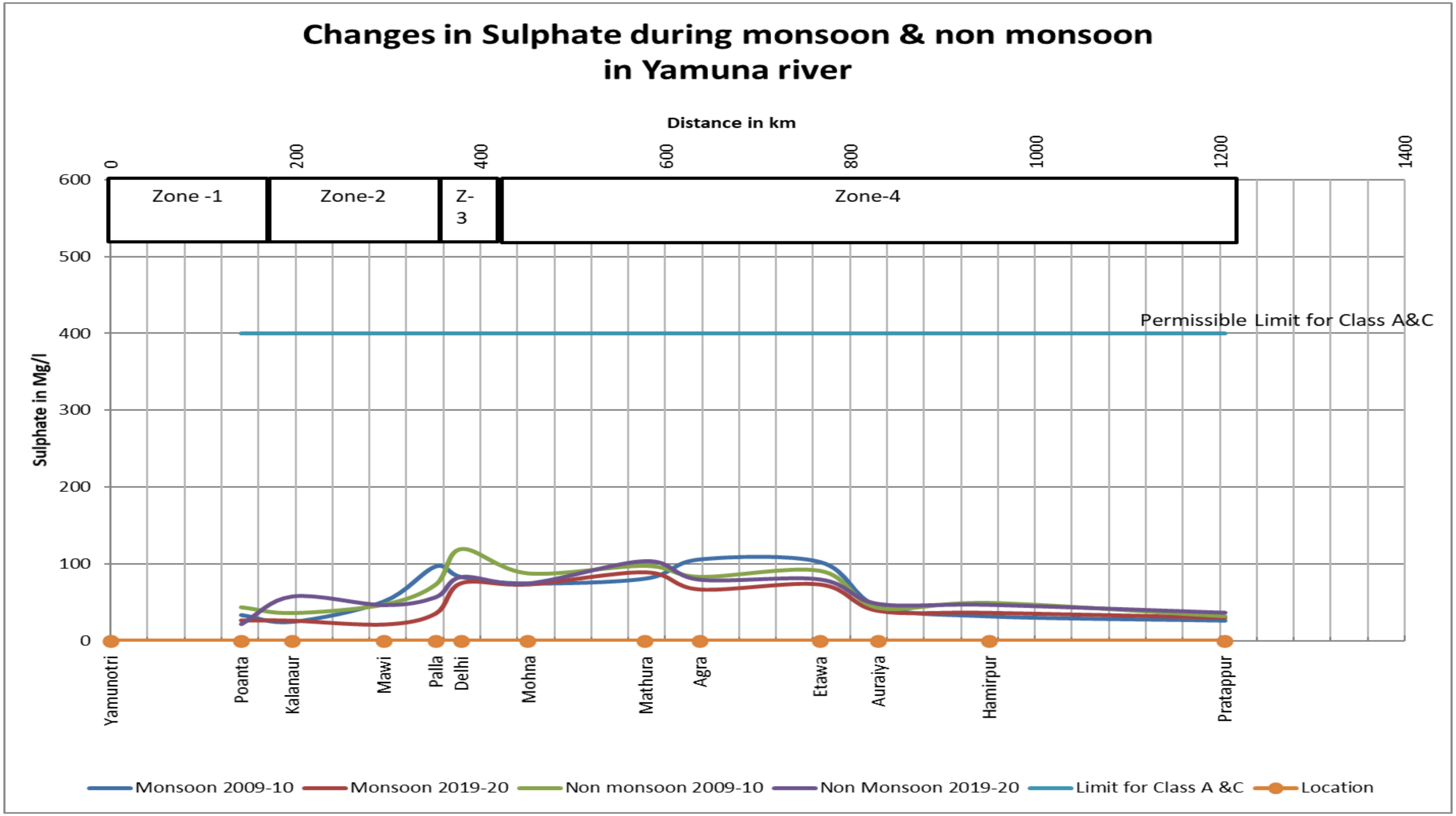


Figure : 12 – Sulphate variation during (2009-10 & 2019-20) in Yamuna River

7.10 % Sodium:

During the period of the study, the average values of % Sodium observed during monsoon and non-monsoon period in the River Yamuna at Poanta to Pratappur are given in the following figure.

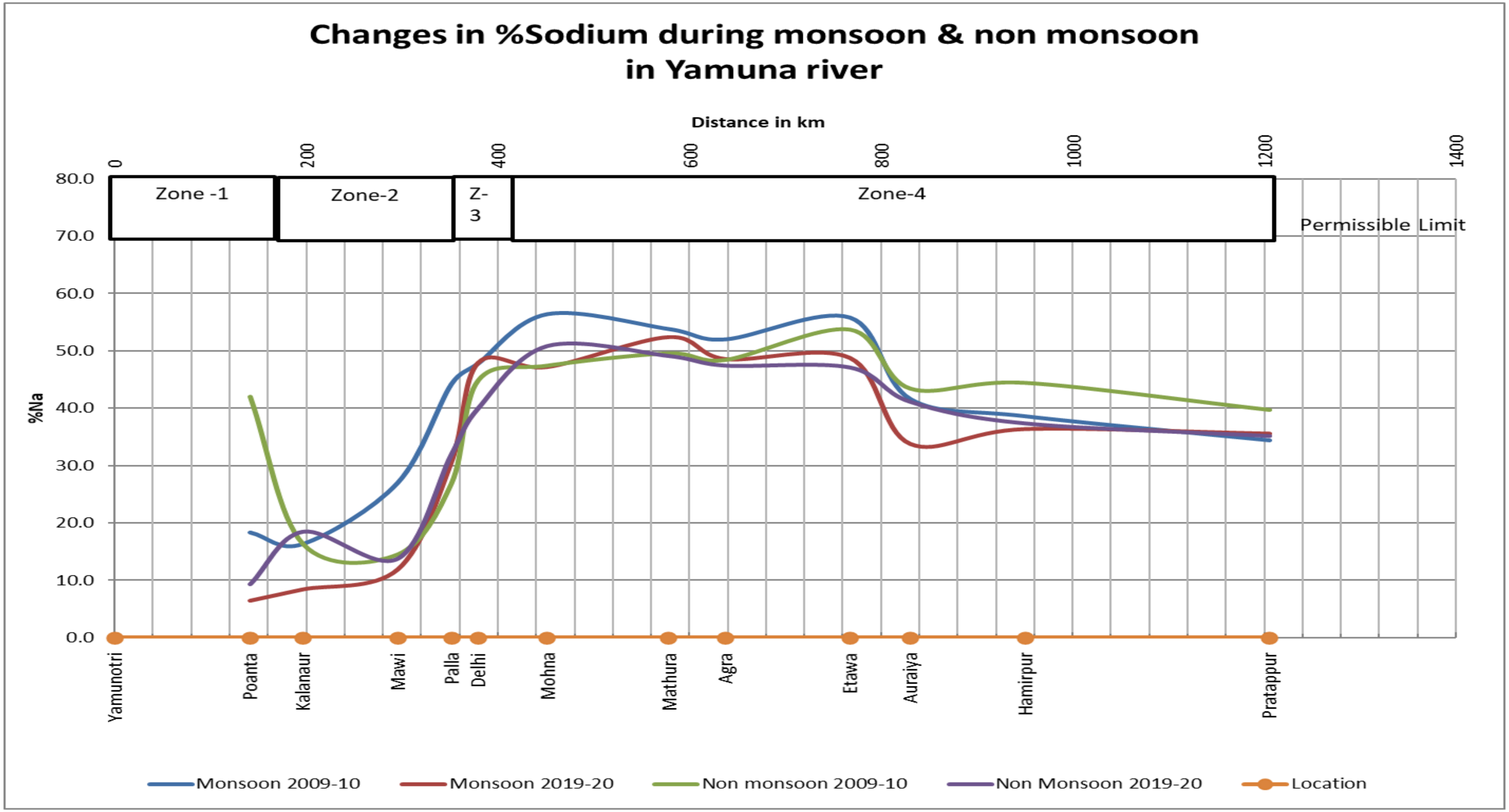


Figure: 13 – % Sodium variation during (2009-10 & 2019-20) in Yamuna River

Fitness of water in respect of Classes as per IS :2296 1992 of River Yamuna

1.Non-Monsoon(2009-10 & 2019-20)

Fitness of water in respect of Classes as per IS :2296 1992 in Non-Mansoon (2009-10)											
Name of Site	EC_GEN (µmho/cm)	pH_GEN (pH units)	TDS	B (mg/L)	Ca (mg/L)	Cl (mg/L)	F (mg/L)	SO4 (mg/L)	BOD3-27 (mg/L)	DO (mg/L)	HAR_Total (mgCaCO3/L)
Poanta	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C	A to D	A
Kalanaur	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	A to D	A
mawi	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	A to D	A
palla	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	A to D	A
Delhi	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	Not Fit	Not Fit
Mohna	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	B,C,D	Not Fit
Mathura	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	B,C,D	Not Fit
Agra	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	B,C,D	Not Fit
Etawah	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	A to D	Not Fit
Auriya	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	B,C	A to D	Not Fit
Hamirpur	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	B,C	A to D	Not Fit
Partapur	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C	A to D	Not Fit

Fitness of water in respect of Classes as per IS :2296 1992 in Non-Mansoon (2019-20)											
Name of Site	EC_GEN (µmho/cm)	pH_GEN (pH units)	TDS	B (mg/L)	Ca (mg/L)	Cl (mg/L)	F (mg/L)	SO4 (mg/L)	BOD3-27 (mg/L)	DO (mg/L)	HAR_Total (mgCaCO3/L)
Poanta	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C	A to D	Not Fit
Kalanaur	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C	A to D	A
mawi	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	B,C	A to D	A
palla	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	C,D	A
Delhi	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	Not Fit	Not Fit
Mohna	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	Not Fit	Not Fit
Mathura	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	Not Fit	Not Fit
Agra	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	C,D	Not Fit
Etawah	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	B,C,D	Not Fit
Auriya	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	A to D	Not Fit
Hamirpur	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	B,C	A to D	Not Fit
Partapur	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C	A to D	Not Fit

2. Monsoon (2009-10 & 2019-20)

Fitness of water in respect of Classes as per IS :2296 1992 in Mansoon (2009-10)											
Name of Site	EC_GEN (µmho/cm)	pH_GEN (pH units)	TDS	B (mg/L)	Ca (mg/L)	Cl (mg/L)	F (mg/L)	SO4 (mg/L)	BOD3-27 (mg/L)	DO (mg/L)	HAR_Total (mgCaCO3/L)
Poanta	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C,D	A to D	A
Kalanaur	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C,D	A to D	A
mawi	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	B,C	A to D	Not Fit
palla	E	A to E	B,C	E	A	A,C,E	A,B,C	A,C,E	Not Fit	A to D	A
Delhi	E	A to E	B,C	E	A	A,C,E	A,B,C	A,C,E	Not Fit	Not fit	Not Fit
Mohna	E	A to E	B,C	E	A	A,C,E	A,B,C	A,C,E	Not Fit	A to D	Not Fit
Mathura	E	A to E	B,C	E	A	A,C,E	A,B,C	A,C,E	Not Fit	B,C,D	Not Fit
Agra	E	A to E	B,C	E	A	A,C,E	A,B,C	A,C,E	Not Fit	Not Fit	Not Fit
Etawah	E	A to E	B,C	E	A	A,C,E	A,B,C	A,C,E	Not Fit	A to D	Not Fit
Auriya	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	B,C,D	A to D	Not Fit
Hamirpur	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C,D	A to D	A
Partapur	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	B,C,D	A to D	A

Fitness of water in respect of Classes as per IS :2296 1992 in Mansoon (2019-20)											
Name of Site	EC_GEN (µmho/cm)	pH_GEN (pH units)	TDS	B (mg/L)	Ca (mg/L)	Cl (mg/L)	F (mg/L)	SO4 (mg/L)	BOD3-27 (mg/L)	DO (mg/L)	HAR_Total (mgCaCO3/L)
Poanta	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C,D	A to D	A
Kalanaur	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C,D	A to D	A
mawi	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	B,C,D	B,C,D	A
palla	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	B,C,D	A
Delhi	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	Not Fit	Not Fit
Mohna	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	Not Fit	Not Fit
Mathura	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	Not Fit	Not Fit
Agra	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	C,D	Not Fit
Etawah	E	A to E	C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	Not Fit	Not Fit
Auriya	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	Not Fit	A to D	A
Hamirpur	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C,D	B,C,D	A
Partapur	E	A to E	A,C,E	E	A	A,C,E	A,B,C	A,C,E	A,B,C,D	A to D	A

CONCLUSION: -

The Yamuna River has high religious importance. Yamuna River maintains reasonably good quality upstream of Delhi and thus it satisfies the designated best use criteria most of the times except sometimes in summer season. The pollution in the Yamuna River originates from domestic, industrial and agricultural activities apart from a totally mismanaged solid waste collection and disposal. Mass bathing in the river, open defecation and disposal of dead animals also add to the problem. Huge amounts of untreated domestic sewage in Delhi and nonavailability of dilution water results in degradation of water quality downstream stretch of the river segment III. The river in its 500 km stretch from Delhi to the Chambal confluence is not fit in segment IV for its designated best use even in the monsoon season when sufficient dilution is available. The pollution is predominantly organic in nature. Therefore, the depletion of oxygen is the major impact on the polluted stretch of the river which disturbs the river ecosystem to a large extent. The biodegradation of this organic pollution results in the release of nutrients which in turn promotes the growth of algae and other aquatic plants in the river. This excessive growth of unwanted plants results in the situation of eutrophication. Due to eutrophic conditions in this segment of the river, the dissolved oxygen during nights is depleted to a large extent resulting in mass killing of fishes and other aquatic life. The conditions are worsened by the addition of untreated domestic sewage from Mathura and Agra i.e. segment IV. Thus in this entire stretch of 500 km, the oxygen is the key factor which determines the health of the river and distribution of aquatic life in it.

The strategies that could restore the Yamuna water quality to its pristine status in the reaches of the river, include the defensive approach (reducing the concentration of the pollutants) and the pro-active approach (augmenting the river's ability to assimilate higher amounts of the pollutants at higher rates).

The following need to be taken by central and state govt immediately. -

1. **Defensive approaches:**
    a. Improving the sewerage system
    b. Wastewater treatment and management
    c. Upgrading the existing sewage treatment plants capacity
    d. Proper disposal of (partially) treated sewage
    e. Industrial waste water management
    f. Improving agriculture practices
    g. Solid waste management
    h. Planning and zoning of the wastewater outfalls

i. Legislation and fines

2. Pro-active approaches

a. Creation of awareness amongst the masses
b. Improving the dilution ratio of the river
c. Artificial and in–stream aeration
d. Increasing the river's waste assimilative capacity
e. Creation of an artificial lake
f. A minimum e-flow of river may be maintained

National River Water Quality Laboratory a overview

National Accreditation Board for Testing and Calibration Laboratories

NABL

CERTIFICATE OF ACCREDITATION

NATIONAL RIVER WATER QUALITY LABORATORY CENTRAL WATER COMMISSION

has been assessed and accredited in accordance with the standard

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TESTING

Certificate Number: TC-5578

Issue Date: 12/04/2020 **Valid Until:** 11/04/2022

This certificate remains valid for the Scope of Accreditation as specified in the annexure subject to continued satisfactory compliance to the above standard & the relevant requirements of NABL.
(To see the scope of accreditation of this laboratory, you may also visit NABL website www.nabl-india.org)

Signed for and on behalf of NABL

N. Venkateswaran
Chief Executive Officer

जल वर्ष-2019-20

Water Year- 2019-20

A Report on Water Quality Scenario of Hoshangabad & Patan station in Narmada River Basin

केन्द्रीय जल आयोग

CENTRAL WATER COMMISSION

नर्मदा मंडल, भोपाल (म.प्र.)

Narmada Division, Bhopal (M.P.)

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1 Introduction

1.1 Basin Description

Narmada Basin is the fifth largest among the twelve major river basins of the country. Narmada is an interstate river having total length of 1312 km, of which 1079 km flows in Madhya Pradesh, 35 km flows along the common border of Madhya Pradesh and Maharashtra, 39 km flows along the border of Maharashtra, and Gujarat and 159 km flows in Gujarat. The total basin area is approximately 98796 sq km, out of which 85859 sq km lies in Madhya Pradesh, 1538 sq km in Maharashtra and 11399 sq km. lies in Gujarat. The river originates from the Amarkantak Plateau of Maikal range at about 1057 metre above Mean Sea Level (MSL) and major part flows through narrow elongated trough running east to west with slight inclination towards the south, before it drains into the Arabian Sea at the Gulf of Khambat near Bharuch in Gujarat.

In its 1312 km long stretch, tributaries of various sizes contribute water and their pollution load to the Narmada River. A characteristic change in the water quality is expected when the tributaries join the river. There are about 19 major tributaries of Narmada listed by Narmada Water Disputes Tribunal, out of which nine are being considered for water quality assessment.

2 Water Quality Observation

2.1 Sampling

Sampling and analysis of water samples is done as per the standard norms set by the Water Quality Assessment Authority (WQAA June 2005). The water samples are collected every month during 08.00 AM to 10.00 AM on first working day of the month provided that the samples reach to the Divisional Laboratory at Bhopal on the next day. These water samples are collected at 30 cm depth from surface without disturbing the bottom sediments, from the point across the river section having maximum depth or maximum flow along the cross section of the river, so that sample must be representative of the source that

The samples are collected in clean and pre-rinsed plastic bottles of one litre capacity, filled up to their full capacity without air bubbles. Measurements of some other parameters like in-situ temperature; depth, velocity of water etc. are written on paper slip and pasted on the polythene bottles for identification. The collected water samples are preserved and transported as per the standard norms to Divisional Laboratory Bhopal by special messenger so as to reach within 24 hours of collection for minimum changes, if any, in the properties during the transit period (time when the samples are collected and the time when they are analysed).

2.2 Method of Analysis

The water sample preserved in laboratory is analysed using standard analytical and/or instrumental methods, which are quick, usually much faster than purely chemical procedures and suited for number of routine analysis. The quantitative estimation for the parameters detailed above are determined by titrimetric methods, electrical methods and optical methods. The applications of different methods to analyse physical and chemical characteristics of water sample are summarized below.

2.2.1 Physical Characteristics

The major physical characteristics or parameters of water are,

- **Discharge** in cumecs is measured by current meter and this average rate of volume of water with concentration of pollutant give the possibility to detect significant pollution sources and its peaking factor.

- **Colour** in water is the result of dissolved extracts from metals in rocks and soil, from organic matter in soil and plants, and occasionally from industrial by-products. The colour of the water sample is determined by visual comparison method.

- **Odour** of the water sample is determined by qualitative human receptor method.

- The in-situ **temperature** in degree centigrade is measured by thermometer and is recorded to decide the intended use of water, the treatment process to remove impurities and its transport.

- The **pH** of water is measure of the acidic or basic nature of the water. Water with pH lower than 7 are acidic and those with a higher pH are basic. This is observed with a pH meter which actually measures the electrical potential exerted by the H^+ ions.
- Measuring its **electrical resistance** between two electrodes dipped in the sample and comparing its resistance with the resistance of a standard solution of potassium chloride at 25° C by Electrical Conductivity meter determines the conductivity of the water sample. The value of conductivity coefficient is measured in micro-mhos/cm and is an indicator of type of dissolved salts in water.

- **Total Dissolved Solids (TDS)** concentration in mg/l, in conjunction with a detailed chemical analysis, is used to assess the suitability of various water sources for alternative uses such as industry or agriculture. Its value should be between 0.55 and 0.70 of the conductivity coefficient. This is measured with a potentiometer.

- **Turbidity** is defined as the presence of soil particles, clay, silt and other colloidal impurities in the water which obstruct the passage of light through water and hence decreases the clarity of water. The degree of turbidity measured in NTU depends on the fineness of the particles and their concentration. This is measured with a turbidity meter (discussed under nephelometric method) by measuring the interference to the passage of light through a water sample. Surface waters in which there is significant increase in the level of turbidity after a rainfall are often identified as "flashing waters". Such water is more difficult to treat than waters in which the level of turbidity remains reasonably constant.

2.2.2 Chemical Characteristics

The common tests used to quantify the inorganic constituents of water are:

- **Titrimetric Method**: The term titrimetric analysis refers to quantitative chemical analysis carried out by determining the volume of a solution of accurately known concentration (standard solution), which is required to react with the known volume of solution of the substance to be determined. The end point of titration is detectable by perceptible change of colour of the solution produced usually by the addition of an auxiliary reagent known as indicator. Parameters determined by this technique are **Carbonate, Bicarbonate, Chloride, Calcium, Magnesium, Oxygen Absorbed in four Hrs, Chemical Oxygen Demand [COD], Dissolved Oxygen [DO] and Biochemical Oxygen Demand [BOD].**

- **Spectrophotometeric/ Colorimeteric Method**: This instrument works on measurement of the amount of optical energy of a particular wavelength absorbed/transmitted by the solution. The instruments used in this method are UV Double Beam Spectrophotometer. A series of standard solutions of known concentration are prepared and treated with appropriate reagents to produce colored solution. Then the light of specific wavelength is passed through the standard solutions. The transmittance / absorbency is plotted against the concentration and this is termed as calibration or reference curve. Water samples are treated with the same reagents for colour development under the same experimental conditions and then transmittance/ absorbance is measured. Concentration of the constituent is being determined from calibration curve. Parameters analysed by this method are **Iron, Chromium, Ammonium, Fluoride, Nitrate, Nitrite, Phosphate and Silicate.**

- **Flame Spectrophotometery Method:** This is also an optical method of analysis based on measurement of the amount of energy of a particular wavelength emitted. If a solution containing 'a metallic salt is aspirated into a flame, the metal atoms are excited by the thermal energy of the flame and then electrons in the ultimate shell go to higher energy levels and eventually return to ground state and emit the energy in form of radiation. The filter, interposed between the flame and the photocell detector, is used to select a given emission line. To convert the measured emission values into the concentration of the substance being determined, a calibration curve is plotted by aspirating into the flame, samples of solutions containing known concentration of salts (standard solution). A graph is plotted with measured emission against the concentration of solutions. Then the test samples are aspirated for flame emission and emission intensity is measured. From these values of emission from unknown test solution, concentration of substance can be determined from the calibration curve. Parameters estimated through this method are **Sodium and Potassium**.

- **Nephelometric Method**: The measurement of the intensity of the scattered light at right angles to the direction of the incident light as a function of the concentration of the solution is the basis of nephelometric analysis. The calibration curve is plotted by measuring the scattering intensity of standard sulphate solutions added with barium chloride to inhibit the growth of micro crystals of barium sulphate against concentration of solution. Then the test samples are allowed for scattering. The concentration of sulphate-ion content of unknown solution is determined from the calibration curve. Turbidity of the water sample is measured directly by calibrating the instrument with standard turbid solution of 10% Hexamethylene and 1 % Hydrazine sulphate. The parameter analysed by nephelometric method are **Sulphate and turbidity.**

Table 1 Details of Water Quality sites of Narmada Division

S No	Name of Exiting Stations	Local River	Frequency	Latitude (In Decimals)	Longitude (In Decimals)	Type of Lab (Level-1 lab or only Sampling Station)
1	Barmanghat	Narmada	Trend	23°01'51"	79°00"56"	Level 1
2	Mandleshwar	Narmada	Trend	22°10'06"	75°39'39"	Level 1
3	Hoshangabad	Narmada	Trend	22°45'22"	77°43'58"	Level 1
4	Handia	Narmada	Trend	22°29'30"	76°59'37"	Level 1
5	Gadarwara	Shakkar	Trend	22°55'22"	78°47'27"	Level 1
6	Sandia	Narmada	Trend	22°54'57"	78°20'51"	Level 1
7	Manot	Narmada	Trend	22°44'09"	80°30'47"	Level 1
8	Patan	Hiran	Trend	23°18'40"	79°39'43"	WQSS
9	Belkheri	Sher	Trend	22°55'40"	79°20'23"	WQSS
10	Mohgaon	Budner	Trend	22°45'57"	80°37'24"	Level 1
11	Kogaon	Kundi	Trend	22°06'05"	75°41'03"	WQSS
12	Chhidgaon	Ganjal	Trend	22°24'21"	77°18'29"	WQSS
13	Dindori	Narmada	Trend	22°56'52"	81°04'34"	WQSS
14	Bamni	Banjar	Trend	22° 29'03"	80°22'41"	Level 1
15	Bhalwara	Gaur	Trend	23°06'32"	79°58'18"	WQ
16	Mandla	Narmada	Trend	22°35'57"	80°21'50"	WQ

TABLE 2:

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)

S. 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

2.0 Analysis of the samples: The collected water samples were analysed for physical and chemical parameters using standard analytical procedure and/or instrumental methods (APHA 23rd edition 2017). The quantitative estimation for the chemical parameters is determined by titrimetric, spectrophotometric, flame photometric method as shown in Table- 3.

Result and Discussion: -

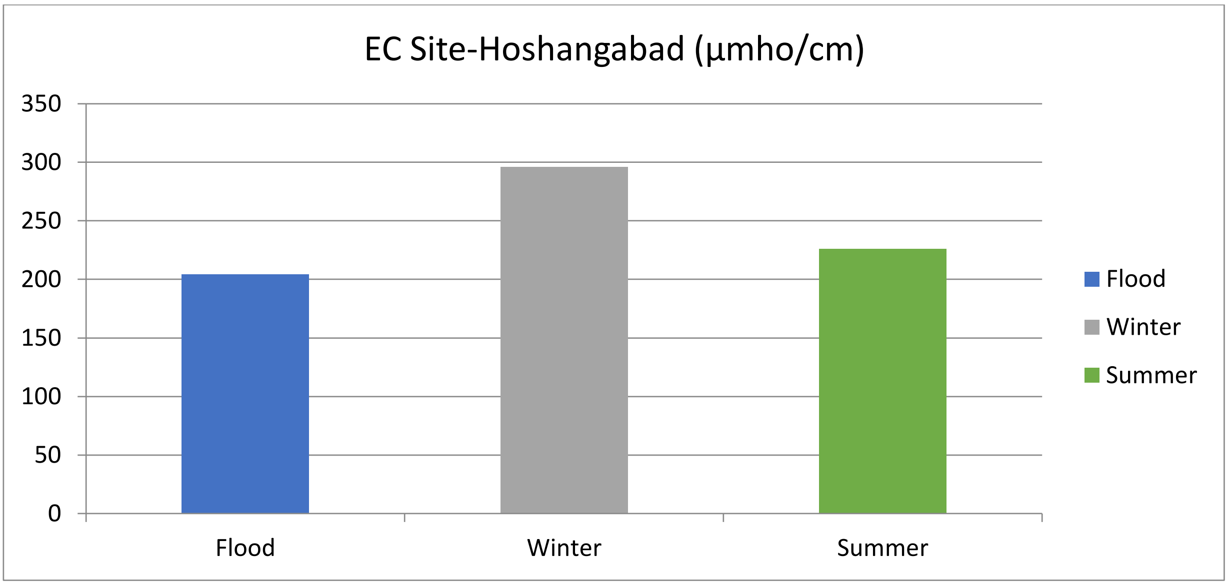
Study of the seasonal variation in the river water quality

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 EC, pH, TDS, D.O. B.O.D, & Nitrate-N and the comparative seasonal variation at site Hoshangabad and Site Patan are given below-

Seasonal Variation in the river water quality

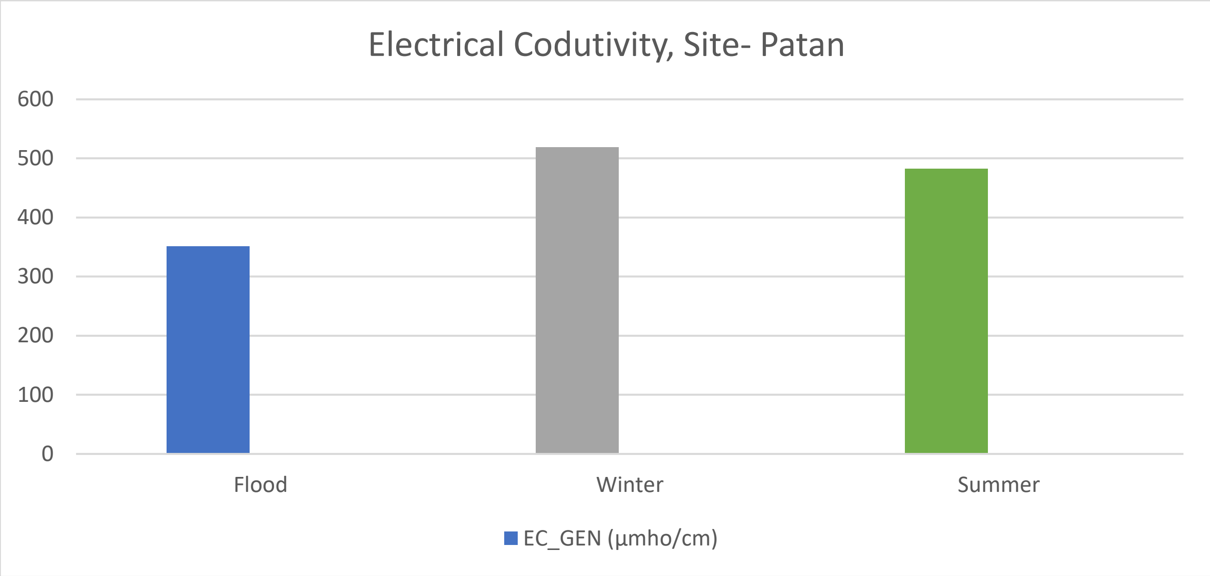
Electrical Conductivity- Hoshangabad

Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Hoshangabad	204	296	226



Electrical Conductivity- Patan

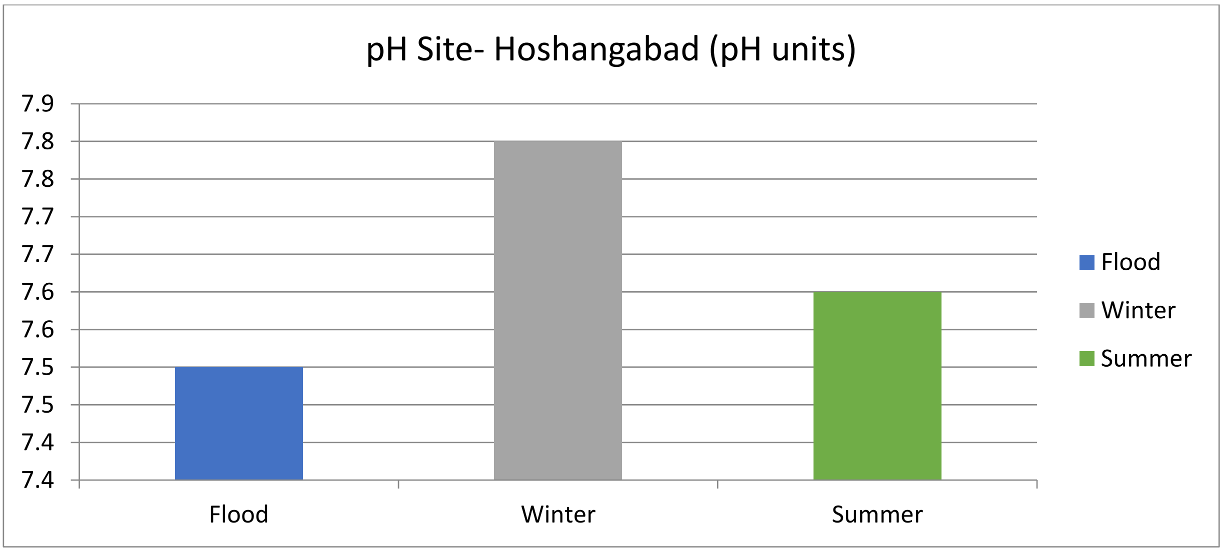
Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Patan	351	519	482



The graphical data shows variation in the value of EC, Flood season plays an important role as it dilutes the river water up to some extent. Hence it results in lower value of EC as compared to summer season.

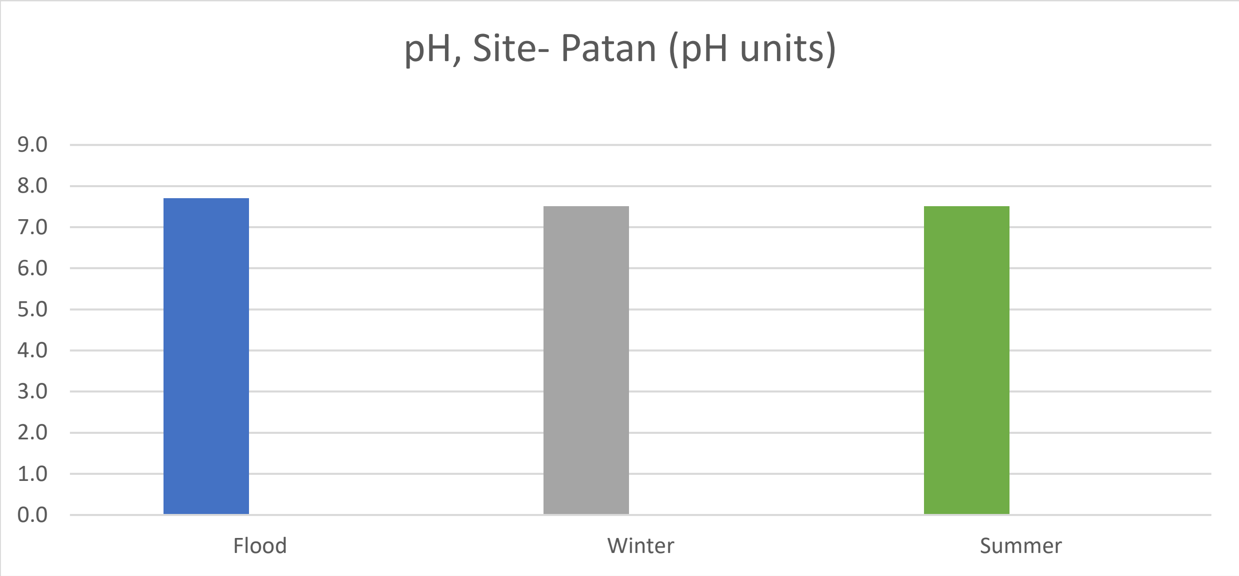
pH site-Hoshangabad

Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Hoshangabad	7.5	7.8	7.6



pH, Site- Patan

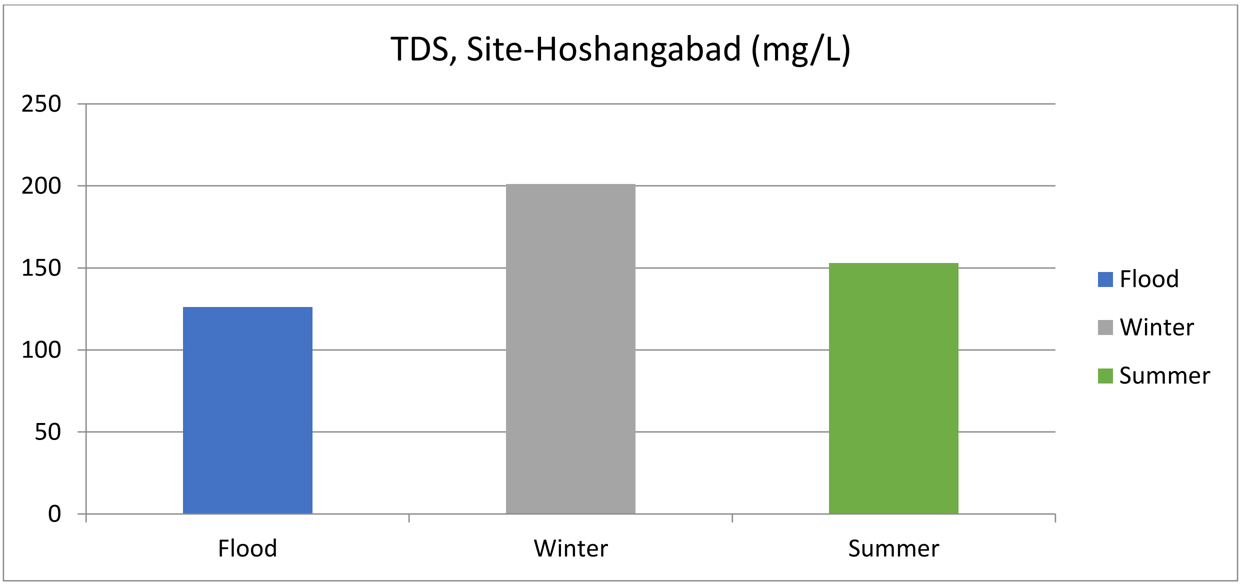
Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Patan	351	519	482



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. Site Patan shows some deviation from it.

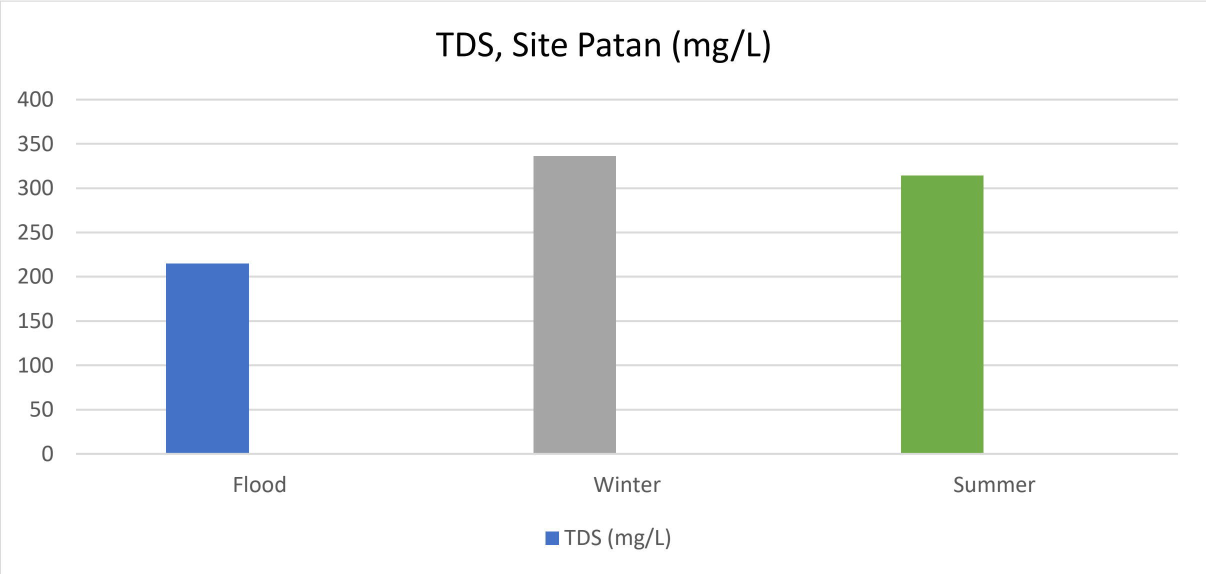
TDS site-Hoshangabad

Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Hoshangabad	126	201	153



TDS, site- Patan

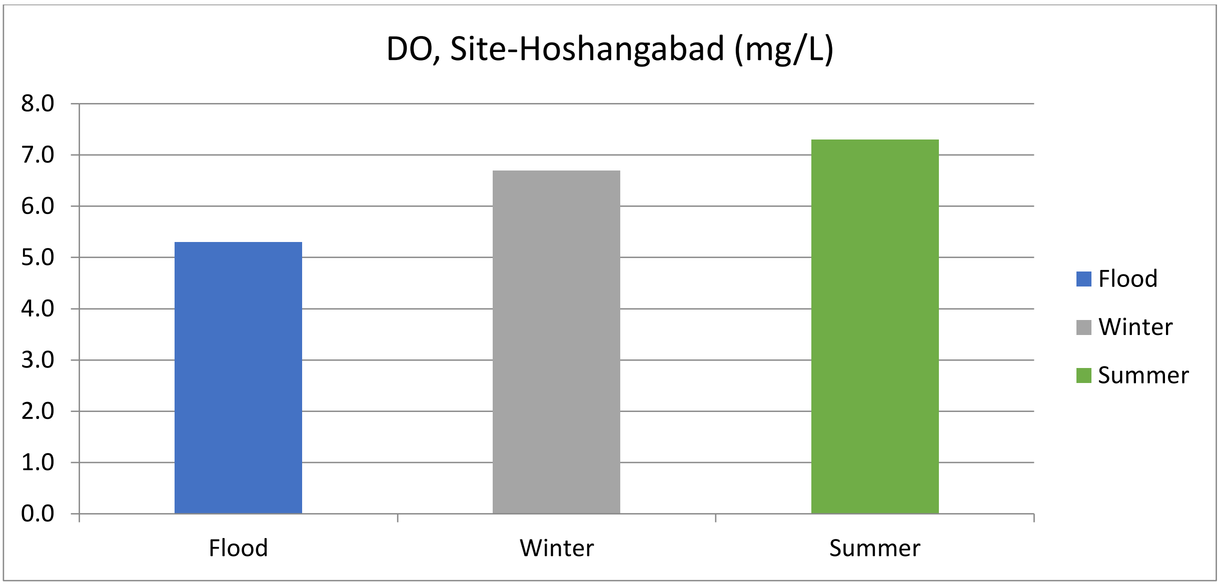
Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Hoshangabad	215	336	314



The graphical data shows variation in the value of TDS depending upon the concentration of dissolved inorganic solids, in summer season generally TDS is maximum due to evaporation of river water and minimum in flood season due to dilution of river water but It can be attributed reduced anthropogenic sources of contamination of river water owing to the lockdown in the month of March and April (Summer season)

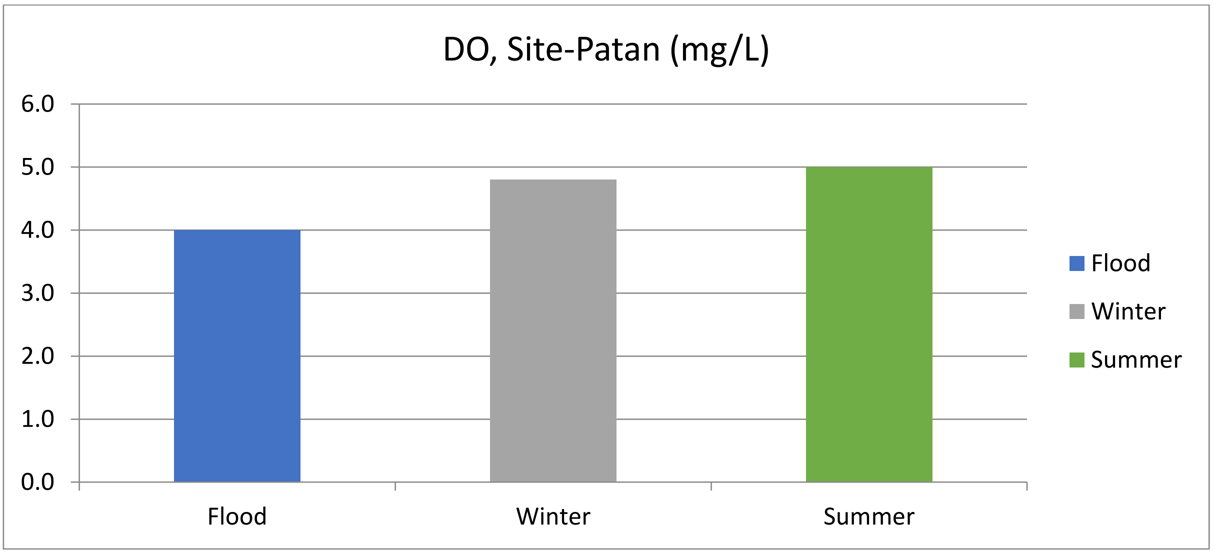
Oxygen Demand, Site Hoshangabad

Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Hoshangabad	5.3	6.7	7.3



Oxygen Demand, Site Patan

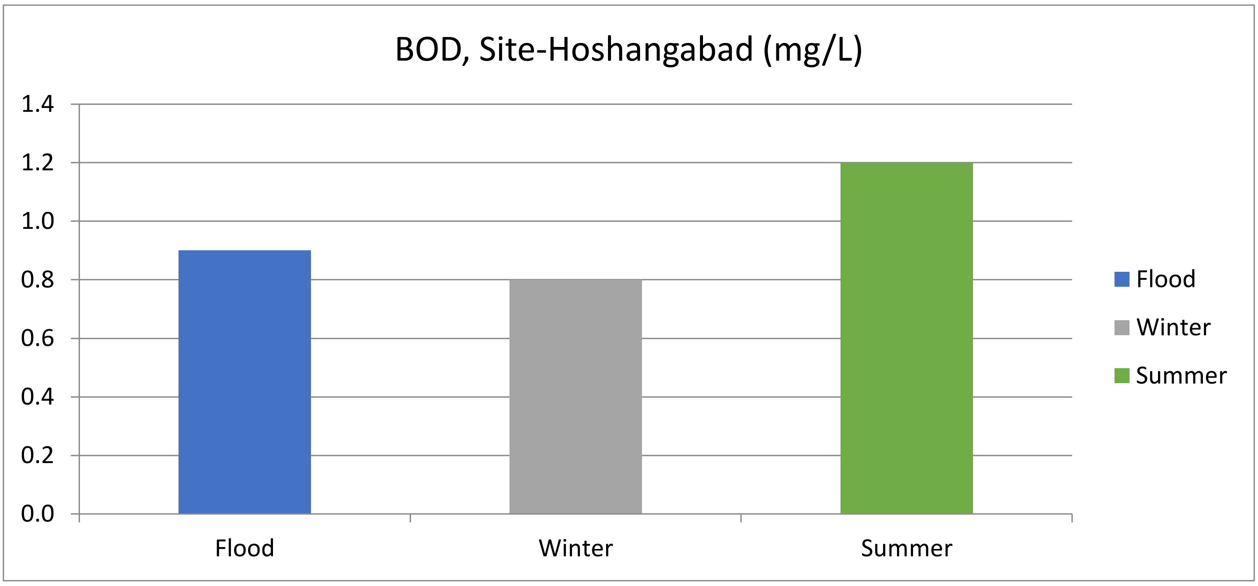
Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Patan	4.0	4.8	5.0



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.

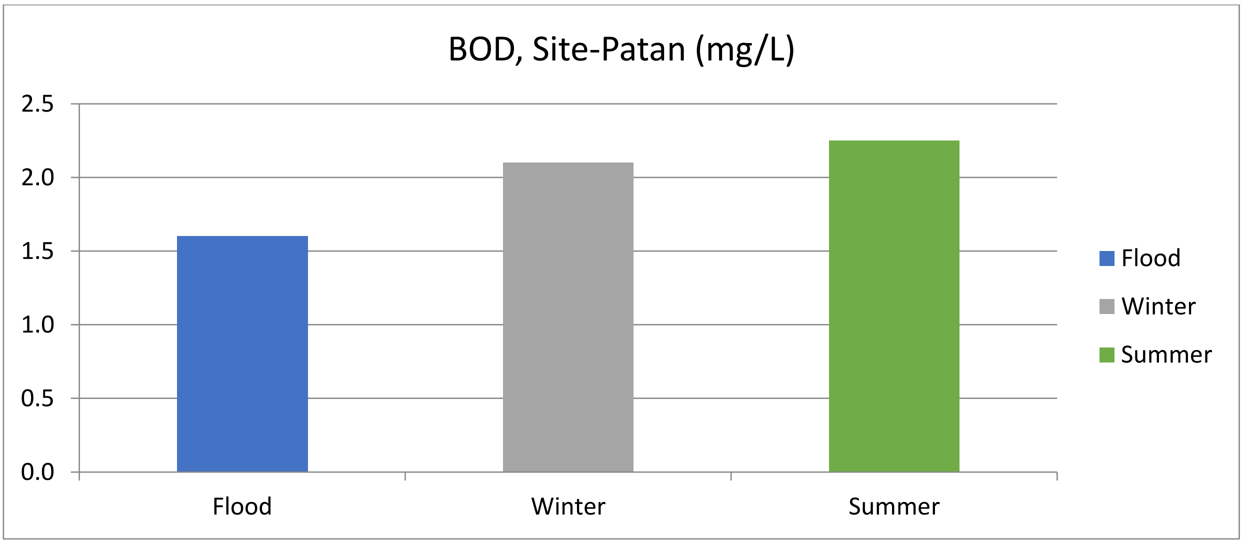
Biochemical Oxygen Demand, Site Hoshangabad

Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Hoshangabad	0.9	0.8	1.2



Biochemical Oxygen Demand, Site Patan

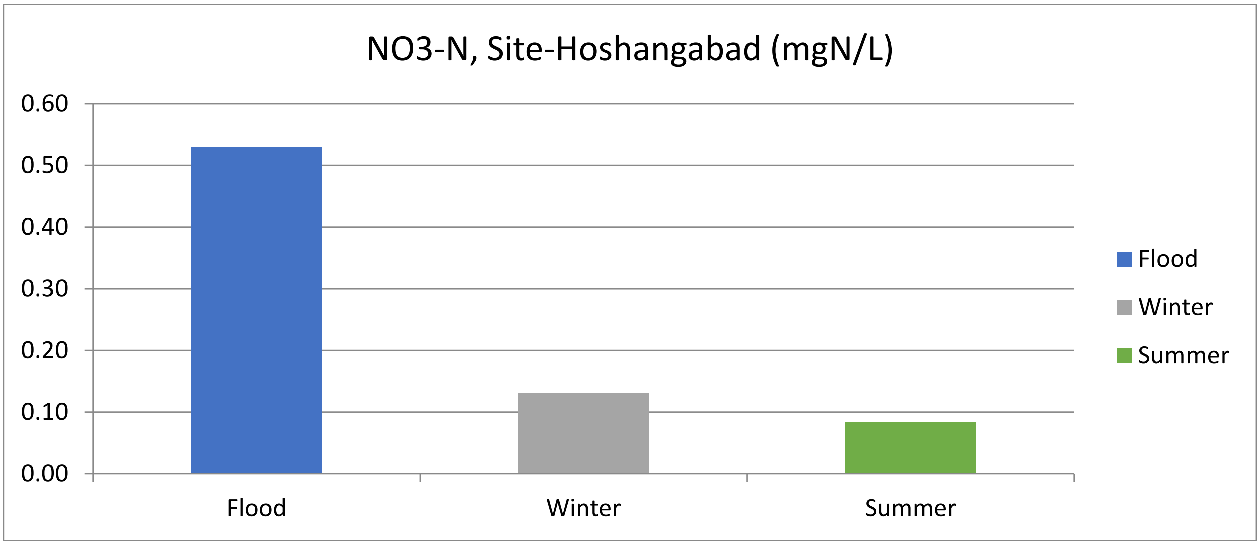
Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Patan	1.6	2.1	2.3



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.

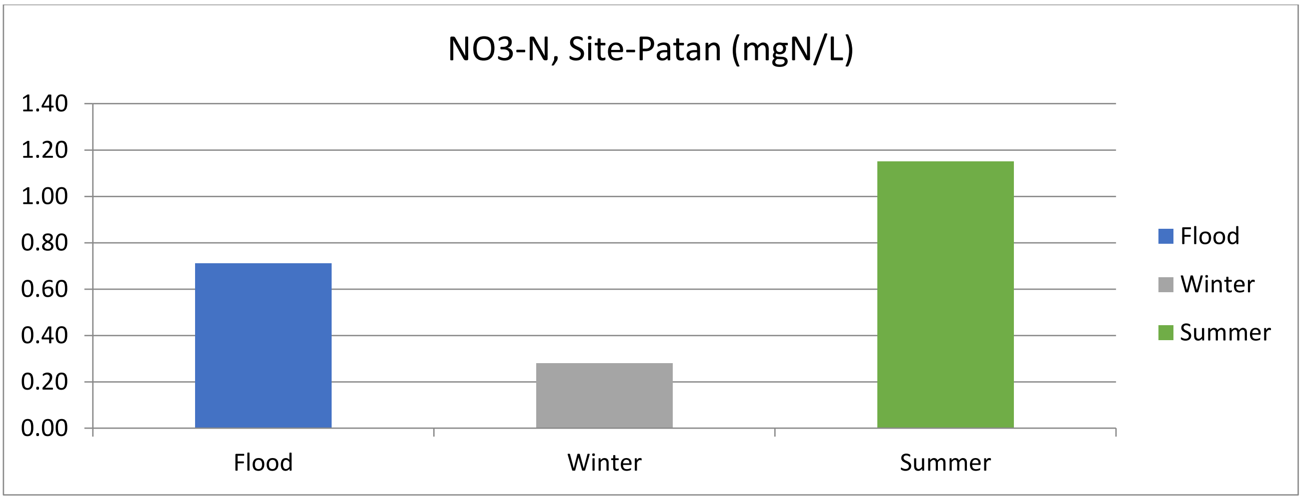
Nitrate, Site-Hoshangabad

Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Hoshangabad	0.53	0.13	0.084



Nitrate, Site-Patan

Sl. No.	Location of Sampling Point	Flood	Winter	Summer
1	Hoshangabad	0.71	0.28	1.15



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.

Conclusion: -

The study “Report on Water Quality Scenario of Rivers” in which - Study of the seasonal variation in the river water quality at site Hoshangabad and Patan was done based on – EC, pH, TDS, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), & Nitrate-N. As per this study the main conclusion can be drawn that the changes in river water quality that generally occured in summer were slight lessen due to Lockdown in summer season, also this can be understand that the main reasons for river WQ degradation is discharge of municipal effluents without proper treatment, excessive uses of chemical fertilizer and pesticides, 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 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.

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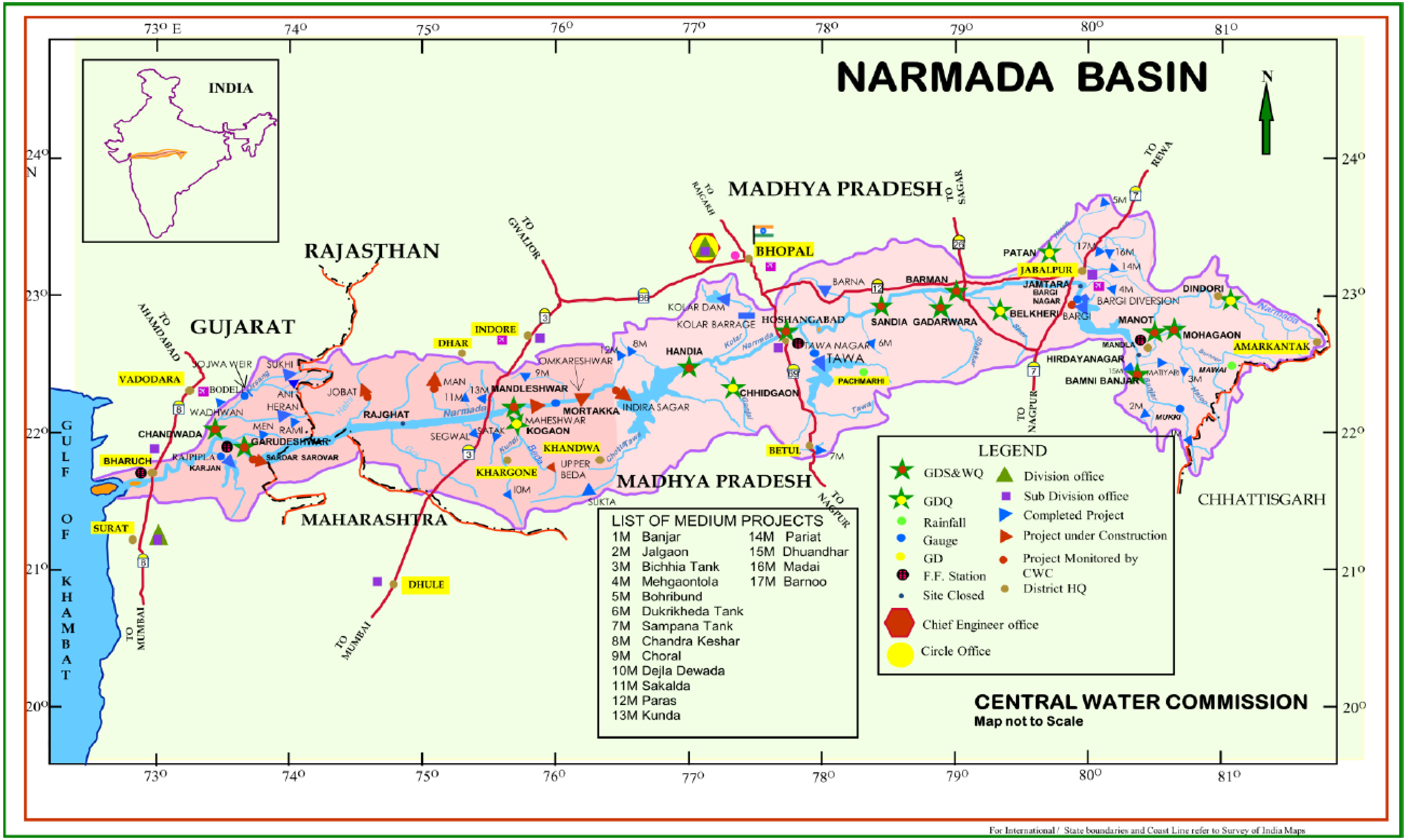
Ankit Kumar Mourya,
Senior Research Assistant

Narmada Basin map



CENTRAL WATER COMMISSION
HIMALAYAN GANGA DIVISION ,DEHRADUN

CONCEPTUAL DESIGN REPORT ON WATER QUALITY SCENARIO OF SONG RIVER IN DEHRADUN

By-

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-
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Introduction

Water contains a variety of chemical constituents at different concentrations. The major part of the soluble constituents in water are a result from soluble minerals in soils and sedimentary rocks, whereas, some of it is also is due to the atmosphere and surface water bodies. Agricultural run offs, domestic discharge and waste disposal from social community also constitutes to the composition of water in ground and surface. For most of the surface water sample, Ions are represented by only a few major ionic species , the positively charged cations like Sodium (Na^+), Potassium (K^+), Calcium (Ca^{++}) and Magnesium (Mg^{++}), and the negatively charged anions Chloride (Cl^-), Sulphate (SO_4^{--}), Bicarbonate (HCO_3^-) and Nitrate (NO_3^-). These ionic species when added together account for most of the salinity that is commonly referred to as total mineralization or total dissolved solids (TDS).

The present study deals with the analysis of physical and Chemical parameters of the Song River at Dehradun. In the Present Study of song River water Quality parameters like Temperature ,Colour ,Odour, Total Dissolved Solids, Electrical Conductivity, pH, Total Hardness, Alkalinity, Chlorides, Sulphate ,Nitrate ,Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand were Undertaken.

Study Area

Song River is a river in Dehradun district that drains the central and eastern part of Dehradun.

A tributary of Sooswa river,which in turn is a tributary of the Ganges,it originates as spring fed stream in the southern slopes of the Mussoorie ridge of the Himalayan range and run from Dhanaulti towards Narendranagar.

Song is one of the largest river that drain Dehradun and its tributaries includes ,Kali Gad,Shahastradhara, Assan River and Rispana river.

Song River is a spring fed river Originated from different small rivulets of the mountainous range of Dhanolti,crossing with Sahastradhara streams flow downward towards Doon Valley and Finally it assimilates into River Ganga at Raiwala.

The present Study of the Song river its physic-chemical Characteristics viz- pH, Electrical Conductivity,Total Dissolved Solids,Dissolved Oxygen,Biochemical Oxygen Demand,Chemical Oxygen Demand,Chloride,Sulphate and Alkalinity .

Accurate assessment of water quality ,whether in relation to the requirements of intented water uses or in order to determine the impacts of an activity on the water resource depends on the results generated by specific monitoring activities which define the physical,chemical and biological condition of the resource.

Collection of Water Samples

One of the main goals of any research is to collect samples that are representative of the site conditions so that an accurate assessment of the study area can be made with a minimum number of samples. The sample collection and its analysis should be the real representative of water in general being used by the community for their purposes.

Sampling stations were selected considering the population, location and source of water. These samples were analyzed for various parameters in the laboratory according to standard procedures (APHA 2017). Various physicochemical parameters like Temperature,Color,Odour, pH, Total Dissolved Solids (TDS),Total Hardness, Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Electrical Conductivity (EC), Chloride, Sulphate, Total Alkalinity, Chemical Oxygen Demand (COD), Fluoride, Calcium, Magnesium, Nitrate-Nitrogen were recorded and analyzed.

Polythene bottles of 1 litre capacity with stopper were used for collecting samples. Each bottle was washed with 2% Nitric acid and then rinsed three times with distilled water. The bottles were then preserved in a clean place.

Sampling Points

Water samples were collected at depth of 30 cm from water surface. The sample point was 3-5 meter away from the river edge to ensure that water sample being collected from the flowing water within the river current. The water along the river coast is more prone to contaminated deposits and additional bacteriological formations. The sample was collected with the help of a sampler which consists of a glass bottle and a cord tied to a lid. The whole assembly was lowered into water to the desired depths and the cord of the lid was then pulled and released only when displaced air bubble ceased to come to the surface. The whole assembly was withdrawn and the water transferred into pre cleaned bottles.

The sampling bottles were fully filled leaving no air space. The bottles were then be sealed to prevent any leakage. Each bottle was clearly labeled with the name and address of the sampling station, sampling description and date of sampling. Then all the samples carried carefully to the lab and analyzed immediately. A back end drawback of sampling site with site details, surroundings ,weather condition while collecting samples was maintained to later analyzed spatial and temporal variation.

Sample Sites Location

There were numerous sites those were visited. All feasibility variables were listed and studied to make the sample collection plan an effective one. It was concluded that samples must be taken from locations that are representative of the water source, its usage at that point and it's availability at that point and all other considerations as cited in table.

Sl. No.	Sampling site Location Name	Type of Water	Classification
1.	Shikharfall(R 1)	River Water	Surface Water
2.	Sahastradhara (R 2)	River Water	Surface Water
3.	Bindal Rao + Rispana River Confluence(R 3)	River Water	Surface Water
4.	Doiwala Bridge (R 4)	River Water	Surface Water
5.	Satyanarayan (R 5)	River Water	Surface Water

Result and Disscusion

The physico-chemical parameter obtained the study period are tabulated in the below table.
Fluctuation in Water Quality Parameters were Observed at different Sampling Site Location In the Song River at Dehradun.

- **Temperature**

During the Study period out of all five (R1 to R 5) Sampling site location maximum temperature (18.2^{o} C) Observed was Observed at Sampling site R3 and minimum (12.4^{o}C) at Sampling site R1. The fluctuation in temperature was well within the limit of survival of fishes and living organism in the River Water.

- **Colour**

Colour of water of all Sites was Colourless except site Location –R 3. The Colour of Water at R 3 was light black due to the discharge of household waste and sewage waste in the River Water. It was the main Polluted Section of the Study area. Bindal Rao and rispana River which drain Doon Valley Confluence near Mothorowala after Confluence these meet in song River.

- **Odour**

Water of all Sites was Odourless except Site R3 .The Odour of site R3 was Smelling unpleasent due to Organic,Inorganic and other pollutants matter in Water.

- **pH**

pH values is reported as a number between 0 and 14 (as a standard pH unit). This unit is equivalent to the negative logarithm of the hydrogen ion molar concentration (-log[H+]) in the solution. Depending on the accuracy of the measurement, the pH value can be carried out to one or two decimal places.
pH is an important factor that determines the suitability of Water for various purposes
including toxicity to Human,Animal and Plants.
If the pH of water is too high or too low, the aquatic organisms living within it will die. pH can also affect the solubility and toxicity of chemicals and heavy metals in the water . The majority of aquatic creatures prefer a pH range of 6.5-9.0, though some can live in water with pH levels outside of this range.
In the present Study the value of pH were found near faintly alkaline in the all Sampling site.
The Maximum value of pH 8.50 was Observed at Sampling site R3 and minimum value of pH 8.11 was observed at Sampling Site R5.

- **Conductivity**

Conductivity is a measurement of capability of water to pass electrical flow. This ability is directly related to the concentration of ions present in the water.

Conductivity, in particular specific conductance, is one of the most useful and commonly measured water quality parameters. Conductivity is an early indicator of change in a water system. Most bodies of water maintain a fairly constant conductivity that can be used as a baseline of comparison to future measurements . Significant change, whether it is due to natural flooding, evaporation or man-made pollution can be very detrimental to water quality.

A sudden increase or decrease in conductivity in a body of water can indicate pollution. Agricultural runoff or a sewage leak will increase conductivity due to the additional chloride, phosphate and nitrate ions . An oil spill or addition of other organic compounds would decrease conductivity as these elements do not break down into ions . In both cases, the additional dissolved solids will have a negative impact on water quality.

In the present Study maximum Electrical Conductivity 735.4 µS/cm was Observed at Sampling Site R 3 and minimum Electrical Conductivity 385.8 µS/cm was observed at Sampling site R 5 .

- **Total dissolved solids**

Total dissolved solids (TDS) combine the sum of all ion particles that are smaller than 2 microns (0.0002 cm) . This includes all of the disassociated electrolytes that make up salinity concentrations, as well as other compounds such as dissolved organic matter. In “clean” water, TDS is approximately equal to salinity . In wastewater or polluted areas, TDS can include organic solutes (such as hydrocarbons and urea) in addition to the salt ions .

Dissolved solids are also important to aquatic life by keeping cell density balanced . In distilled or deionized water, water will flow into an organism’s cells, causing them to swell . In water with a very high TDS concentration, cells will shrink. These changes can affect an organism’s ability to move in a water column, causing it to float or sink beyond its normal range .

TDS can also affect water taste, and often indicates a high alkalinity or hardness .

The deterioration of the Water Quality was mainly due to the Concentration of Total dissolved solids.

In the Study period the value of Total Dissolved solid Observed to be Maximum 465.4 mg/L at Sampling site R3 and Minimum 245.6 mg/L at Sampling Site R4 .

Hard water (or water hardness) is a common quality of water which contains dissolved compounds of calcium and magnesium and, sometimes, other divalent and trivalent metallic elements.

- **Hardness**

The term hardness was originally applied to waters that were hard to wash in, referring to the soap wasting properties of hard water. Hardness prevents soap from lathering by causing the development of an insoluble curdy precipitate in the water; hardness typically causes the buildup of hardness scale. Dissolved calcium and magnesium salts are primarily responsible for most scaling in pipes and water heaters and cause numerous problems in laundry, kitchen, and bath. Hardness is usually expressed in mg/L or ppm as calcium carbonate equivalent.

The high level of total Hardness is due to mixing sewage effluent into the River water. **Permanent hardness** in **water** is **hardness** due to the presence of the chlorides, nitrates and sulphates of calcium and magnesium, which will not be precipitated by boiling.

Temporary hardness in **water hardness is** due to the presence of carbonates and bicarbonates of calcium and magnesium, which can be precipitated by heating the **water**. It can be removed by processes such as boiling or lime softening.

During the Study period Maximum value 528 mg/L of Total Hardness was found at Sampling Site R 3 and minimum value 272 mg/L was observed at Sampling site R 5 .

- **Alkalinity**

The alkalinity of water or a solution is the quantitative capacity of that solution to buffer or neutralize an acid. In other words, alkalinity is a measurement of water's ability to resist changes in pH. This term is used interchangeably with acid-neutralizing capacity. If a body of water has a high alkalinity, it can limit pH changes due to acid rain, pollution or other factors . The alkalinity of a stream or other body of water is increased by carbonate-rich soils (carbonates and bicarbonates) such as limestone, and decreased by sewage outflow and aerobic respiration. Due to the presence of carbonates, alkalinity is more closely related to hardness than to pH . However, changes in pH can also affect alkalinity levels (as pH lowers, the buffering capacity of water lowers as well) . pH and alkalinity are directly related when water is at 100% air saturation. .

Alkalinity refers to carbonate ($CO3^{2-}$) and bicarbonate ($HCO3^{-}$) ion present in the Water body.

The reason of the High Alkalinity is due to Calcium carbonate and Industrial discharge in the Water Body System. In the present study of Song river at Dehradun High Alkalinity was observed at Sampling site R3 and Minimum Alkalinity Was Observed at Sampling site R5 .The reason of High alkalinity at Sampling Site R3 is due Domestic sewage and other sewage mix water.

➢ Chloride

Chloride is a naturally occurring element that is common in most natural waters and is most often found as a component salt of sodium chloride or in some cases in combination with calcium or magnesium . Chlorides are not usually harmful to people; however, the sodium part of table salt has been linked to heart and kidney disease. Sodium chloride may impart a salty taste at 250 mg/L; however, calcium or magnesium chloride are not usually detected by taste until levels of 1000 mg/L are reached.

Chlorides may get into surface water from several sources including agricultural runoff , wastewater from industries, effluent wastewater and road salting.

The Concentration of chloride vary from maximum 37.83 mg/L at Sampling site R3 and minimum 7.06 mg/L at Sampling site R 1.

➢ Dissolved oxygen

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality.

Non-compound oxygen, or free oxygen (O_2), is oxygen that is not bonded to any other element. Dissolved oxygen is the presence of these free O_2 molecules within water. The bonded oxygen molecule in water (H_2O) is in a compound and does not count toward dissolved oxygen levels. One can imagine that free oxygen molecules dissolve in water much the way salt or sugar does when it is stirred .

Dissolved oxygen is necessary to many forms of life including fish, invertebrates, bacteria and plants. These organisms use oxygen in respiration, similar to organisms on land. Fish and crustaceans obtain oxygen for respiration through their gills, while plant life and phytoplankton require dissolved oxygen for respiration when there is no light for photosynthesis [4]. The amount of dissolved oxygen needed varies from creature to creature. Bottom feeders, crabs, oysters and worms need minimal amounts of oxygen (1-6 mg/L), while shallow water fish need higher levels (4-15 mg/L).

Microbes such as bacteria and fungi also require dissolved oxygen. These organisms use DO to decompose organic material at the bottom of a body of water. Microbial decomposition is an important contributor to nutrient recycling. However, if there is an excess of decaying organic material , in a body of water with infrequent or no turnover , the oxygen at lower water levels will get used up quicker .

Dissolved Oxygen is one of the major indicators of water quality. Just as humans need oxygen to breathe, aquatic life needs sufficient amounts of oxygen dissolved in water to survive. Dissolved oxygen depletion can occur for several naturally occurring reasons, most of which are highly preventable or treatable. The primary cause of oxygen depletion in a water body is from excessive algae and phytoplankton growth driven by high levels of phosphorus and nitrogen. During the nighttime hours, these photosynthetic organisms consume oxygen through respiration when engaging in active photosynthesis. Additionally, as algae and phytoplankton die, the process of decomposition also requires significant amounts of dissolved oxygen. If these blooms are dense or a die off occurs suddenly, the impacts to fish can be more severe and cause fish-kills. Fish are cold blooded animals which means their body temperature and activities are regulated by the water they inhabit and warm water increases the fish's consumption of oxygen by accelerating their metabolic rate. Aside from temperature, weather also is a contributor to dissolved oxygen levels within a resource. On cloudy days, the production of oxygen through photosynthesis is slowed or halted. Additionally, still and windless days do not allow circulation of the water in a resource and limits surface diffusion of atmospheric oxygen. During the hot summer months, deeper ponds experience stratification as the water near the surface warms and becomes less dense than the cooler water near the bottom. As the season progresses, the cool water near the bottom becomes stagnant and depleted of oxygen. As the top layer of water cools from either a heavy rain storm or a cold front the water then mixes or "turnover" with the deep, oxygen deficient water and a pond wide oxygen depletion can occur and harm fish populations, possibly even causing die-offs.

In a highly oxygenated environment, nutrients that cause algae blooms bind to free molecules such as Iron and precipitate out of the water column. Another strategy to combat algae growth is the application of beneficial bacteria. Beneficial bacteria out-compete algae for available nutrients thus eliminating the aggressive blooms that can cause dissolved oxygen sags. By eliminating stratification and reducing the chances of dense algae and phytoplankton blooms, a pond owner can keep dissolved oxygen levels high and eliminate the stressors to the fish populations.

The average value of Dissolved Oxygen Level 6.5 mg/L indicate the average quality of river Water.

The Maximum amount 9.21 mg/L of Dissolved Oxygen was observed at Sampling Site location R2 and the minimum amount 1.75 mg/L of Dissolved Oxygen was observed at Sampling site location R3 ,during the study period .

➢ BOD

Biochemical oxygen demand (BOD) represents the amount of oxygen consumed by bacteria and

other microorganisms while they decompose organic matter under aerobic (oxygen is present) conditions at a specified temperature.

The presence of a sufficient concentration of dissolved oxygen is critical to maintaining the aquatic life and aesthetic quality of streams and lakes. Determining how organic matter affects the concentration of dissolved oxygen (DO) in a stream or lake is integral to water- quality management. The decay of organic matter in water is measured as biochemical or chemical oxygen demand. Oxygen demand is a measure of the amount of oxidizable substances in a water sample that can lower DO concentrations.

Certain environmental stresses (hot summer temperatures) and other human-induced factors (introduction of excess **fertilizers** to a water body) can lessen the amount of dissolved oxygen in a water body, resulting in stresses on the local aquatic life. One water analysis that is utilized in order to better understand the effect of bacteria and other microorganisms on the amount of oxygen they consume as they decompose organic matter under aerobic (oxygen is present) is the measure of biochemical oxygen demand (BOD).

Determining how organic matter affects the concentration of dissolved oxygen in a stream or lake is integral to water-quality management. BOD is a measure of the amount of oxygen required to remove waste organic matter from water in the process of decomposition by aerobic bacteria (those bacteria that live only in an environment containing oxygen). The waste organic matter is stabilized or made unobjectionable through its decomposition by living bacterial organisms which need oxygen to do their work. BOD is used, often in wastewater-treatment plants, as an index of the degree of organic pollution in water.

Biochemical Oxygen Demand Level Indication in mg/L

BOD level in mg/L	Water Quality
1-2	**Very Poor**-There will not be organic waste present in the Water
3-5	**Fair**- Moderately clean
6-9	**Poor**-Indicate organic matter is present and Bactertia are decomposing these Organic waste
100 or more than 100	**Very Poor**- Very Polluted , Containing excessive amont of organic waste

During the Study period, the minimum range of BOD 1.36 mg/L was observed at Sampling site R 5 and the maximum range of BOD 18.7 mg/L was observed at Sampling site R3 .

Low BOD indicate low Nutrient level ,therefore much of the Oxygen present in Water and the maximum range of BOD indicate low Oxygen in Water

- **COD**

The Chemical Oxygen Demand- COD value indicates the amount of oxygen which is needed for the oxidation of all organic substances in water

COD is used as a general indicator of water quality and is an integral part of all water quality management programs. Additionally, COD is often used to estimate BOD (Biochemical Oxygen Demand) as a strong correlation exists between COD and BOD, however COD is a much faster, more accurate test.

It is commonly used to indirectly measure the amount of Organic compound in Water. This makes COD useful as an indicator of organic pollution in surface water.

The minimum value 7.08 mg/L of COD was observed at Sampling site R 5 and maximum value 94.7 mg/L at site R3 .

- **Sulfate**

Sulfates (SO_4^{--}) can be naturally occurring or the result of municipal or industrial discharges. Point sources include sewage treatment plants and industrial discharges such as tanneries, pulp mills, and textile mills. Runoff from fertilized agricultural lands also contributes sulfates to water bodies. Sodium, potassium and magnesium sulfates are all highly soluble in water, whereas calcium and barium sulfates and many heavy metal sulfates are less soluble.

The minimum value of Sulphate was observed 25.7 mg/L at sampling site R5 and the maximum value was observed 48.9 mg/L at sampling site R3

- **Nitrogen**

Nitrogen is one of the most abundant elements. About 80 percent of the air we breath is nitrogen. It is found in the cells of all living things and is a major component of proteins. Inorganic nitrogen may exist in the free state as a gas N_2, or as nitrate NO_3^-, nitrite NO_2^- or ammonia NH_3. Organic nitrogen is found in proteins, and is continually recycled by plants and animals.

Nitrogen-containing compounds act as nutrients in streams, rivers, and reservoirs. The major routes of entry of nitrogen into bodies of water are municipal and industrial wastewater, septic tanks, feed lot discharges, animal wastes (including birds and fish), runoff from fertilized agricultural field. Bacteria in water quickly convert nitrites [NO_2^-] to nitrates [NO_3^-] and this process uses up oxygen. Excessive concentrations of nitrites can produce a serious condition in fish called "brown blood disease." Nitrites also can react directly with hemoglobin in the blood of humans and other warm-blooded animals to produce methemoglobin. Methemoglobin destroys the ability of red blood cells to transport oxygen.

This condition is especially serious in babies under three months of age. It causes a condition known as methemoglobinemia or "blue baby" disease.

Nitrate determinations are important in assessing the potential biological productivity of surface water.

In the present study maximum value of nitrate was observed 0.56 mg/L at Sampling site R3 and the minimum value was observed 0.22 mg/Lat Sampling site R 1.

➢ Variations of different Parameters of Song River

Sl.No.	Parameters	Sampling site location Name				
		Sahastradhara (R1)	Shikharfall (R2)	Binal Rao and Rispana River Confluence (R3)	Doiwala Bridge (R 4)	Satayanarayan (R 5)
1.	**Colour**	Clear	Clear	Light black	Light Brown	Clear
2.	**Odour**	Odourfree	Odourfree	unpleasent	Odourfree	Odourfree
3.	**Temperature**	12.4 °C	14.5°C	18.2°C	14.8°C	15.5°C
4.	**pH**	8.34	8.39	8.50	8.21	8.11
5.	**Electrical Conductivity in µs/cm**	431.3	405.9	735.4	448.5	385.8
6.	**Total Dissolved Solids (mg/l)**	271.8	255.2	465.4	286	245.6
7.	**Total Hardness as CaCO3 (mg/l)**	320	300	528	320	272
8.	**Calcium Hardness(mg/l)**	208	192	300	172	164
9.	**Magnesium Hardness (mg/l)**	112	108	228	148	108
10.	**Carbonate (mg/L)**	0	1.33	12.04	0	0
11.	**Bicarbonate (mg/L)**	285.6	266.56	500.48	312.8	236.64
12.	**Chloride (mg/l)**	7.06	7.53	37.83	8.47	11.64
13.	**Sodium (mg/l)**	3.80	2.97	25.4	4.35	6.28
14.	**Potassium (mg/l)**	2.20	1.92	9.20	3.22	3.44
15.	**Sulphate (mg/L)**	38.4	28.7	48.9	31.5	25.7
16.	**Dissolved Oxygen (mg/L)**	8.82	9.21	1.75	7.64	8.03
17.	**Biochemical Oxygen Demand(mg/L)**	2.15	1.56	18.7	2.34	1.36
18.	**Chemical Oxygen Demand (mg/L)**	9.27	6.81	94.7	8.42	7.08
19.	**Nitrate (mg/L)**	0.22	0.28	0.56	0.34	0.27

Site Location Photos

Fig.1.1- Sampling Site Location -1 (R1)-Song River Flowing at **Shikharfall**

Fig.1.2-Sampling site Location-2 (R2)-Song river at **Sahastdhara**

Fig 1.3-**Rispana river** Polluted due to Domestic Waste and Sewage

Fig. 1.4-Bindal Roa River Polluted Section due to Domestic waste and Sewage

Fig.1.5- Sampling site Location -3 **(R3) –Bindal roa and Rispana River** Confluence,after Confluence Bindal Rao and Rispana river assimilates into **Song River** near Kansrao.

Fig.1.6-Sampling site Location -4 **(R4)-Song river** flowing under **Doiwala Bridge**

Fig 1.7 –Sampling Site location -5 **(R 5)-Song River** Flowing Under **Satayanarayan Bridge**

❖ Conclusion

The Study Concludes that although there were minor fluctuations in physico-Chemical parameters of Song River at all the five different sampling points but it is an alarming situation of increasing pollution load as most of the parameters studies are nearby to the permissible Limits.

Reference

APHA 23rd addition 2017,Standard methods for the examination of Water and waste water, Washington D.C.,New York

Government of India

Ministry of Jal Shakti
Department of Water Resources, River Development & Ganga Rejuvenation

Study of the seasonal variation in the Water Quality of the Mahi river basin

Mahi Tapi Basin Organisation

Mahi Division Water Quality Laboratory
Mahi Division
Central Water Commission
Gandhinagar

CONTRIBUTIONS

GUIDANCE			
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DATA COMPILATION AND REPORT PREPARATION DONE BY			
7	Shri. K. P. Gireendran	:	Assistant Research Officer, Mahi Division, Gandhinagar
9	Shri. Utsa Sen	:	Senior Research Assistant, Mahi Division, Gandhinagar
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Abstract:

Assessment of seasonal variation in River Water quality is a key aspect for evaluating time-variations of river pollution due to natural or anthropogenic inputs of different sources. In this study, River water quality data for 5 parameters collected from 4 monitoring stations i.e Mataji, Rangeli, Paderdibadi, Khanpur of Mahi river during the year 2018-19 are analysed. The present work aimed to evaluate the seasonal variations of water quality parameters of Mahi River basin. Seasonal variation of Water quality parameters like **pH, Electrical Conductivity (EC), Dissolved oxygen (DO), Biochemical Oxygen Demand (BOD) and Total Coliform** are taken into consideration from June 2018 to May 2019 along with trend analysis of Water Quality Data set of 4 parameters during a previous period of 9 years (2010-2018) to assess the Water Quality trend.

Introduction:

Life of all living organism is substantially dependent upon water and dearth of such water may jeopardise the life. Many civilizations emerged in the territory of various rivers which could make water accessible for drinking and other purposes. It is indispensable to keep this aquatic environment as clear as possible. It is essential to estimate the certain water quality parameter to assess the quality of river water.

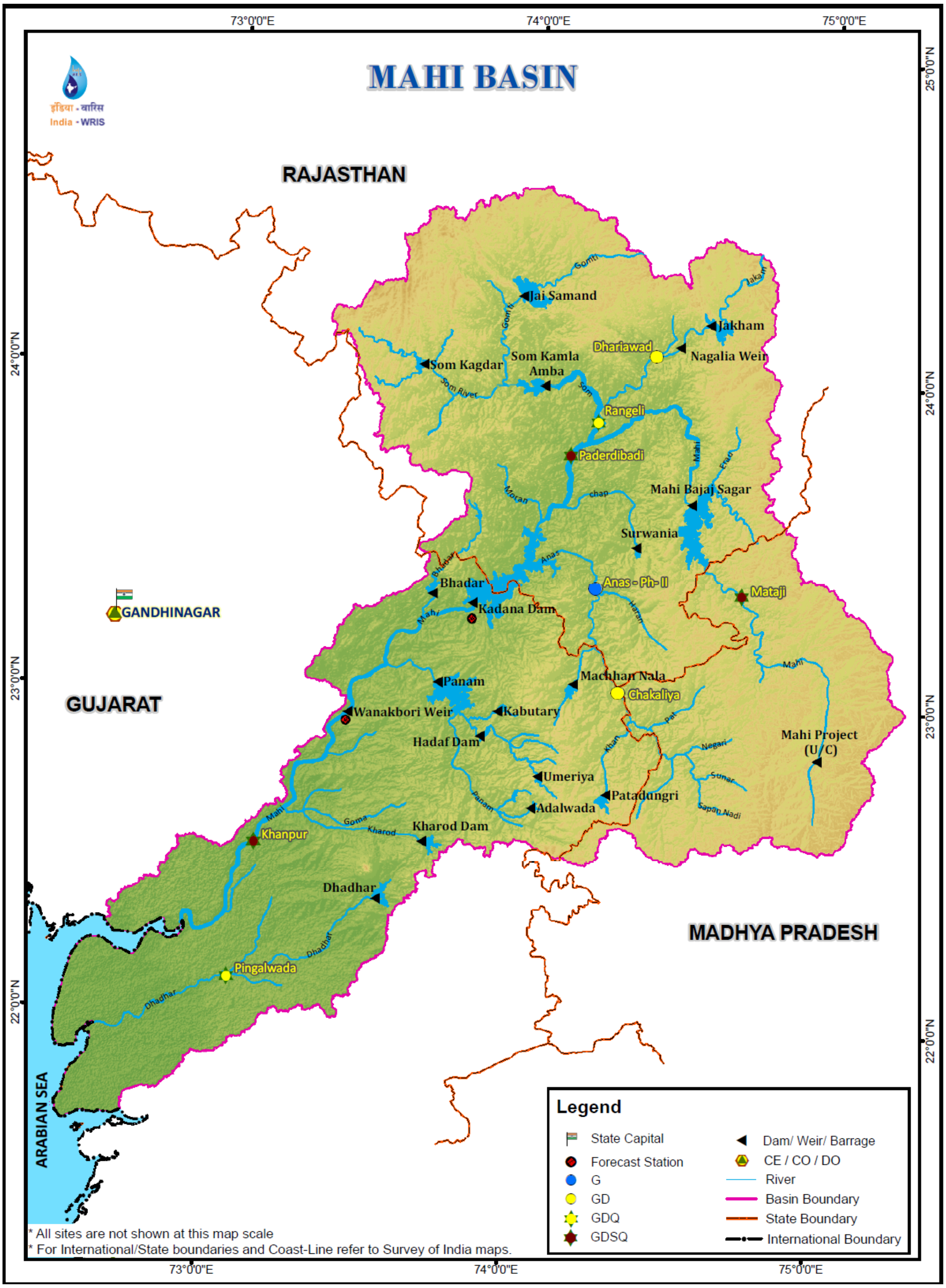
Study Area

Mahi Basin description

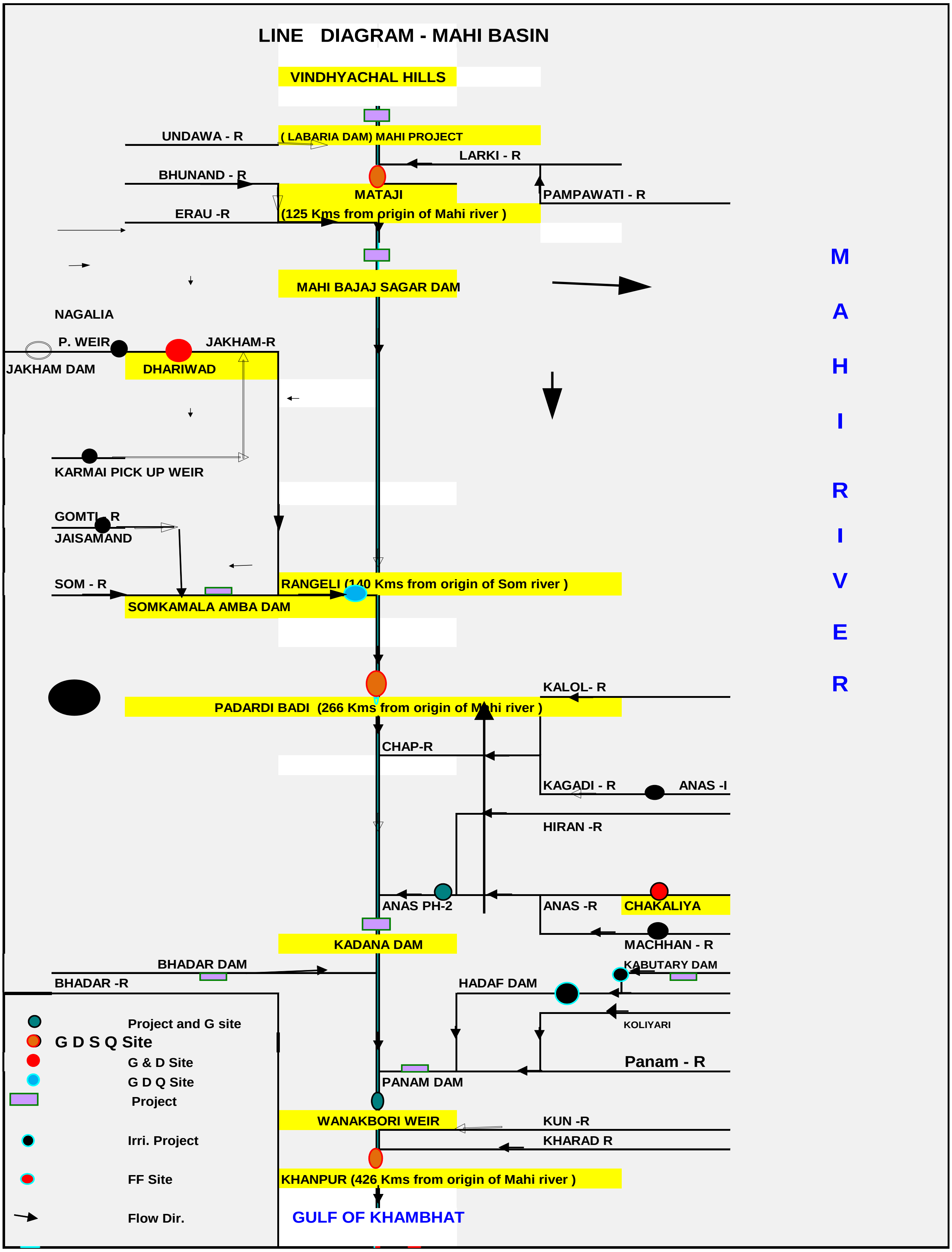
The river Mahi is third major west flowing interstate river of India, draining into the Gulf of Cambay. Its basin map is enclosed. It originates in the northern slopes of Vindhya hill range near village Sardarpur in Dhar district of Madhya Pradesh at an elevation of 500 m above mean sea level. Its length is 583 km, traversing 167 km in Madhya Pradesh, 174 km in Rajasthan and the remaining 242 km in Gujarat. It flows initially in North West direction through Dhar and Jhabua districts of Madhya Pradesh. Thereafter, it takes turn to the left and flows in south-west direction through Banswara district of Rajasthan, Panchmahal and Anand districts of Gujarat State before draining into Gulf of Cambay. It drains an area of 34,842 sq.km, spread over Rajasthan (47%), Madhya Pradesh (19%) and Gujarat (34%). The basin lies between the geographical co-ordinates of 73^0 00' to 74^0 20' east longitudes and 22^0 30' to 24^0 20' north latitudes. The basin is bound by the Aravalli hills in north and north-west, by the ridge separating it from Chambal basin in the east, by the Vindhya hill range in the south and finally by Gulf of Cambay in the west. In Rajasthan, the basin consists of hills, forests and eroded terrain. In Gujarat upto the confluence of Mahi and Panam, the basin comprises semi developed lands. Below Wanakbori Weir and up to the mouth, the basin is flat, fertile and well developed alluvial track. The main focus of this study is to correlate the seasonal variation in the Water Quality of the four stations Mataji, Rangeli, Paderdibadi, Khanpur located on Mahi river.

Table-1: Water quality monitoring Stations

SI. No	Name of Station	River / Tributary	Site Code	Latitude	Longitude	Location
1	Mataji	Mahi	01 02 13 001	23°20'57" N	74°43'31" E	Madhya Pradesh
2	Rangeli	Som	01 02 13 005	23°52'22" N	74°13'25" E	Rajasthan
3	Paderdibadi	Mahi	01 02 13 006	23°46'02" N	74°08'12" E	Rajasthan
4	Khanpur	Mahi	01 02 13 012	22°31'55" N	73°08'27" E	Gujarat



Map of Mahi river basin with stations under study


LINE DIAGRAM - MAHI BASIN
VINDHYACHAL HILLS
UNDAWA - R
(LABARIA DAM) MAHI PROJECT
LARKI - R
BHUNAND - R
MATAJI
PAMPAWATI - R
ERAU -R
(125 Kms from origin of Mahi river)
MAHI BAJAJ SAGAR DAM
NAGALIA
P. WEIR
JAKHAM-R
JAKHAM DAM
DHARIWAD
KARMAI PICK UP WEIR
GOMTI - R
JAISAMAND
SOM - R
RANGELI (140 Kms from origin of Som river)
SOMKAMALA AMBA DAM
KALOL- R
PADARDI BADI (266 Kms from origin of Mahi river)
CHAP-R
KAGADI - R
ANAS -I
HIRAN -R
ANAS PH-2
ANAS -R
CHAKALIYA
KADANA DAM
MACHHAN - R
BHADAR DAM
KABUTARY DAM
BHADAR -R
HADAF DAM
KOLIYARI
Panam - R
PANAM DAM
WANAKBORI WEIR
KUN -R
KHARAD R
KHANPUR (426 Kms from origin of Mahi river)
GULF OF KHAMBHAT
M A H I R I V E R
Project and G site
G D S Q Site
G & D Site
G D Q Site
Project
Irri. Project
FF Site
Flow Dir.

Sampling

The water samples were usually collected from a point, 15 to 20 cm below the water surface having maximum depth of flow along the cross-section of river. Water samples were collected in clean and pre rinsed polythene bottles of 1 litre and were filled up to their full capacity without any air bubble. BOD samples were collected in 300 ml B O D glass bottles and bacteriological samples were being collected in 125 ml sterilised glass bottles.

The samples are sent to Mahi Division Water Quality Laboratory located at Gandhinagar from sites after collection. Their particulars like in-situ temperature, depth, velocity etc. written on paper slip are pasted on the polythene bottles. Six parameters are tested either in situ or at the field water quality monitoring station i e Level-I lab and reporting in HP WQ-01 form. The samples are being analysed at Mahi Division Water Quality |Laboratory, Mahi Division, CWC, Gandhinagar, which is an NABL accredited Laboratory, and accreditation is valid up to 25th November 2020.

Table-2 : Testing method specification

Sl.No.	Parameters	Testing method specification
1.	pH	APHA 23rd Edition 2017-4500 H^+B (Electrometric Method)
2.	Electrical Conductivity	APHA 23rd Edition 2017-2510 B (Laboratory Method)
3.	Dissolved Oxygen	APHA 23rd Edition 2017-4500 O C(Azide Modification Iodometric Method)
4.	Biochemical Oxygen Demand	APHA 23rd Edition 2017-5210 B (20^oC, 5 Day BOD Test Method)
5.	Total Coliform	MPN Method

Various equipments at Mahi Division Water Quality Laboratory , CWC, Gandhinagar

1. Turbidity Meter 2. PH Meter 3. Conductivity Meter 4. Ion Meter (From Left to right)

Wet Laboratory of Mahi Division Water Quality Laboratory , Gandhinagar

UV Visible Spectrophotometer at MDWQL, Gandhinagar

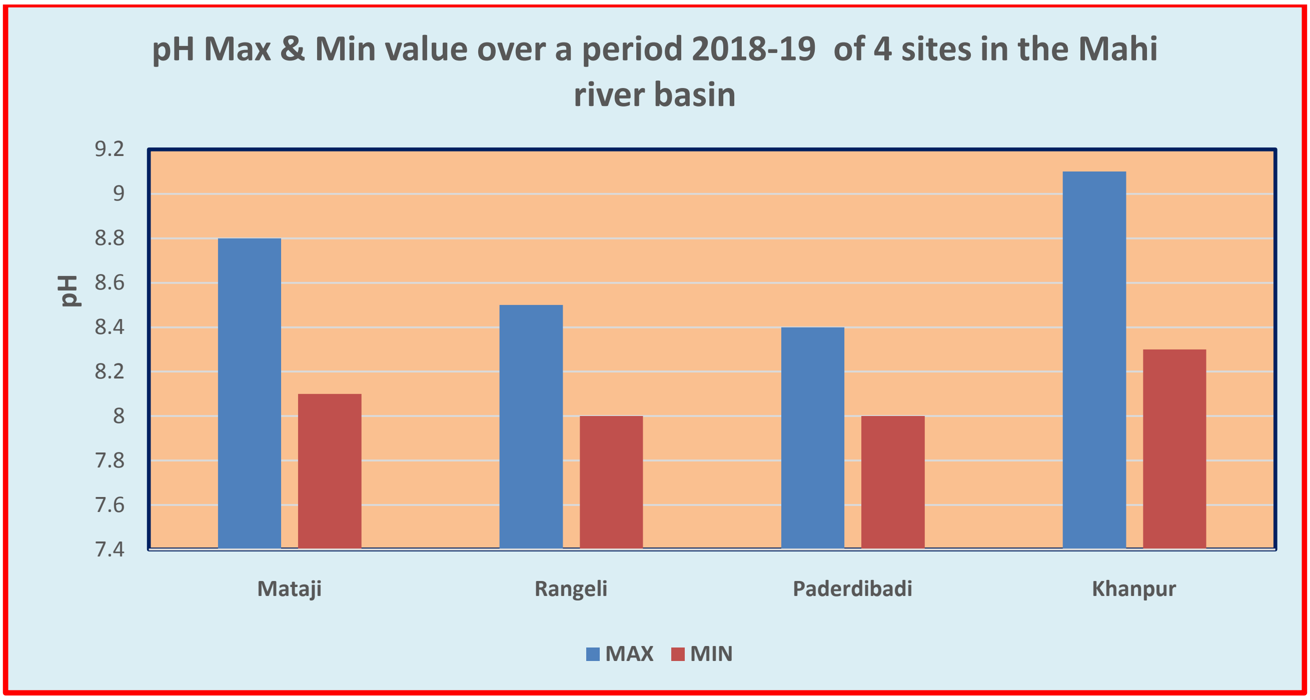
Bacteriological Laboratory at Mahi Division Water Quality Laboratory, Gandhinagar

RESULT AND DISCUSSION:

pH:-

Water samples were tested for pH measurement. It was observed from the pH values that water samples were slightly alkaline mostly varying between 8.1 – 8.9 for the year 2018-19 for all the 4 sites in the Mahi river basin. As per drinking water specification of IS 10500: 2012 agreeable limit is 6.5- 8.5. As pH has no direct adverse effect on health. However, higher values of pH hasten the scale formation in the water heating apparatus and also reduce germicidal potential of chloride. pH below 6.5 starts corrosion in irrigation pipes thereby releasing toxic metals such as Zn, Pb, Cd and Cu etc from pipes used for irrigation purpose. In the present study, the trend in pH value over the years is increased and can be accounted by the graphical representation of different four sites in the Mahi river basin during Flood, Winter and Summer season.

Graph-1: pH Max & Min value of four sites in the Mahi river basin during 2018-19



Graph-2: Season wise average of pH values of four sites in the Mahi river basin during 2018-19

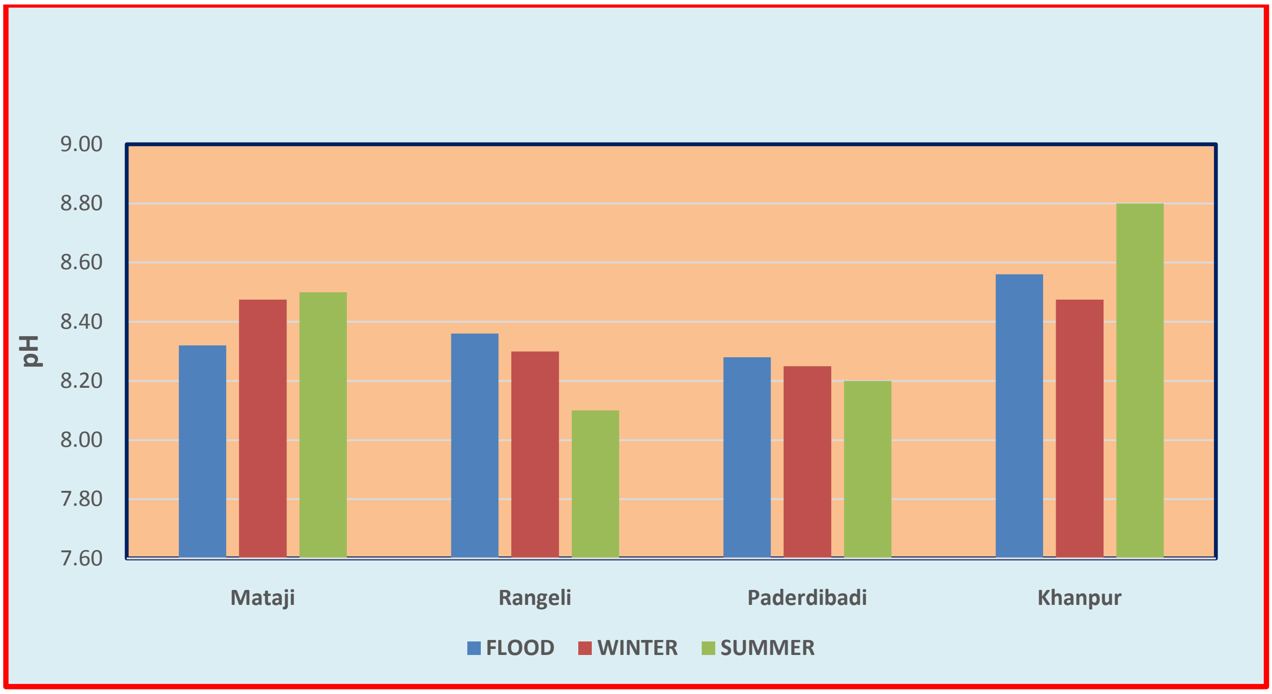
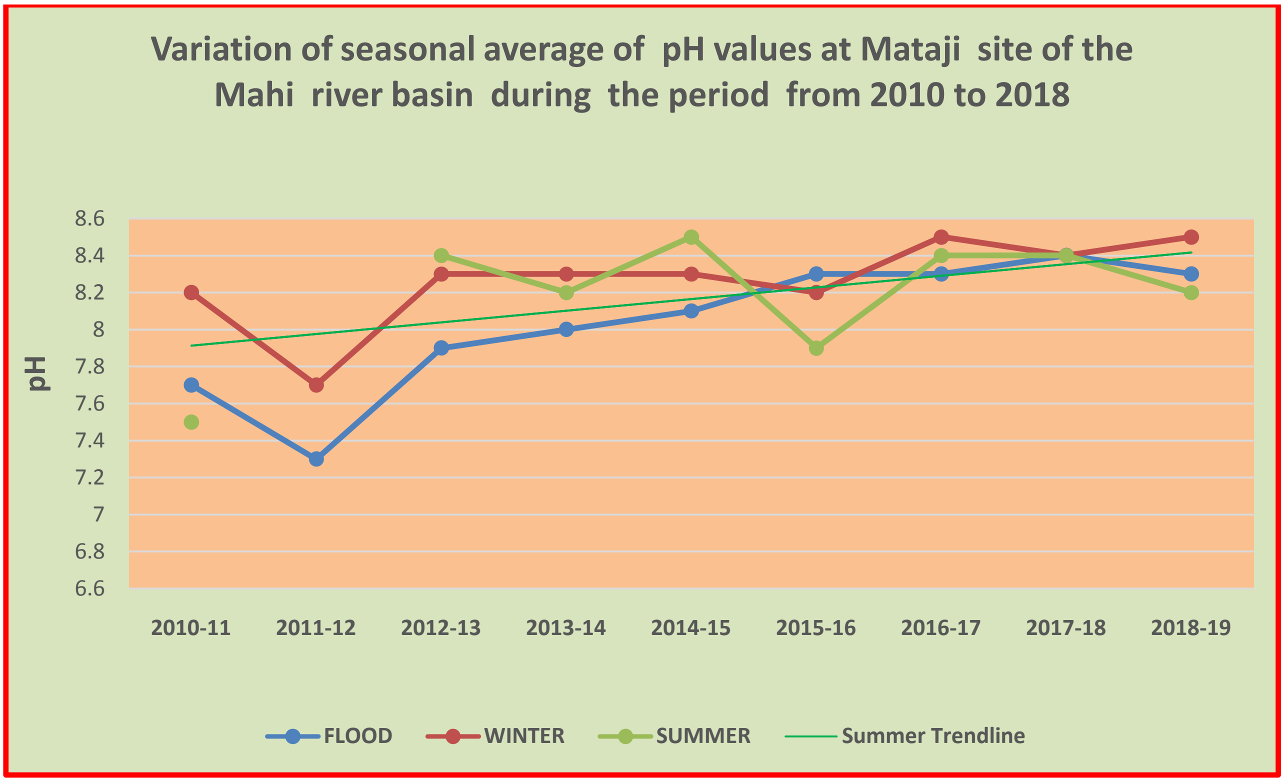


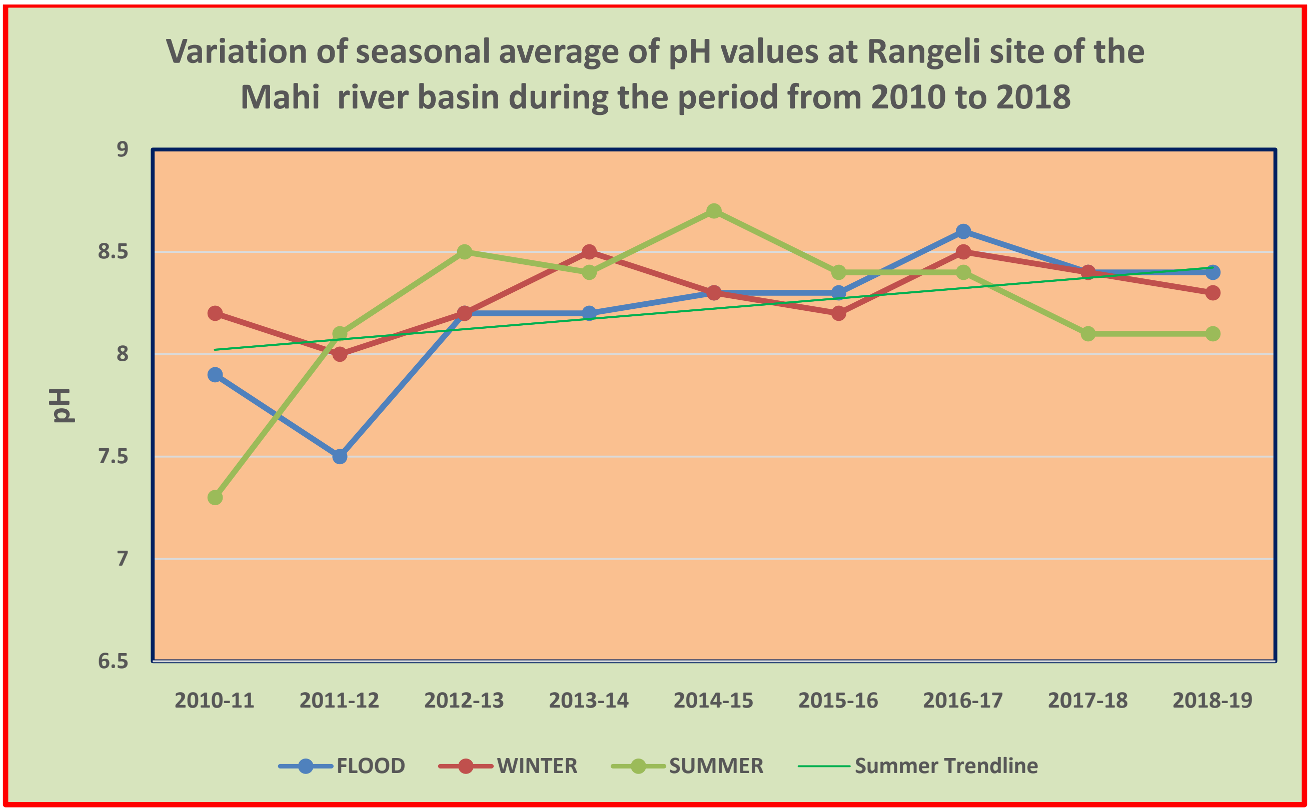
Table-3: pH values of four sites in the Mahi river basin during 2018-19

	pH			
Month	**Mataji**	**Rangeli**	**Paderdibadi**	**Khanpur**
Jun-18	8.2	8.4	8.3	8.9
Jul-18	8.2	8.0	8.0	8.5
Aug-18	8.6	8.5	8.4	8.6
Sep-18	8.3	8.4	8.3	8.4
Oct-18	8.3	8.5	8.4	8.4
Nov-18	8.3	8.4	8.4	8.6
Dec-18	8.1	8.2	8.2	8.3
Jan-19	8.7	8.4	8.3	8.5
Feb-19	8.8	8.2	8.1	8.5
Mar-19	8.5	8.1	8.2	8.4
Apr-19	8.6	8.1	8.2	8.9
May-19	8.4	8.1	8.2	9.1
MAX	8.8	8.5	8.4	9.1
MIN	8.1	8.0	8.0	8.3
Season	**Mataji**	**Rangeli**	**Paderdibadi**	**Khanpur**
FLOOD	8.32	8.36	8.28	8.56
WINTER	8.48	8.30	8.25	8.48
SUMMER	8.50	8.10	8.20	8.80

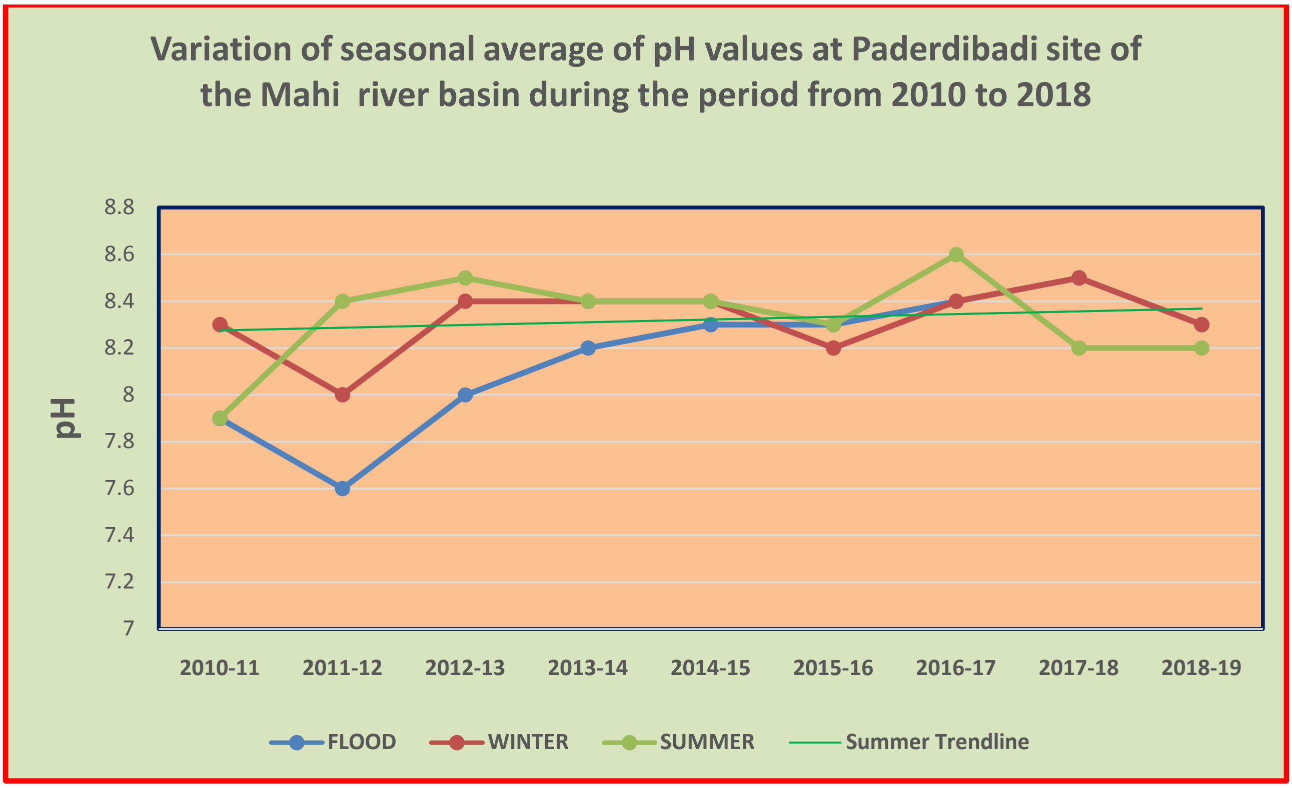
Graph-3 : Seasonal average of pH values for the period 2010- 2018 at the Site Mataji



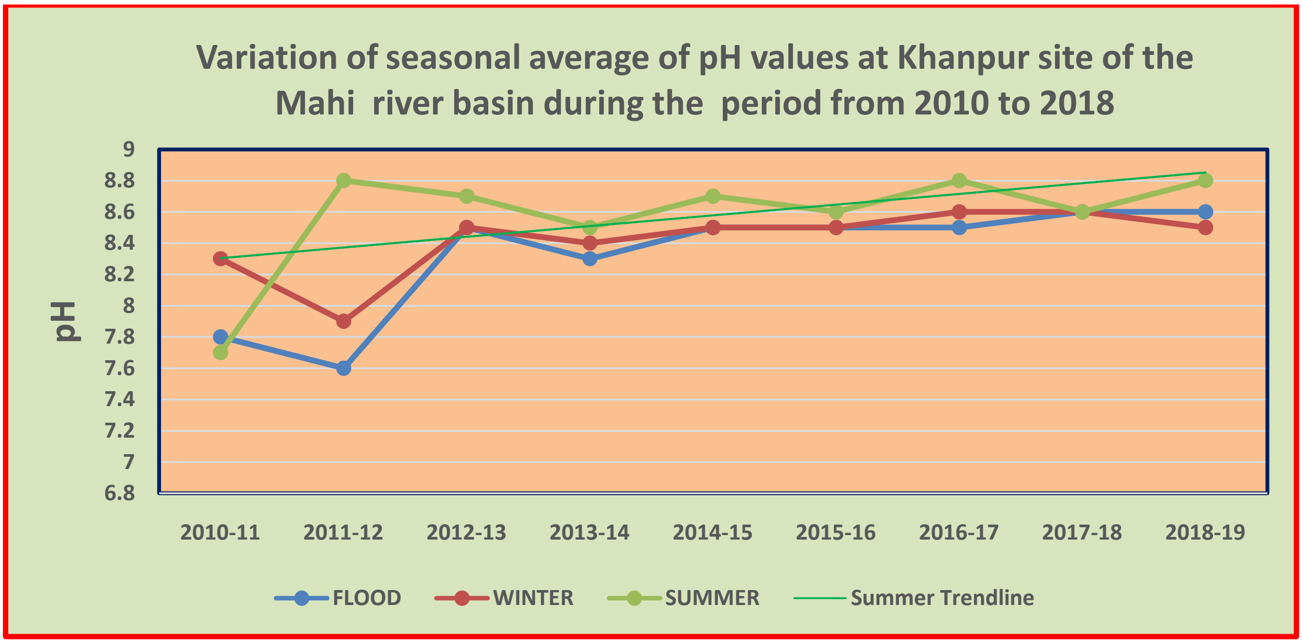
Graph-4 : Seasonal average of pH values for the period 2010- 2018 at the Site Rangeli



Graph-5 : Seasonal average of pH values for the period 2010- 2018 at the Site Paderdibadi



Graph-6 : Seasonal average of pH values for the period 2010- 2018 at the Site Khanpur



Conductivity:-

The EC values of water samples were found within the permissible limit. It shows water quality is medium throughout the year. It is in the range of 195- 637 µmho/cm. Use of such water for agricultural fields creates no problems in consideration of only EC parameter. TDS can be measured indirectly by measuring the EC. EC is important because it directly affects the quality of water used for drinking and irrigation. In the present study, the overall trend in EC Values in the period of 2018-19 is increased. Seasonal variations can be accounted by the graphical representation of different four sites in the Mahi river basin during Flood, winter and summer season.

Graph-7: EC Max & Min Value of four sites in the Mahi river basin during 2018-19

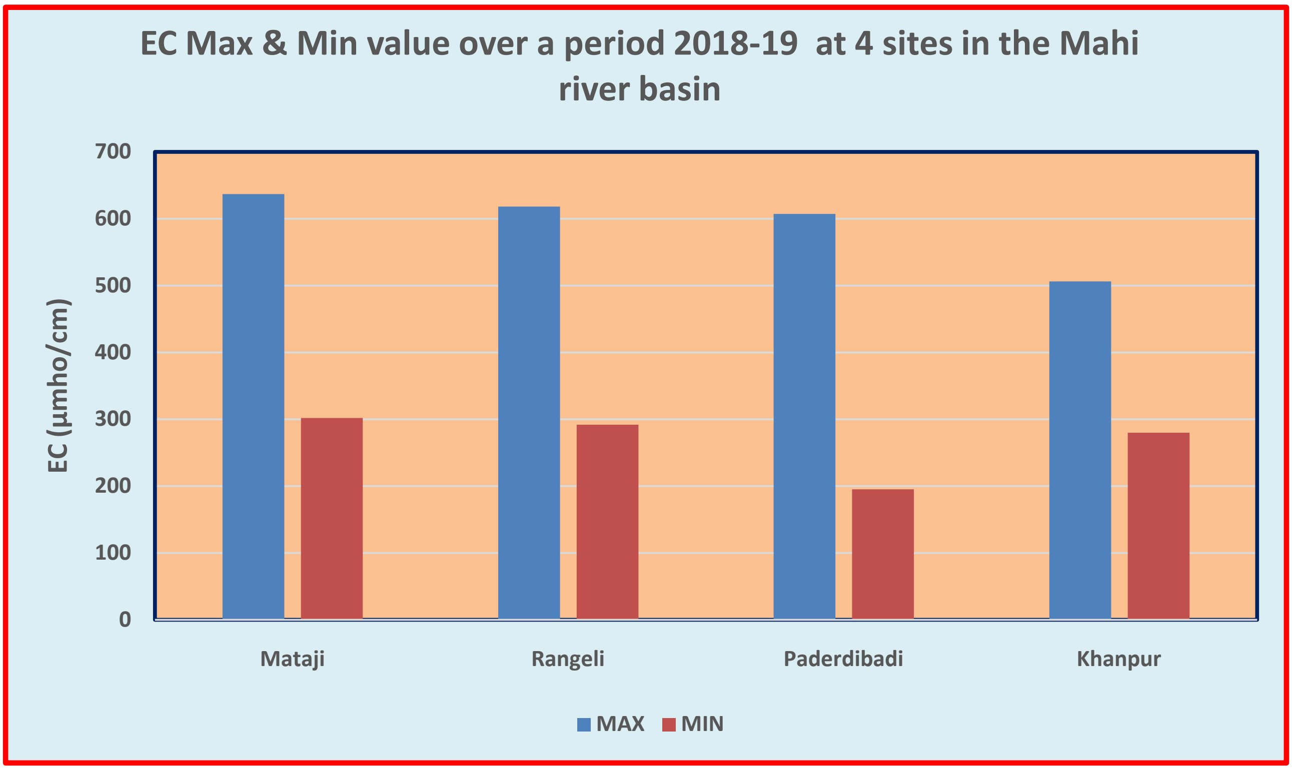
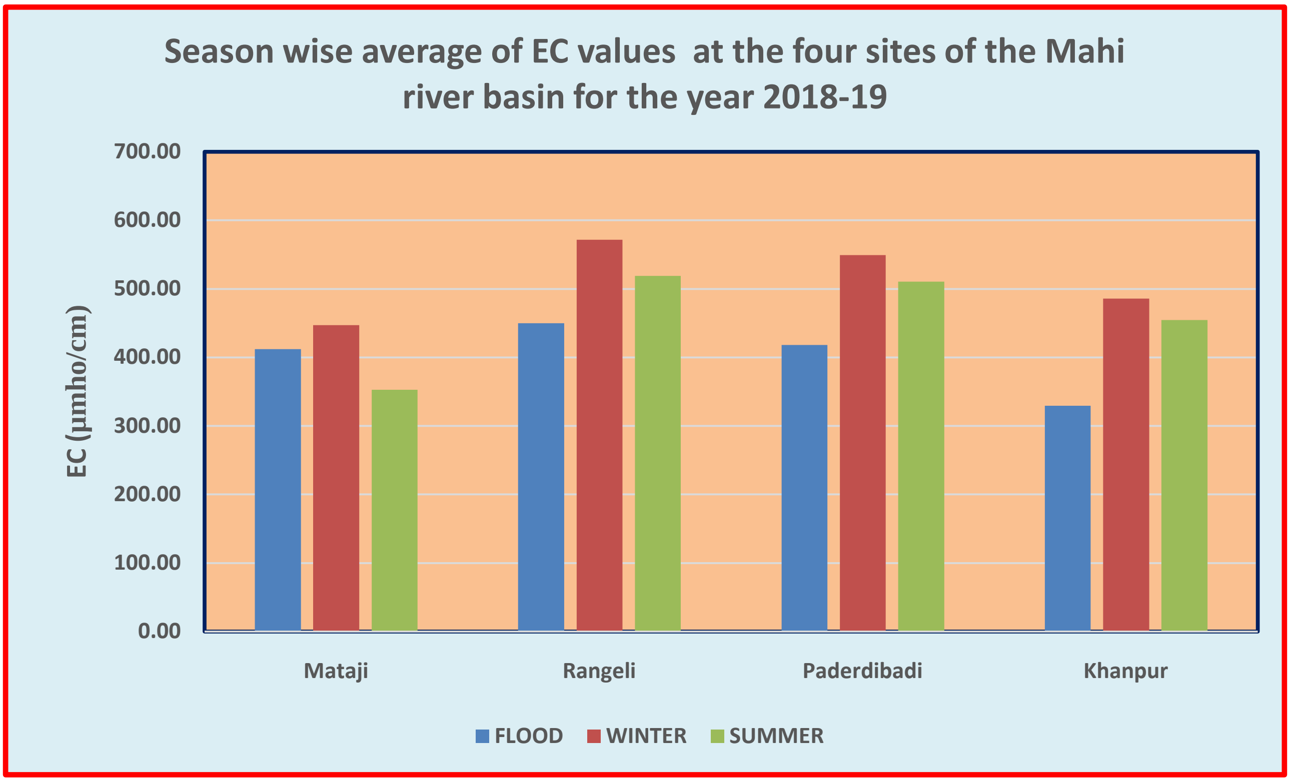


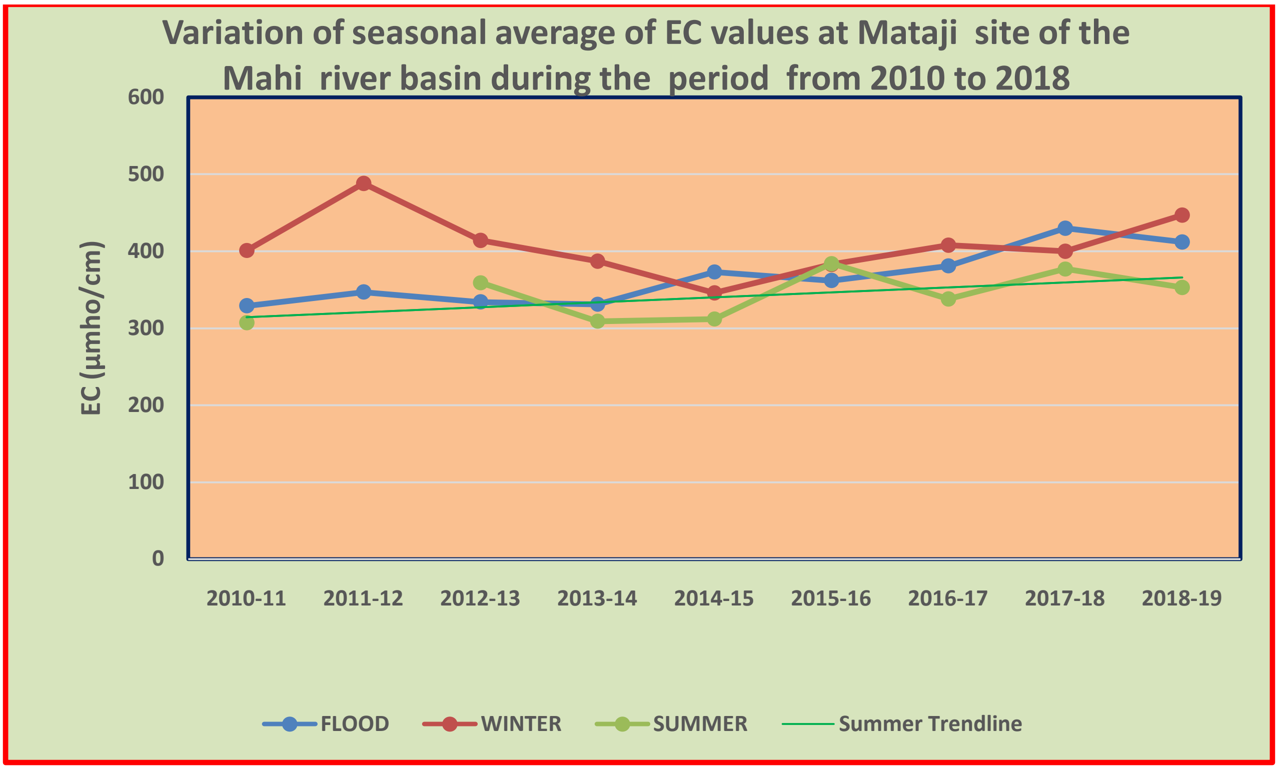
Table-4: EC values of the four sites in the Mahi river basin during 2018-19

	EC (µmho/cm)			
Month	**Mataji**	**Rangeli**	**Paderdibadi**	**Khanpur**
Jun-18	637	451	389	425
Jul-18	302	292	195	280
Aug-18	352	476	447	280
Sep-18	397	527	545	280
Oct-18	373	504	514	383
Nov-18	445	530	541	477
Dec-18	456	554	510	467
Jan-19	471	585	540	494
Feb-19	416	618	607	506
Mar-19	377	485	549	506
Apr-19	341	542	482	442
May-19	341	530	501	416
MAX	637	618	607	506
MIN	302	292	195	280
Season	Mataji	Rangeli	Paderdibadi	Khanpur
FLOOD	412.20	450.00	418.00	329.60
WINTER	447.00	571.75	549.50	486.00
SUMMER	353.00	519.00	510.67	454.67

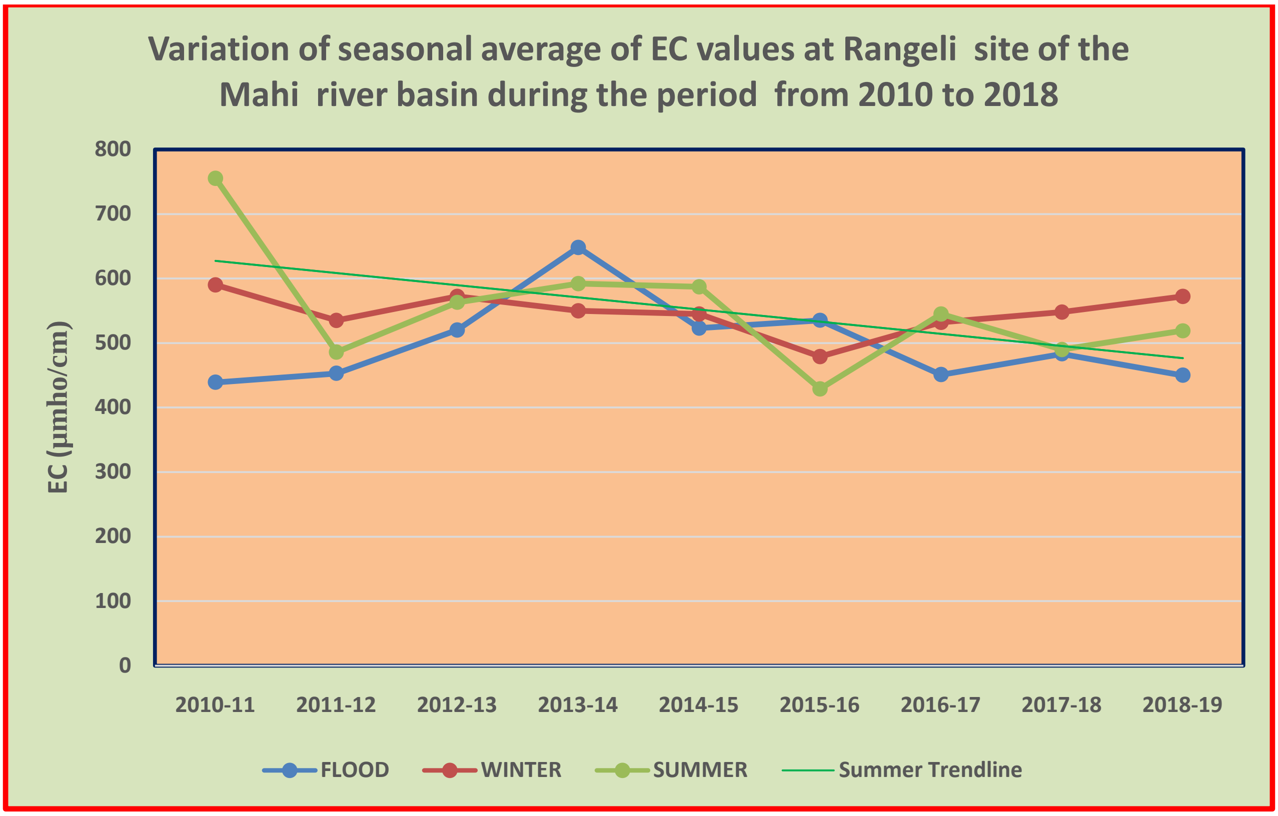
Graph-8: Season wise average of EC values at the four sites in the Mahi river basin during 2018-19



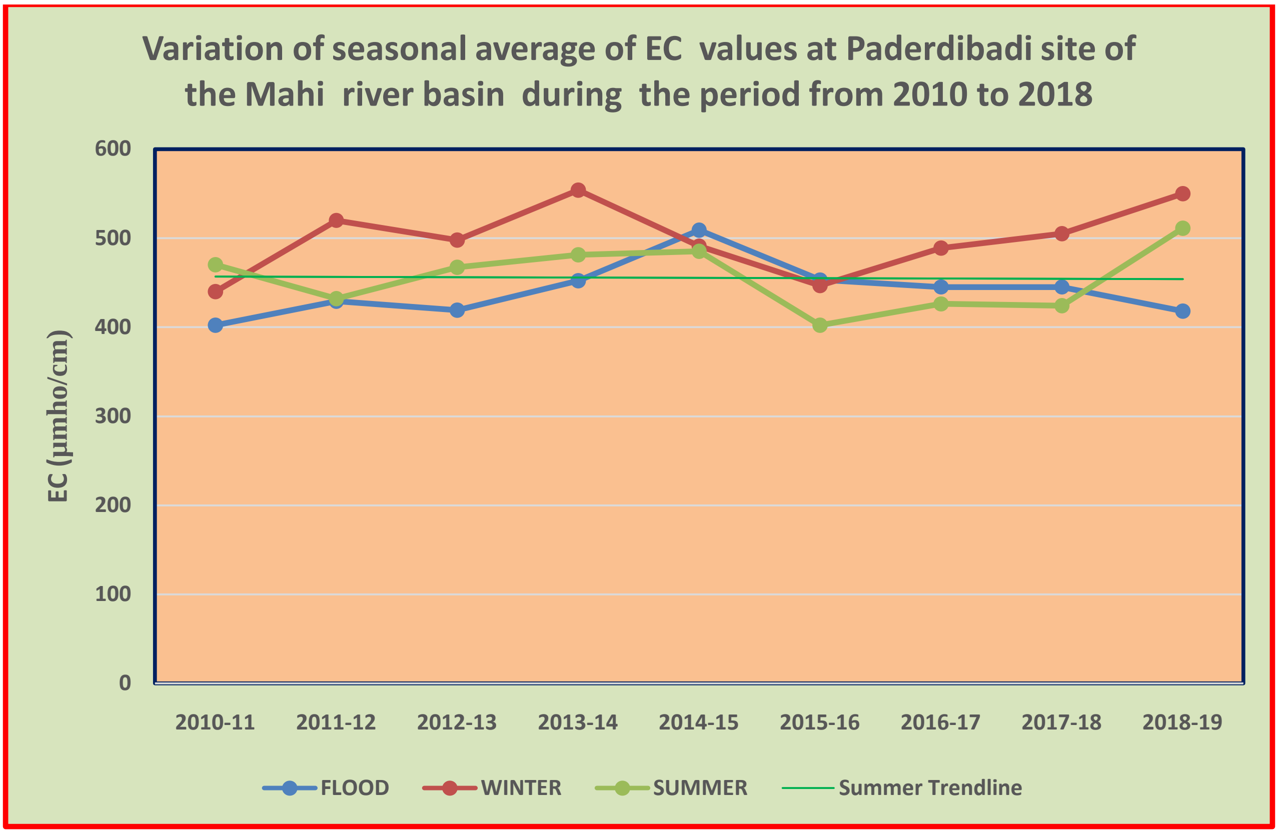
Graph-9 : Seasonal average of EC values for the period 2010- 2018 at the Site Mataji



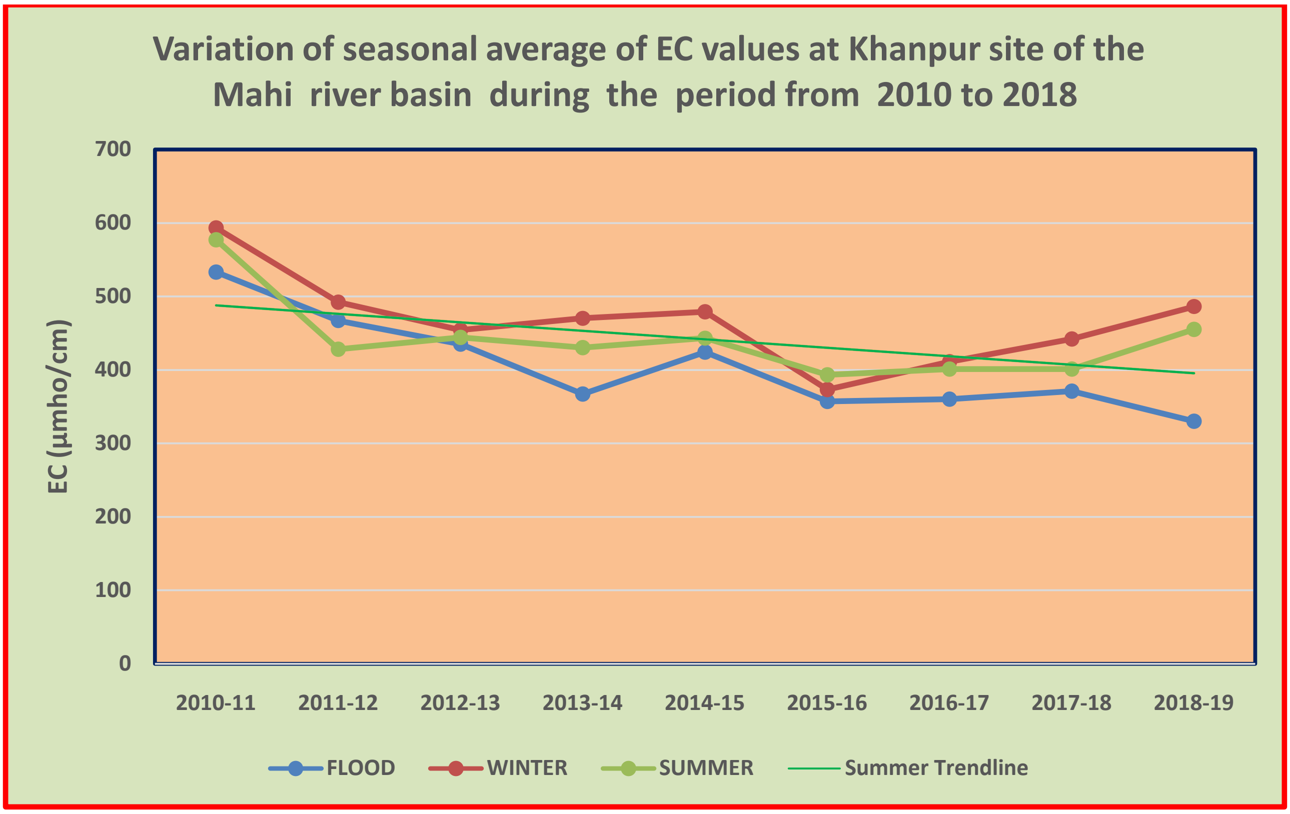
Graph-10 : Seasonal average of EC values for the period 2010- 2018 at the Site Rangeli



Graph-11 : Seasonal average of EC values for the period 2010- 2018 at the Site Paderdibadi



Graph-12 : Seasonal average of EC values for the period 2010- 2018 at the Site Khanpur



Dissolved Oxygen:

The amount of DO present in river water rely on water temperature, turbulence, salinity, and altitude. DO is the prominent factor that determines whether biological alterations are brought by aerobic or anaerobic organisms. A quick fall in the DO indicates a high organic pollution in the river. The optimum value for good water quality is 4 to 6 mg/l of DO for a general perception, which corroborates healthy aquatic life in a water body. In the present study, the trend in DO Value over the years is decreased and can be accounted by the graphical representation of different four sites in the Mahi river basin during Flood, winter and summer season. Generally it is observed that DO Value has increased in winter season at all 4 sites in the Mahi river basin.

Graph-13: DO Max & Min value of the four sites in the Mahi river basin during 2018-19

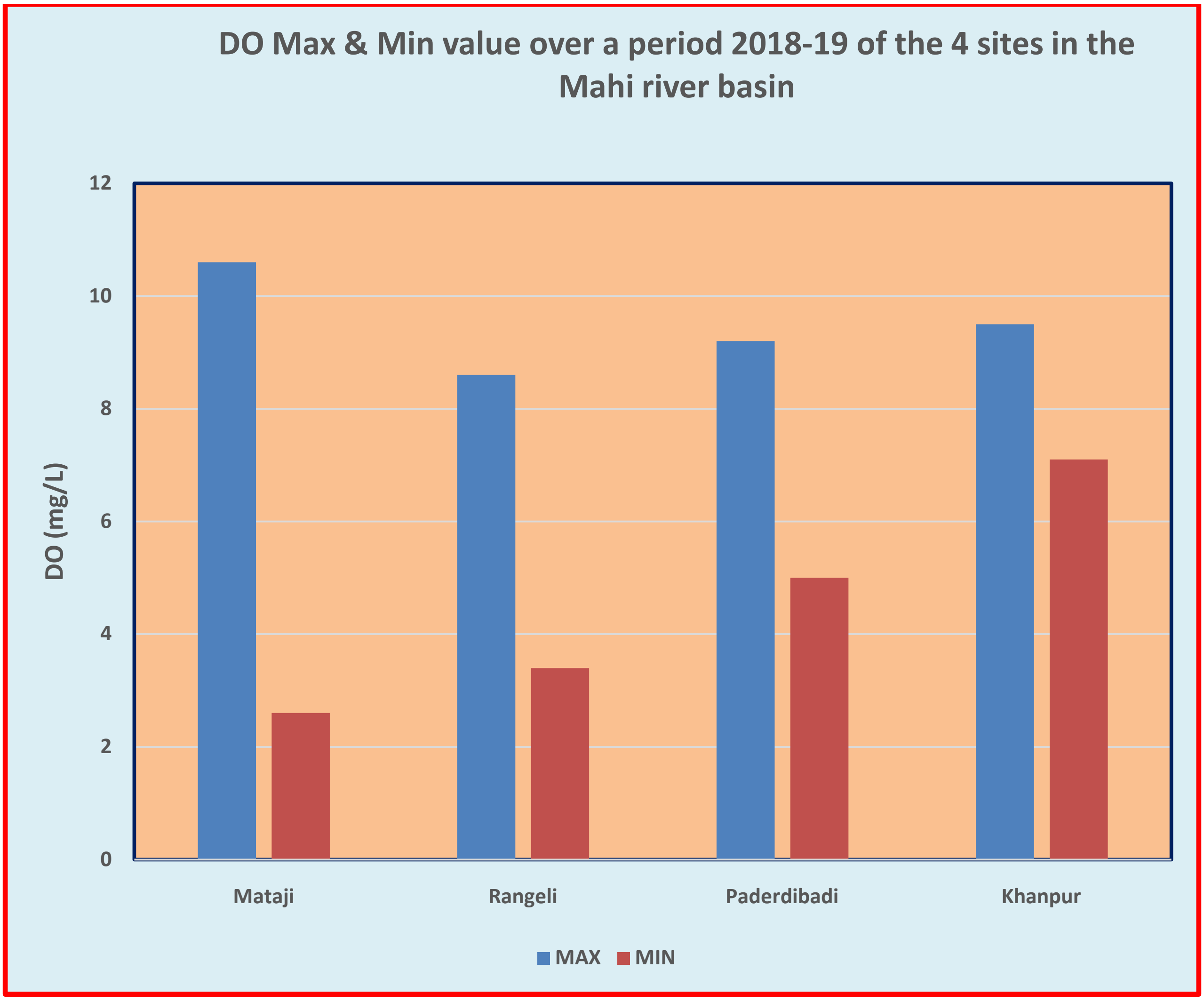
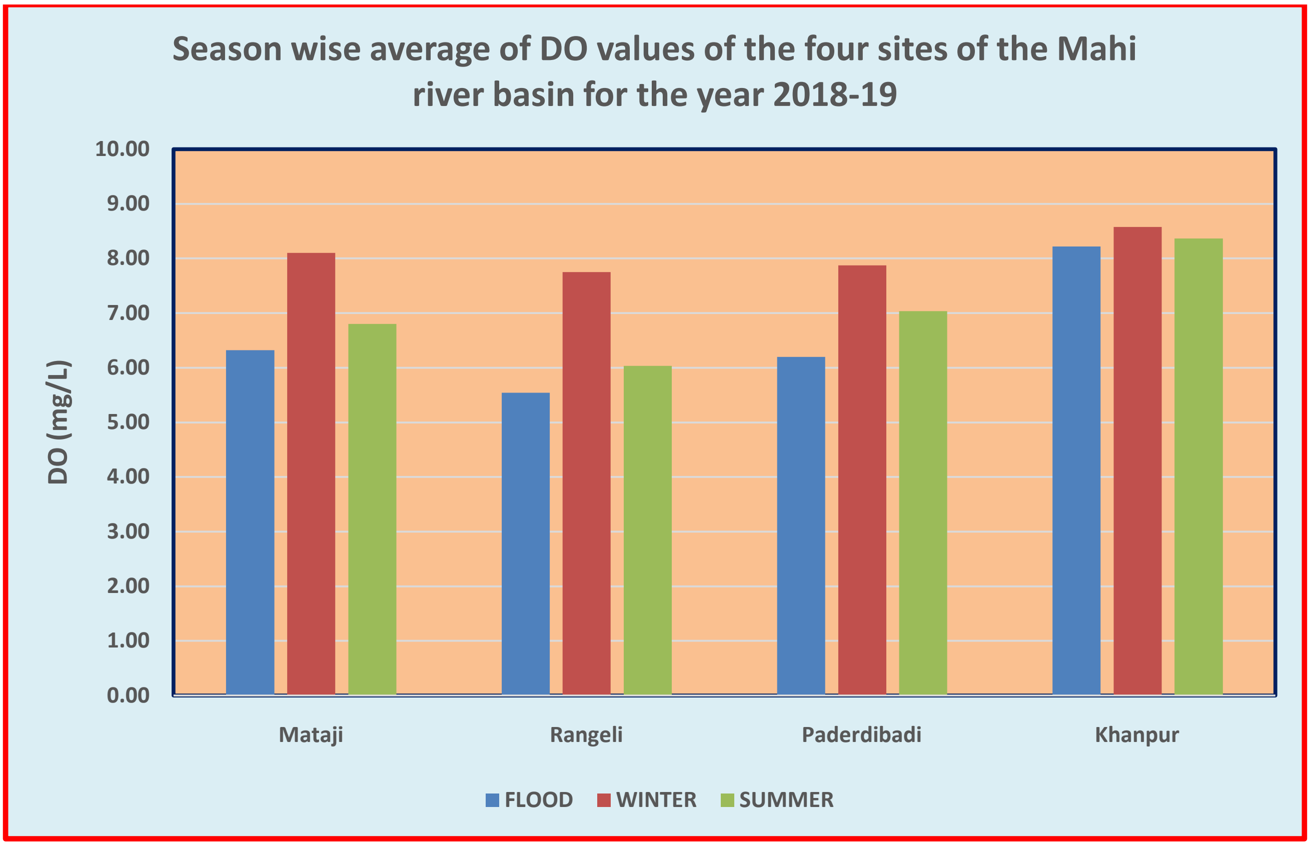


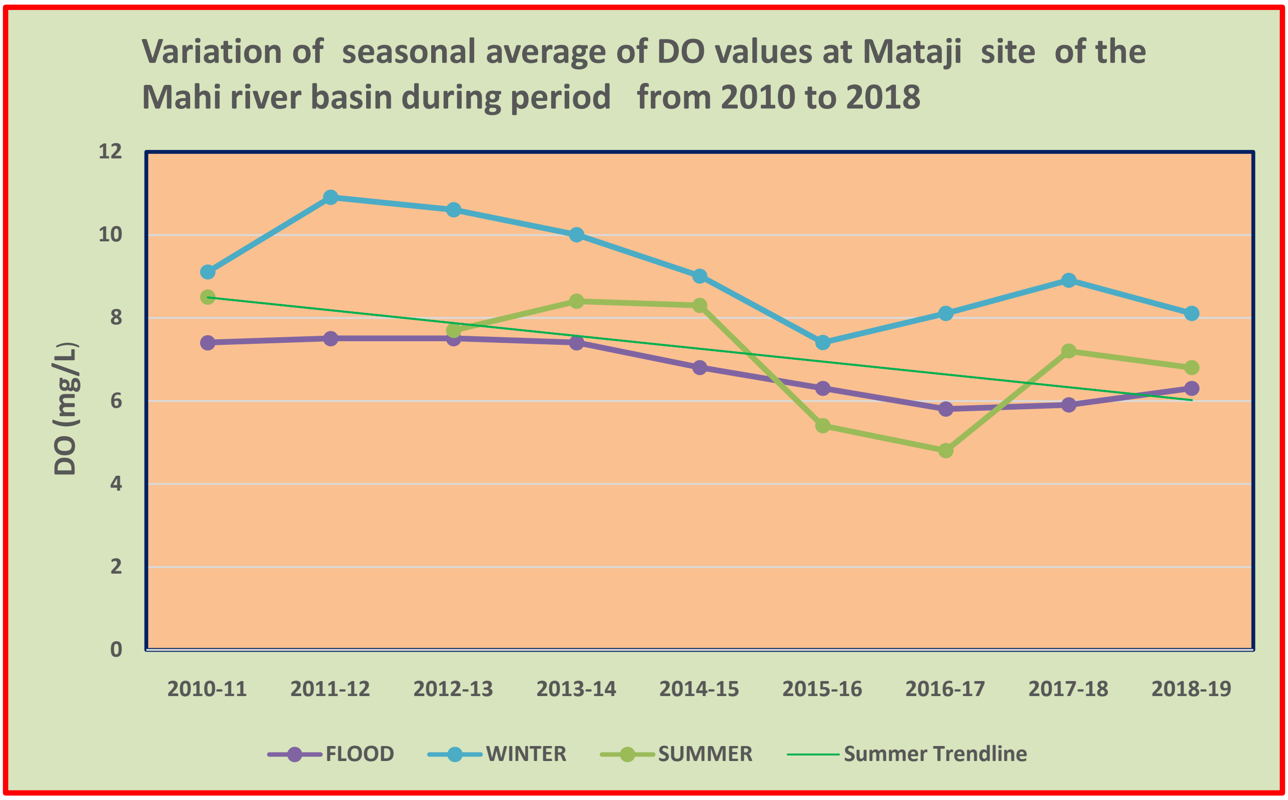
Table-5: DO values of the four sites in the Mahi river basin during 2018-19

DO mg/L				
Month	**Mataji**	**Rangeli**	**Paderdibadi**	**Khanpur**
Jun-18	2.6	3.7	6.6	7.4
Jul-18	5.6	3.4	5.4	8.6
Aug-18	8.3	8.5	5.0	8.5
Sep-18	10.6	6.6	6.7	7.1
Oct-18	4.5	5.5	7.3	9.5
Nov-18	7.4	6.5	7.7	7.8
Dec-18	7.1	8.1	7.8	8.5
Jan-19	9.1	8.6	8.5	9.2
Feb-19	8.8	7.7	7.5	8.8
Mar-19	7.7	7.1	9.2	7.7
Apr-19	6.7	5.9	6.3	8.6
May-19	6.0	5.1	5.6	8.8
MAX	10.6	8.6	9.2	9.5
MIN	2.6	3.4	5	7.1
Season	**Mataji**	**Rangeli**	**Paderdibadi**	**Khanpur**
FLOOD	6.32	5.54	6.20	8.22
WINTER	8.10	7.73	7.88	8.58
SUMMER	6.80	6.03	7.03	8.37

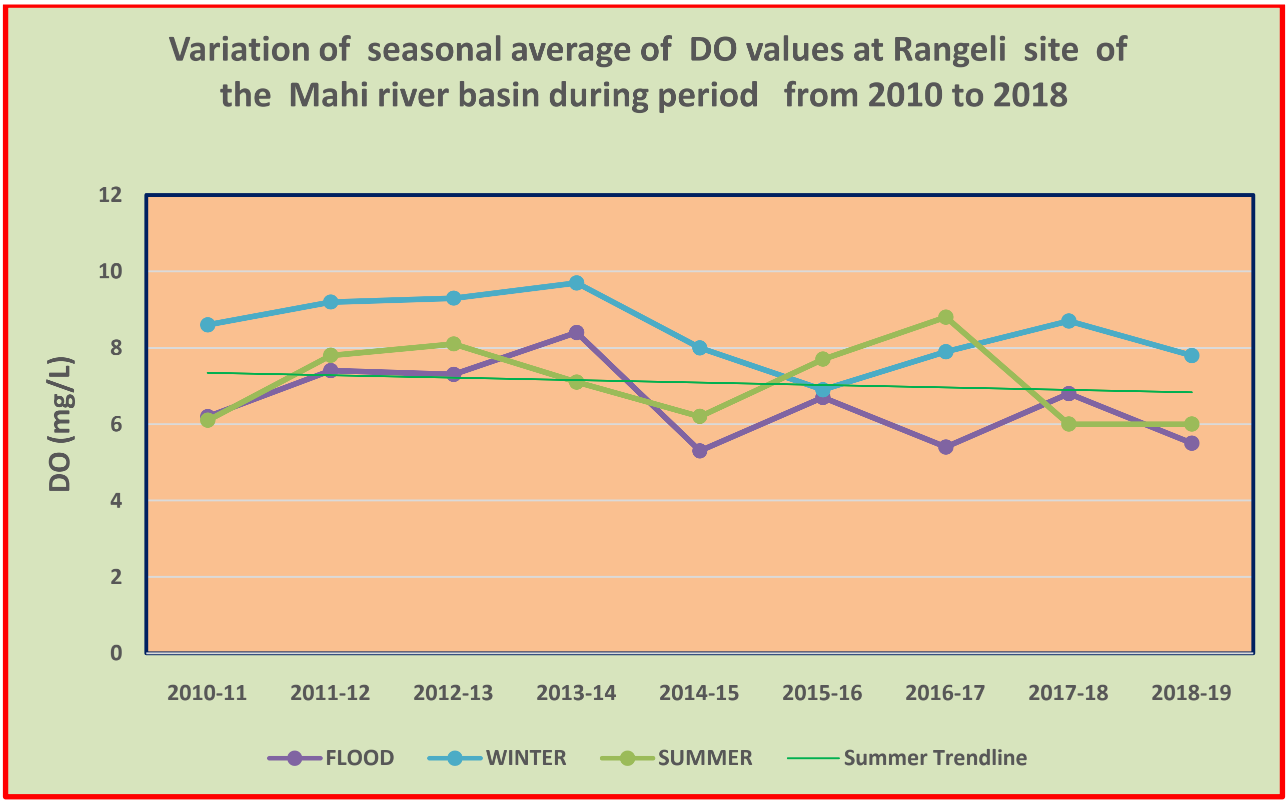
Graph-14: Season wise average of DO values of the four sites in the Mahi river basin during 2018-19



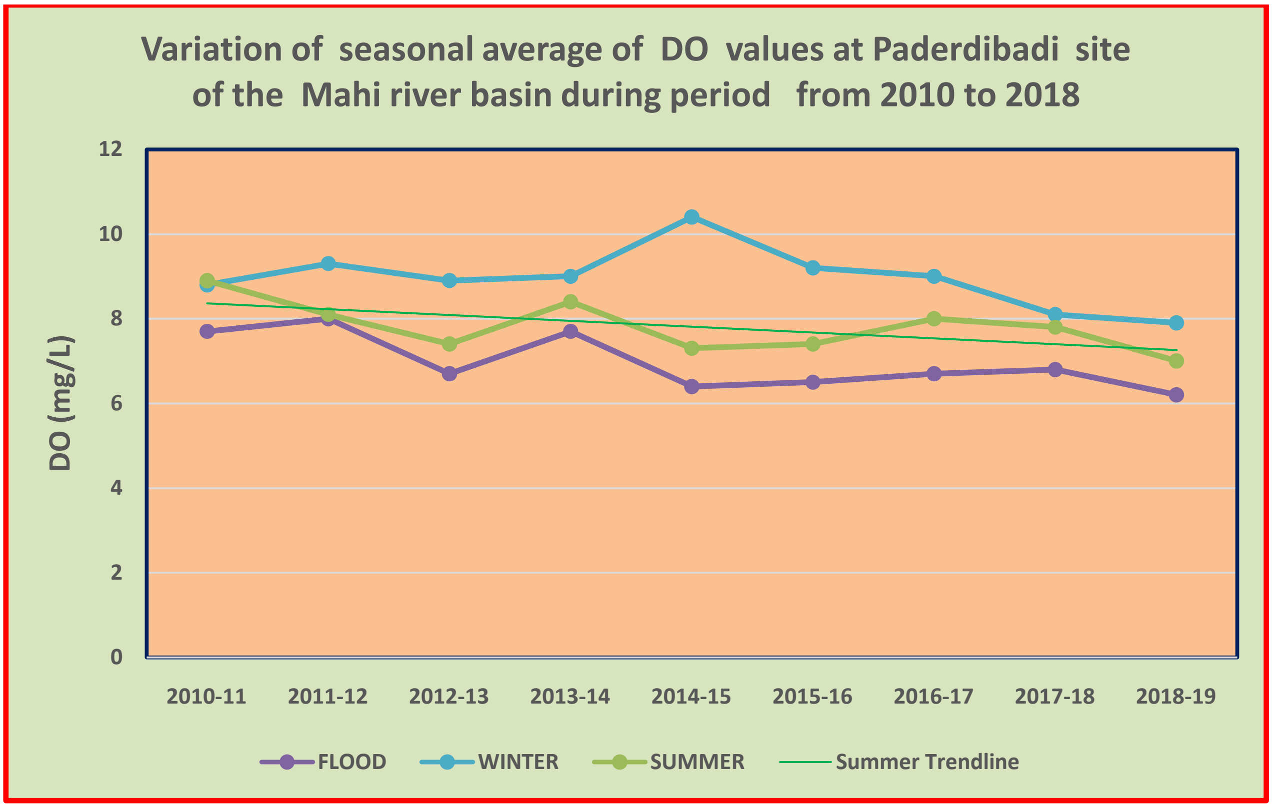
Graph-15 : Seasonal average of DO values for the period 2010- 2018 at the Site Mataji



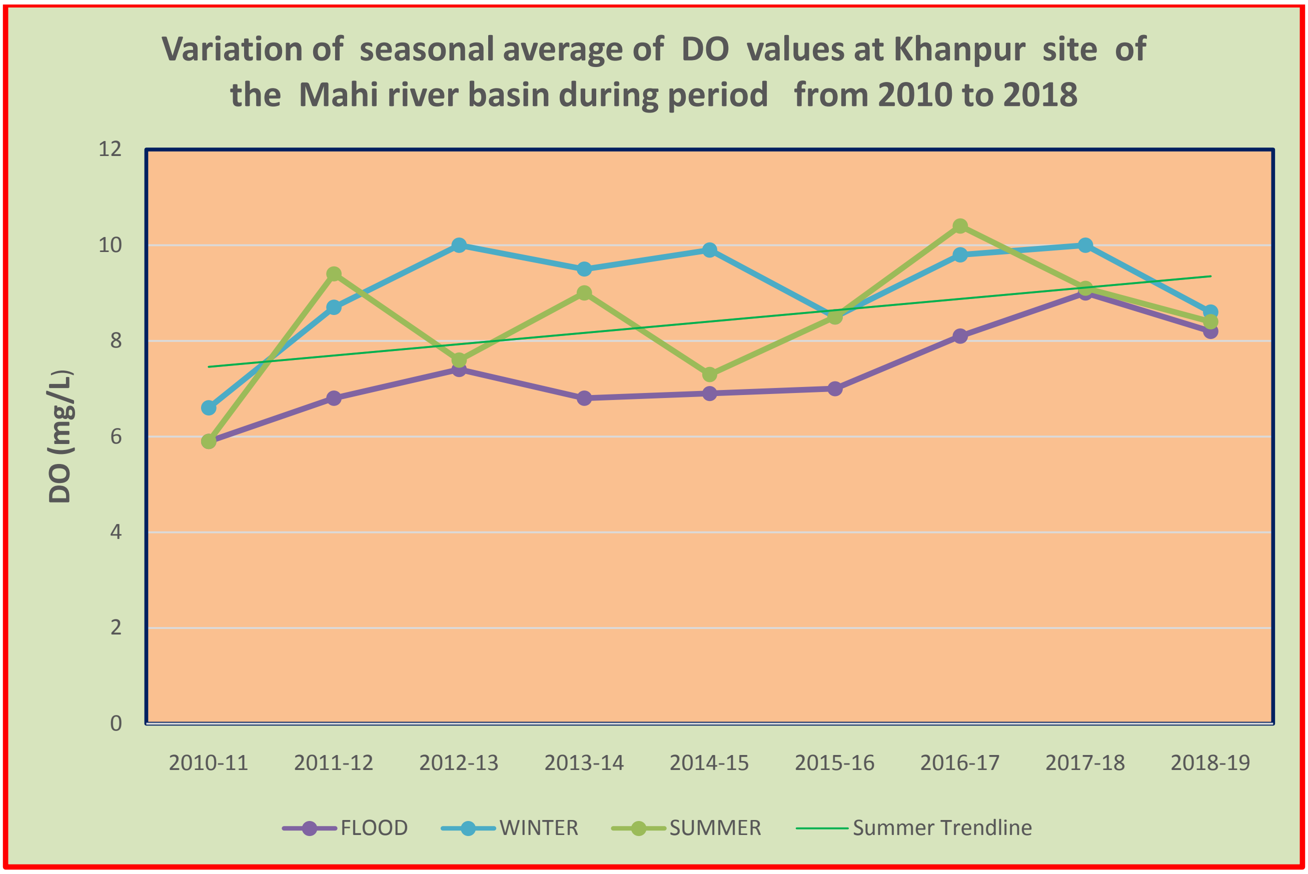
Graph-16 : Seasonal average of DO values for the period 2010- 2018 at the Site Rangeli



Graph-17 : Seasonal average of DO values for the period 2010- 2018 at the Site Paderdibadi



Graph-18 : Seasonal average of DO values for the period 2010- 2018 at the Site Khanpur



Biochemical Oxygen Demand :

The Biochemical oxygen demand (BOD) refers to the amount of oxygen required for the biotic degradation of organic matter in bodies of water. The BOD is a pollution parameter mainly to assess the quality of effluent or wastewater. A BOD level of 1-2 ppm is considered good i.e there will not be much organic waste present in the water sample. In the present study, the trend in BOD value over the years is increased and can be accounted by the graphical representation of different four sites in the Mahi river basin during Flood, winter and summer season. Generally non monsoon comprises with higher BOD value.

Graph-19: BOD Max & Min value at four sites in the Mahi river basin during 2018-19

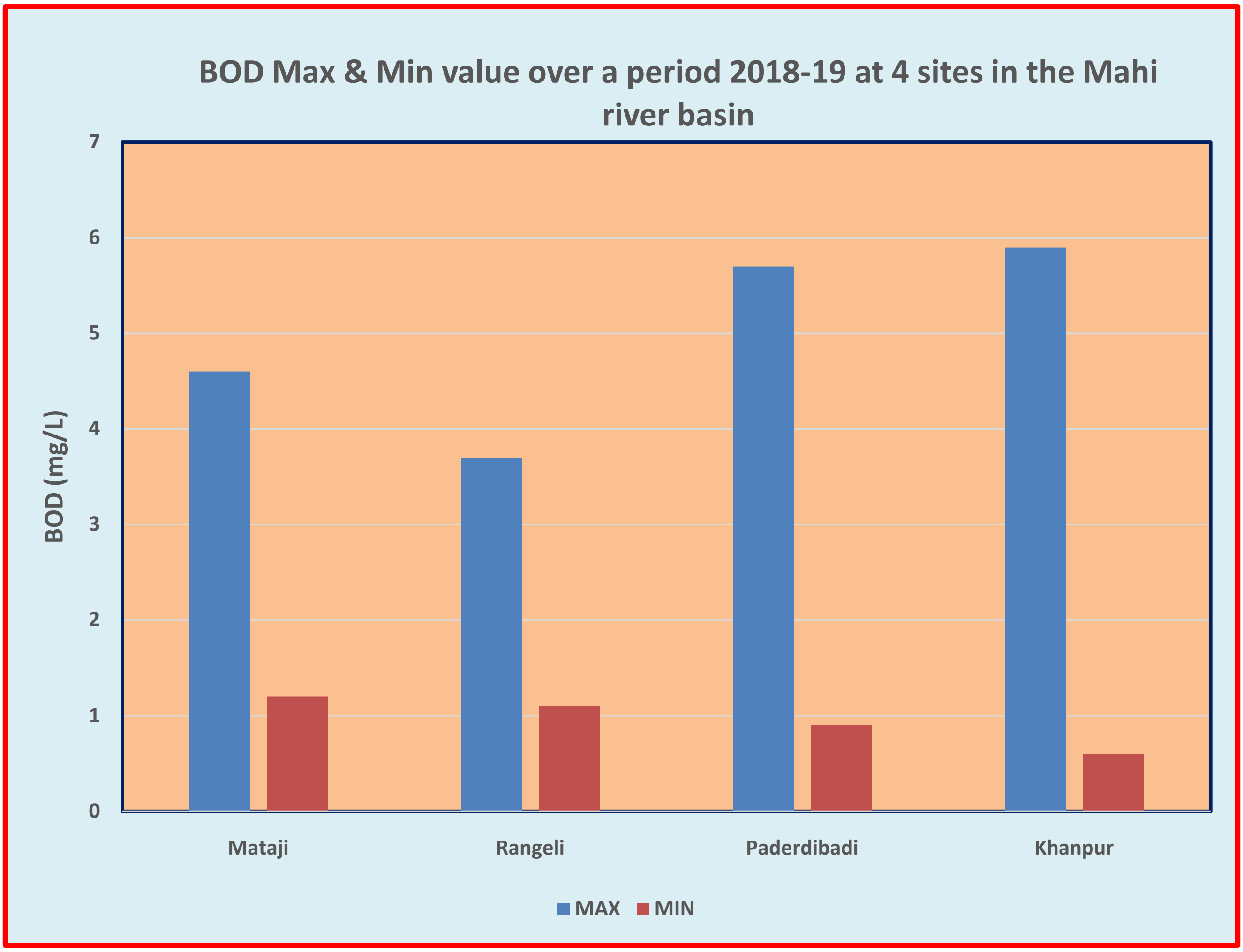
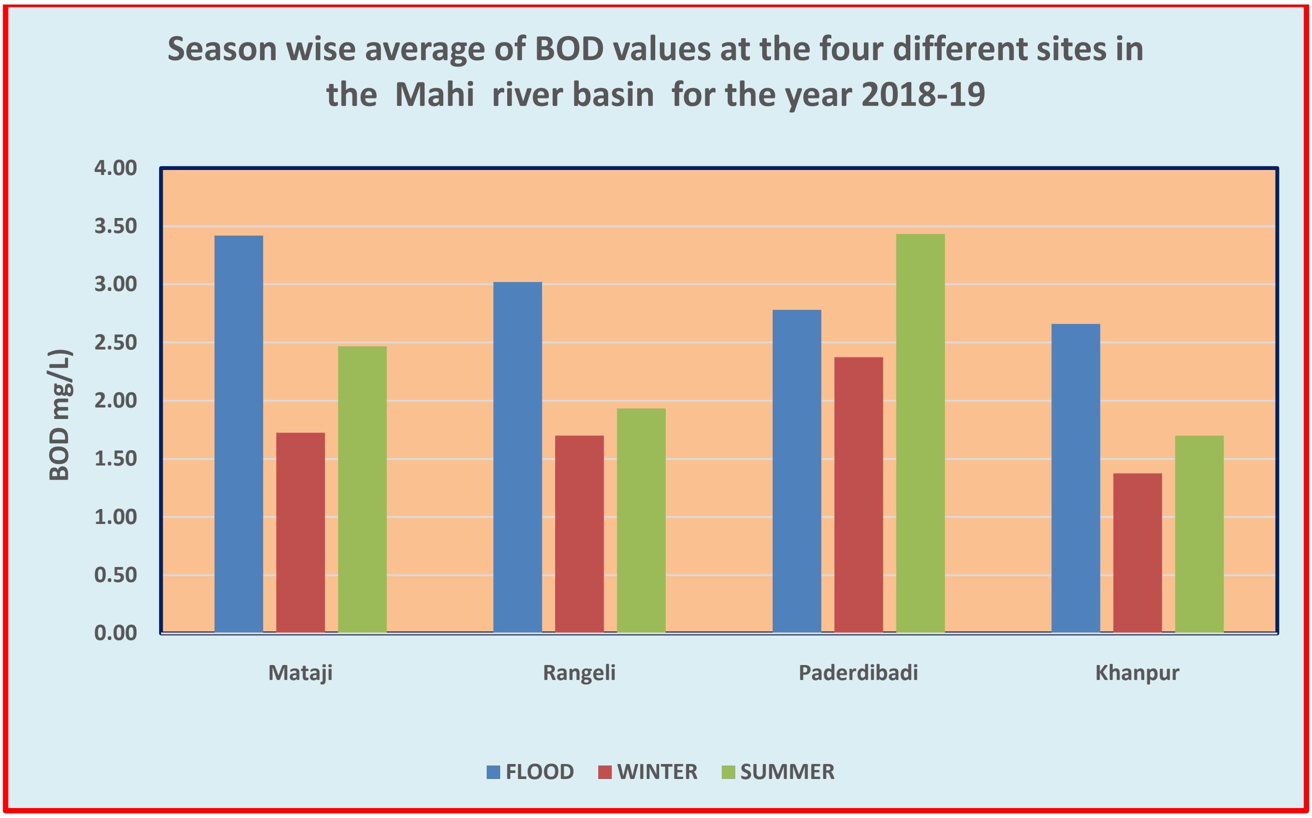


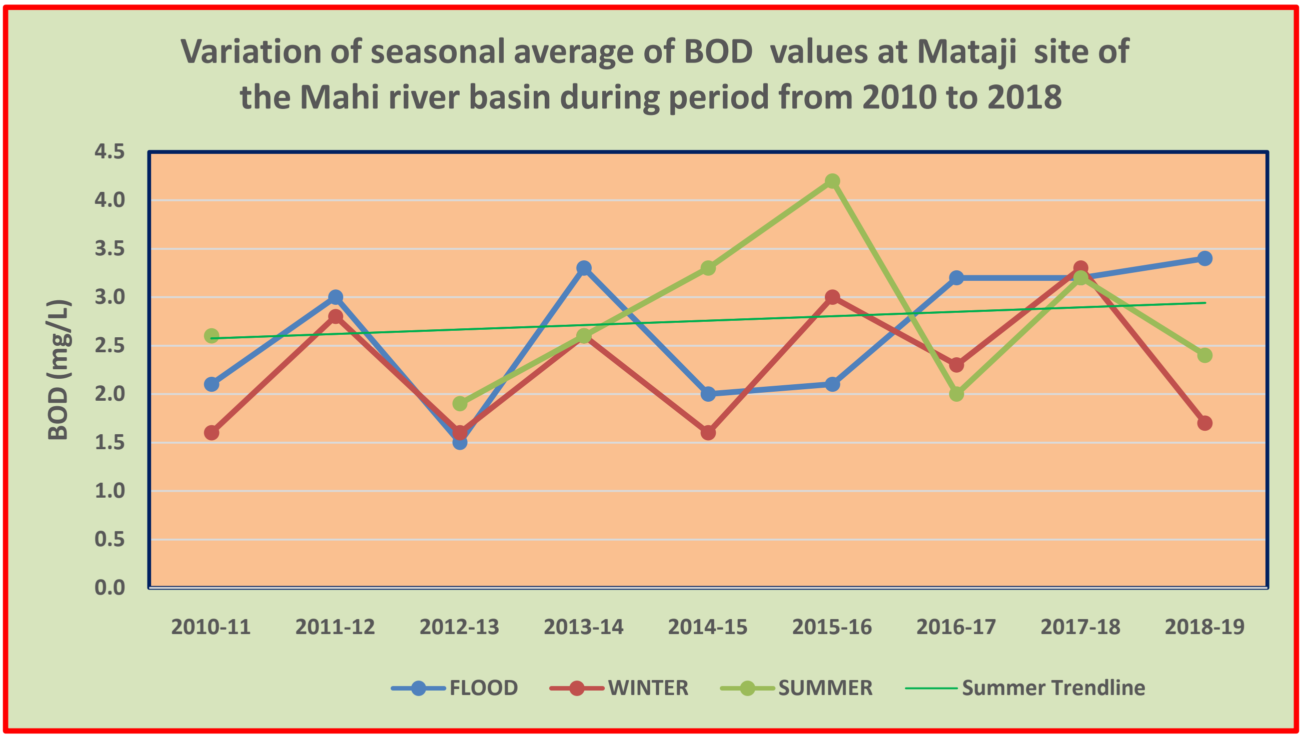
Table-6: BOD values of the four sites in the Mahi river basin during 2018-19

BOD mg/L				
Month	**Mataji**	**Rangeli**	**Paderdibadi**	**Khanpur**
Jun-18	2.5	3.3	5.7	2.1
Jul-18	4.5	3.4	2.6	5.9
Aug-18	2.9	3.7	0.9	3.7
Sep-18	4.6	2.1	2.4	0.6
Oct-18	2.6	2.6	2.3	1.0
Nov-18	2.2	1.1	3.3	1.1
Dec-18	1.4	1.7	1.2	1.2
Jan-19	1.2	1.5	1.9	1.0
Feb-19	2.1	2.5	3.1	2.2
Mar-19	1.4	1.6	2.9	2.3
Apr-19	3.1	1.9	5.1	1.5
May-19	2.9	2.3	2.3	1.3
MAX	4.6	3.7	5.7	5.9
MIN	1.2	1.1	0.9	0.6
Season	**Mataji**	**Rangeli**	**Paderdibadi**	**Khanpur**
FLOOD	3.42	3.02	2.78	2.66
WINTER	1.73	1.70	2.38	1.38
SUMMER	2.47	1.93	3.43	1.70

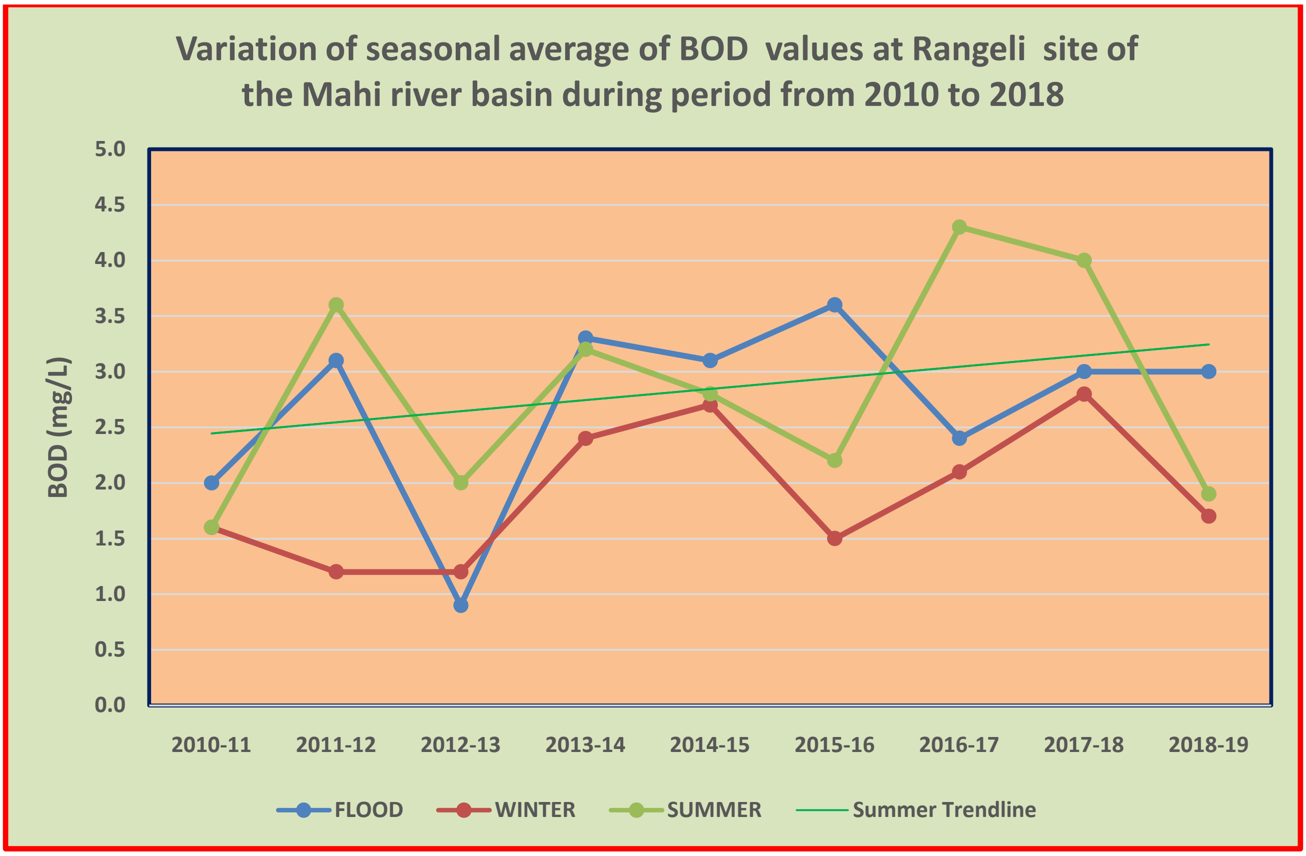
Graph-20: Season wise average of BOD values at four sites in the Mahi river basin during 2018-19



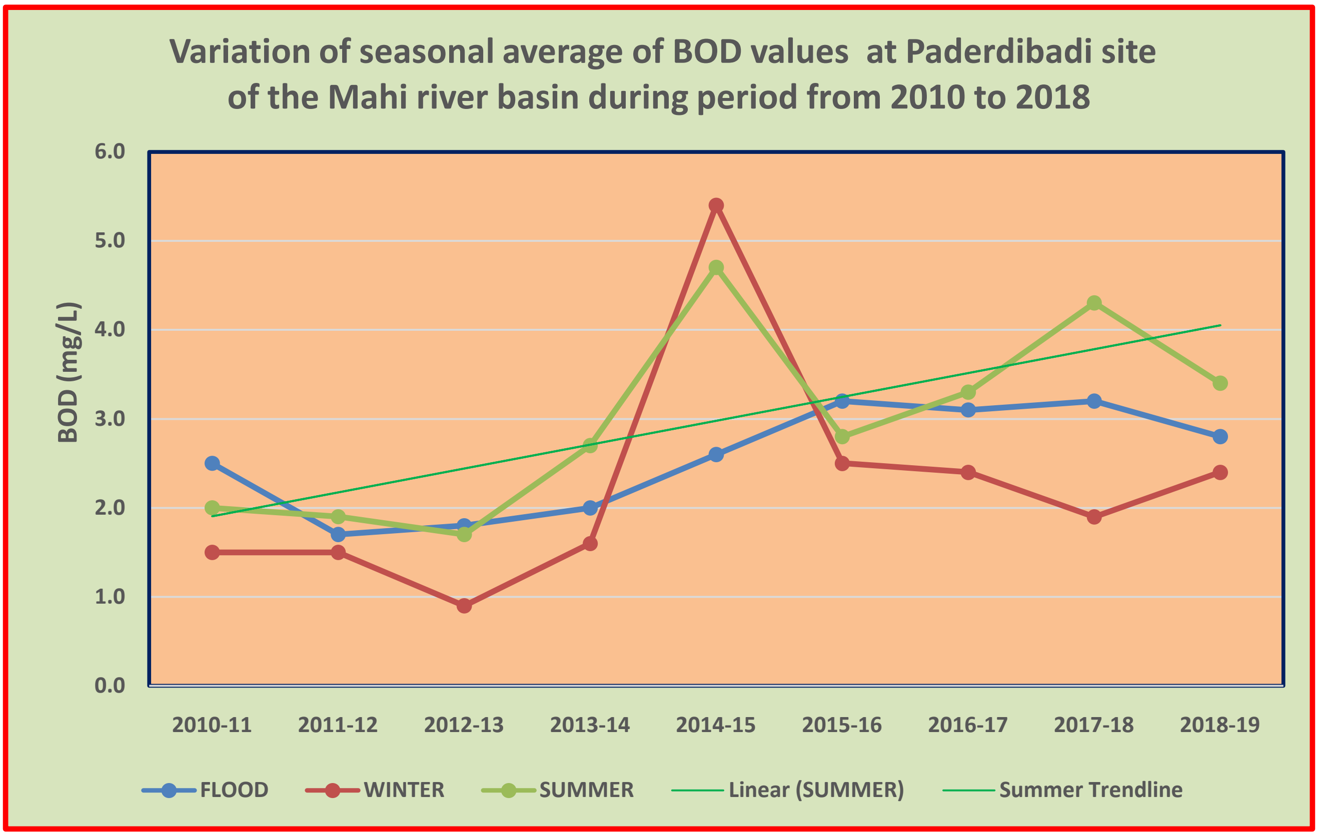
Graph-21 : Seasonal average of BOD values for the period 2010- 2018 at the Site Mataji



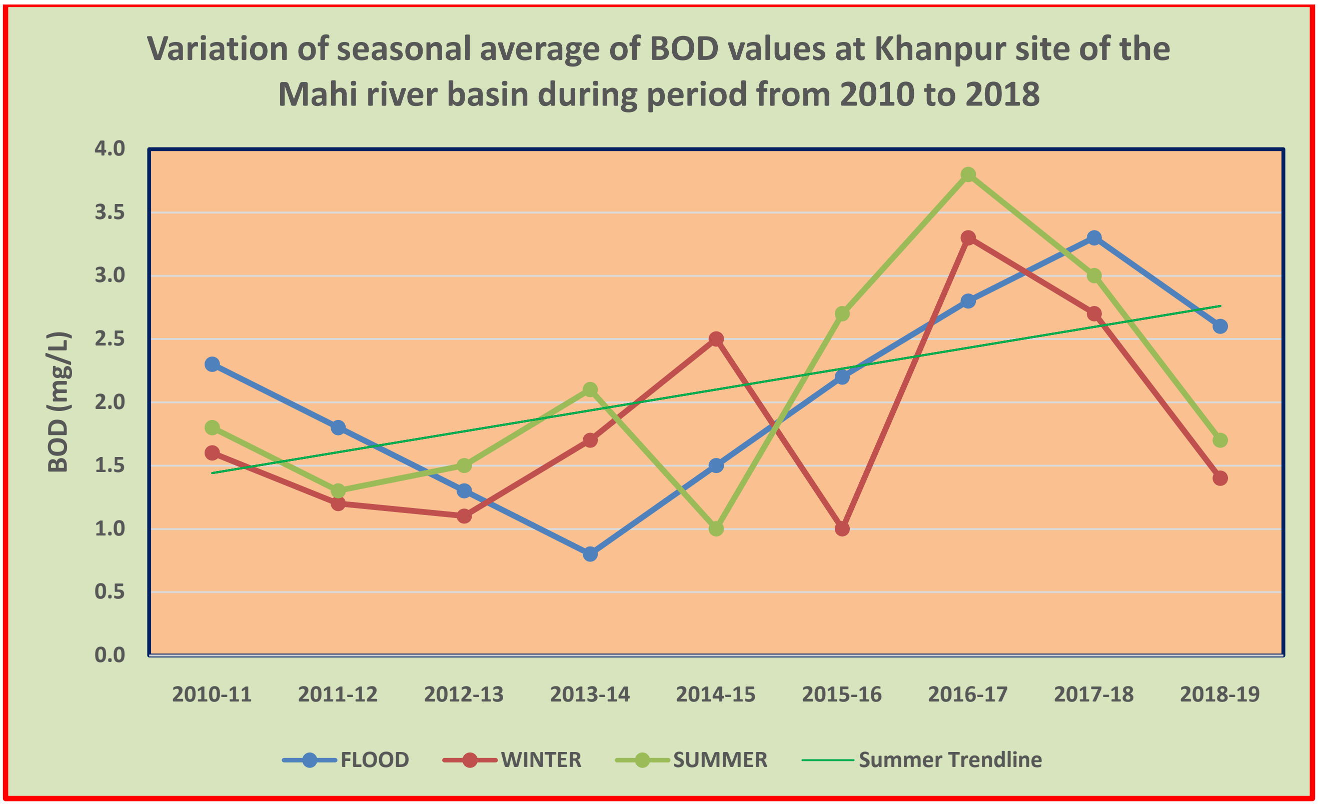
Graph-22 : Seasonal average of BOD values for the period 2010- 2018 at the Site Rangeli



Graph-23 : Seasonal average of BOD values for the period 2010- 2018 at the Site Paderdibadi



Graph-24: Seasonal average of BOD values for the period 2010- 2018 at the Site Khanpur



Total Coliform:

Total Coliforms are a group of related bacteria that are (with few exceptions) not harmful to humans. A variety of bacteria, parasites, and viruses, known as pathogens, can potentially cause health problems if humans ingest them. EPA considers total coliforms a useful indicator of other pathogens for drinking water. It is determined by the **Most Probable Number** (**MPN**) **method.** MPN method is a statistical, multi-step assay consisting of presumptive, confirmed and completed phases.

Graph-24: Total Coliform Max & Min value of the four sites in the Mahi river basin during 2018-19

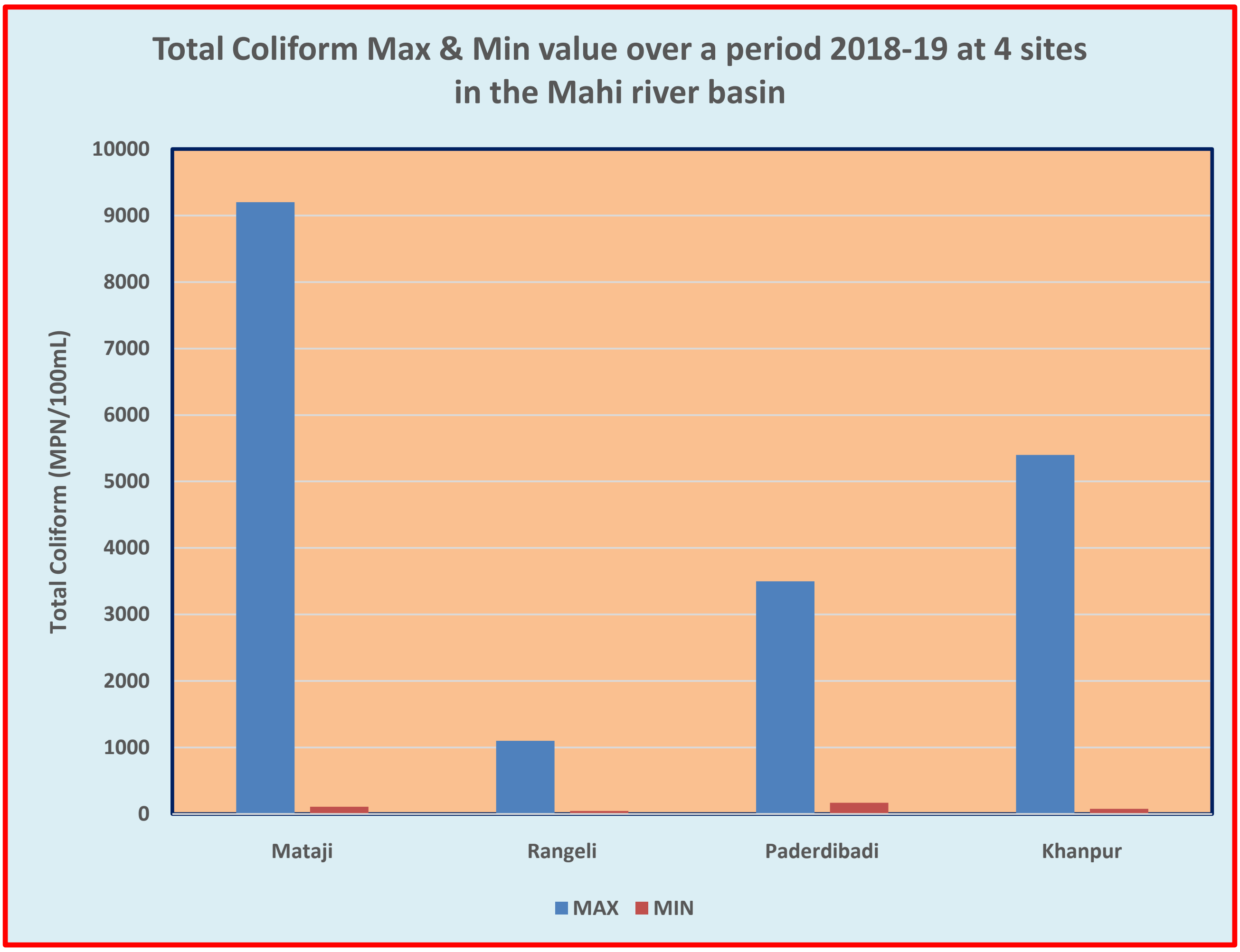
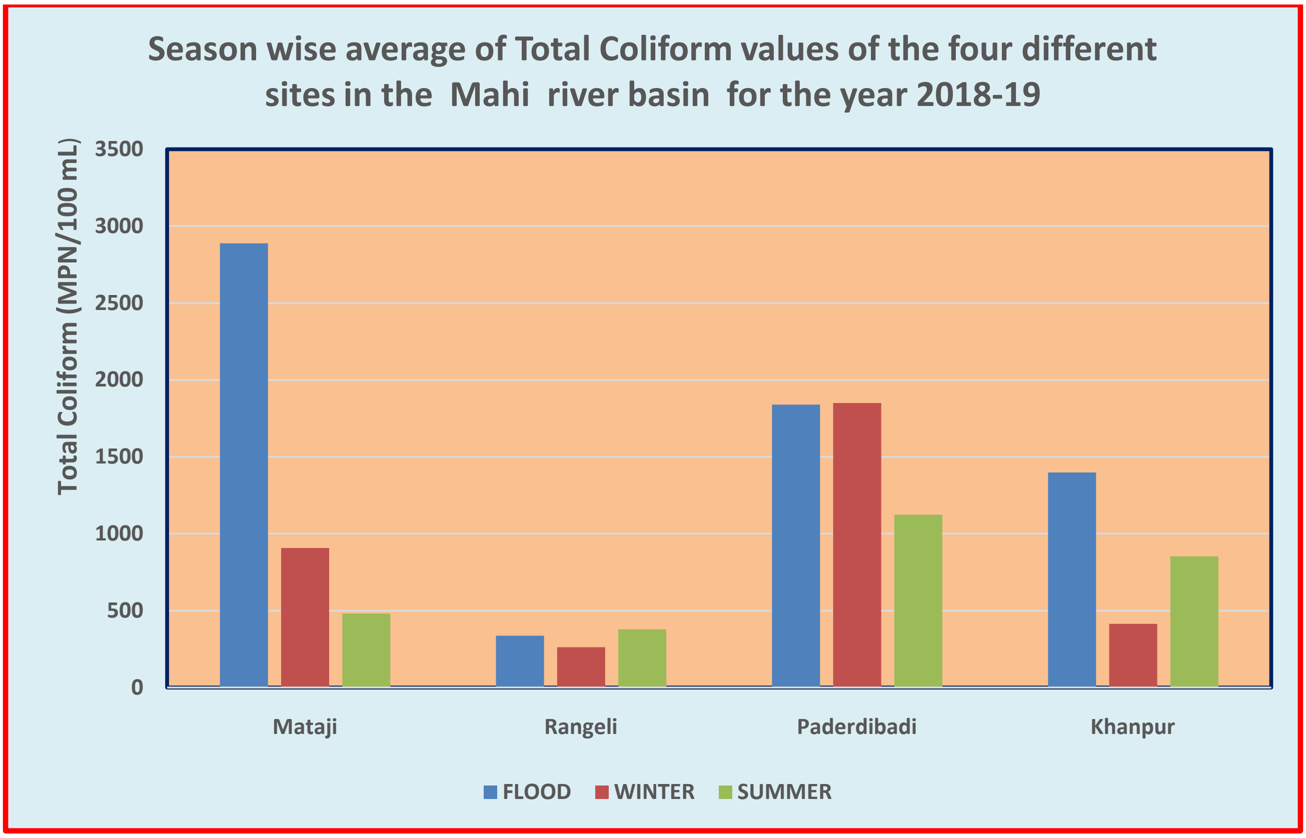


Table-7: Total coliform values of the four sites in the Mahi river basin during 2018-19

Total Coliform MPN/100 mL				
Month	**Mataji**	**Rangeli**	**Paderdibadi**	**Khanpur**
Jun-18	9200	170	2800	5400
Jul-18	340	1100	1100	1100
Aug-18	300	170	500	170
Sep-18	2400	78	3500	230
Oct-18	2200	170	1300	92
Nov-18	2400	130	1700	790
Dec-18	330	130	2200	110
Jan-19	790	460	1100	78
Feb-19	110	330	2400	680
Mar-19	930	780	2100	920
Apr-19	310	45	170	1300
May-19	200	310	1100	340
MAX	9200	1100	3500	5400
MIN	110	45	170	78
Season	**Mataji**	**Rangeli**	**Paderdibadi**	**Khanpur**
FLOOD	2888	338	1840	1398
WINTER	908	263	1850	415
SUMMER	480	378	1123	853

Graph-25: Season wise average of Total Coliform values of the four sites in the Mahi river basin during 2018-19



Conclusion:

The above study is aimed to study the seasonal variation of water quality over the years in the river Mahi. In the Mahi river basin, we have 4 WQ sites and previous 9 year data is assessed to obtain the following inference-

1. There is an increasing trend in pH value over the years, though the values are in tolerance limit (6.5-8.5) in most of the cases.

2. Whenever there is a pooling water or negligible flow, EC value increases. Here EC values of different season over the years are within the limit.

3. DO Values have decreased over the years. Mainly in winter DO values become high compare to the monsoon season.

4. BOD values are found to have increased over the years.

5. Total Coliform value is generally high in monsoon season compare to non monsoon period.

   The above study indicates that water pollution is increasing gradually in the mahi river. This may be due to slight increase in the organic matter present in the river over the years.

Assessment of the Water Quality Standard of Chenab River Basin in terms of Physico-Chemical Parameters

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Abstract: *The present investigation is aimed at assessing the current water quality standard along the stretch of Chenab River Basin in terms of physico-chemical parameters and its comparison with the last ten years (2010-19) values. Six samples were collected along the entire stretches of the river basin during the period from January-2019 to December-2019 on the first working day of every month. Various physico-chemical parameters like pH,, EC, carbonate, bicarbonate, sodium, potassium, calcium, magnessium, sulphate D.O.,B.O.D. etc. were analysed. The present study indicates that the water quality of Chenab River Basin is well within tolerance limit taking the physico-chemical parameters in to considerations.*

Key Words: *Chenab River, Physico-chemical parameters, pH, EC, Sulphate, D.O, B.O.D.*

I. Introduction

As water is the basic need of the habitants, its safeness must be studied before use. The present study aims at detecting the quality of water across the Chenab River in respect of physico-chemical parameters. Although in rural areas of developing countries, the great majority of water quality problems are related to bacteriological and other biological contaminations, a significant number of very serious problems may also occur as a result of physico-chemical imparity of water resources. With rapid industrialization and urbanization, the river water pollution is increasing rapidly. Effect of poor water quality on human health was noted for the first time in 1854 by John Snow, when he traced the outbreak of cholera epidemic in London to the Thames river water which was grossly polluted with raw sewage. Since then the science of water quality monitoring progressed. In the third world countries 80% of all diseases are directly related to poor drinking water and insanitary conditions. As water is one of the most basic needs of the habitants, its safeness must be studied before use. The physico-chemical quality of river water is very important from the health point of view. Thus, constant monitoring of river water quality is needed so as to record any alteration in quality and outbreak of health disorders. The present study reports on the river water quality of six different stations of Chenab River basin as given below. The present study aims at detecting the quality of water in respect of physico_chemical parameters during the study period and its comparison with last ten years (2010-19) values. The possible number of such parameters necessary to completely specify the quality of water is very large. However at present twelve parameters are considered to characterize the Chenab River water.

II. Study Area

The river Chenab is one of the major tributary out of five major tributaries viz. Satluj, Ravi, Beas, Chenab and Jhelum, which are ultimately merging with river Indus in Pakistan.The Chenab basin in India is spread over the two states, Himachal Pradesh and Jammu & Kashmir which comprises the extreme western sector of the Himalayas. Upper catchment lies in the Lahaul area and Pangi tehsil of Chamba district of Himachal Pradesh. This region is roughly in rectangular shape with main Himalayas in the north, mid Himalayas in the south and the connecting lines of heights either ends in east and west respectively. These hills rise to a mean elevation of about 5480 Mts. The Chenab basin in Jammu & Kashmir lies in its southern part covering the districts of Doda-kishtwar, Ramban, Udhampur and Jammu. This region of the state is called Jammu region. The drainage basin covers the area partly between the outer and central Himalayas branches and partly between Shivaliks and outer Himalayas. The total catchment area of the basin within India is about 29050 Sq. Km., out of which about 21206 sq. Km. lies in the Jammu & kishtwar region of the Jammu & Kashmir state and about 7844 Sq. Km. lies in Himachal Pradesh. About 10130 Sq. Km. of the catchment area remain under permanent snow cover.The river Chenab or Chandrabhaga is formed after the two streams namely the Chandra and the Bhaga merge together near Tandi about 6 km south of Keylong, the district head quarter of Lahaul .

Spiti (H. P.). The Chandra Originates at about 5412 mts from the north face of Baralacha pass in Himalayan canton of Lahaul Spiti valley, the initially flowing south east for about 88 km sweeps round the base of mid-Himalayas and joins Bhaga. The total length of the Chandra upto confluence point at Tandi with Bhaga is 125 Km. The combined river, known as Chenab or Chandrabhaga flows in the north westerly direction for about 48 Kms., where it is joined by a major tributary, the Miyar-Nallah on the right bank. Thereafter, it flows for about 96 Km. generally in the northerly direction in Himachal Pradesh and crosses the Pangi valley before entering into the Padder area of Doda district of Jammu & Kashmir state. The river flows in a north–west direction for about 61 Km., where it is joined by its biggest tributary, the Marusudar on the right bank near Bhanderkot. Further, downstream the river flow in a southerly direction for about 32 Km. up to Thathri, where it takes a west-ward direction.

After about 15 km. downstrem of Thathri, the Chenab is joined by Niru-Nalla on left bank. Thereafter, it flows in north-west direction for another 41km. till it receives another right bank tributary called Bichleri. Afterwards, it flows in westerly direction for about 64 Km. In this reach, a number of streams such as Chenani, Talsuen,Yabu & Ans join on the right bank and Panthal khad on the left bank. Down-stream of Ans confluence, the river takes southerly course and flows for about 55 Km. up to Akhnoor, where-after it enters into Sialkot district of Pakistan. The total length of the river between Akhnoor and Chandrabhaga confluence is about 410 Km. The entire course of the river in India is through high cliffs except for a small length of about 32km. between Akhnoor and Reasi. Another important left bank tributary is Stream Tawi, which joins the Chenab in Pakistan, a little distance down-stream of the international boundary.

Introduction of Sampling Stations:

1. **TANDI:** Tandi is a gauge, discharge, silt & water quality site situated on the stream Bhaga near the confluence point of the streams Chandra & Bhaga in the district Keylong in the Lahaul and Spiti valley in the Himachal Pradesh state. The river Bhaga originates at about 4819m from the south face of Baralacha Pass in Himalayan canton of Lahaul &Spiti valley. It merges with the river Chandra at Tandi about 6 km. south of Keylong. The course of river Bhaga is very steep; an average of about 25 m per km. the length of the Bhaga upto confluence point is about 80 km. Its longitude is $76^0 58' 33''$ and latitude is $32^0 33' 00''$. Its catchment area upto site is 1530 Sq. Km. Its average height of the banks is 6 mts. at the right & 5 mts at the left. Its nature of bed is rocky. It is the first originating water quality site on the Chenab Basin.

2. **UDAIPUR:**Udaipur is a gauge, discharge, silt & water quality site situated on the stream Chandrabhaga near the confluence point of stream Miyar-nallah & Chandrabhaga in the district Keylong in the Lahaul and Spiti valley in the Himachal Pradesh state. Its longitude is 76^0 $40' 03''$ and latitude is 32^0 $43' 00''$ N. Its catchment area upto site is about 5764 sq. kms. Its average height of banks is 5 mts at the right and left banks. Its nature of bed is rocky. The course of the stream is very steep. It is approximately 48 kms away downstream of nearest water quality site Tandi.

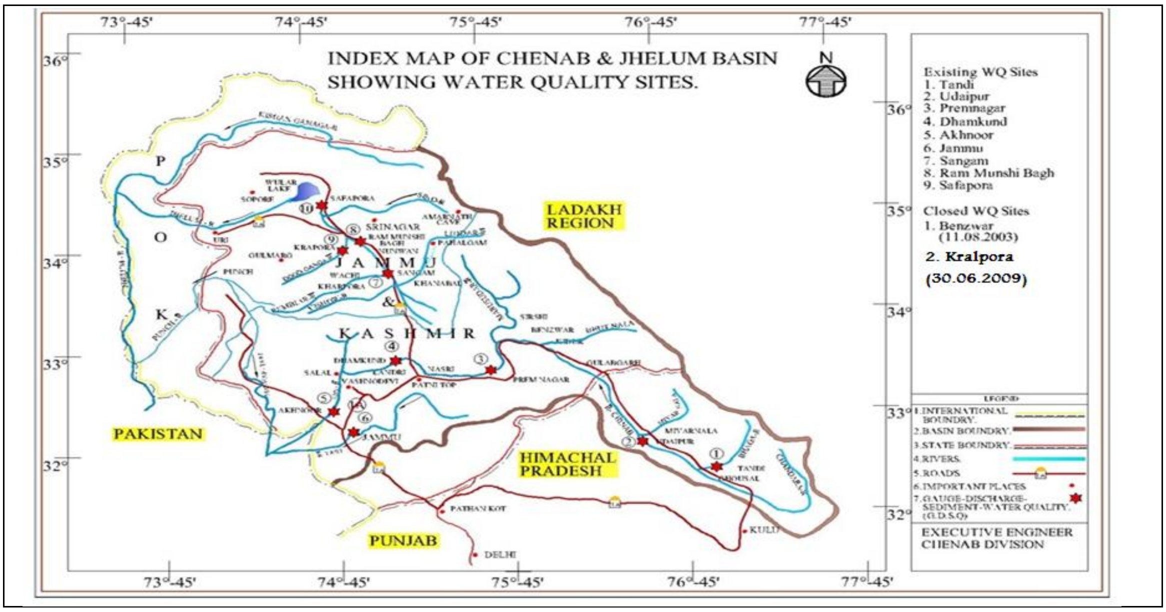
3. **PREMNAGAR:** Premnagar is a gauge, discharge, silt and water quality site situated on the stream Chenab in district Doda in the Jammu & Kashmir state. Its longitude is 75^0 $42^{'}12.75^{''}$E and latitude is 33^0 $09^{'}19.52^{''}$ N. Its catchment area upto site is about 15490 sq. kms. Its average heights of banks are 10 mts. at the right and 11 mts. at the left. Its nature of bed is rocky. The course of stream is steep. It has a small town Premnagar just 3 kms downstream of the site and also a small town Thathri just 13 kms. U/s of the site.

4. **DHAMKUND:** Dhamkund is a gauge, discharge, silt and water quality site situated on the stream Chenab in the district Doda in the Jammu and Kashmir state. Its longitude is $75^0 08^{'}45^{''}$ and latitude is $33^0 14^{'}35^{''}$.Its catchment area is about 18750 sq.kms.Its average heights of banks are 8 Mts at the right and 10 mts at the left. Its nature of bed is rocky. The course of the stream is steep. It is approximately 59 kms upstream of the Akhnoor.

5. **AKHNOOR:** Akhnoor is a gauge, discharge, silt & water quality site situated on the stream Chenab in district Jammu in the Jammu & Kashmir state. Its longitude is $74^0 45^{'}32.21^{''}$ and latitude is $32^0 54^{'}02.93^{''}$. Its catchment area upto site is about 21808 sq. km. Its average height of banks is 20 mts at the right and 15 Mts. at left banks. Its nature of bed is rocky. The course of the stream is very steep.

6. **JAMMU TAWI:** Jammu Tawi site is shifted on 20th June 2014 from its previous location near Bikram Chowk(Jammu City) to new location at Sidhra which is about 5kms upstream (due to proposal of construction of an artificial lake by J&K Govt.). Sidhra is a gauge, discharge, silt & water quality site situated on the River Tawi. It is a tributary of river Chenab, which merge with river Chenab in Pakistan. Its longitude is $74°53^{'}03.93^{''}$ and latitude is $32°$ $45^{'}46.34^{''}$. Its catchment area is about 2168 sq. km. Its length from the start point is about 135 kms. Its average height of banks is 10 mts at the right and 8 mts. at left banks. Its nature of bed is sandy. The course of the stream is steep in upper reach and normal in lower reach. It has major city Jammu on its bank, which is also known as city of temples. It is an industrial city, but it has no major industry on its banks, whose waste may enter into the stream. It has main sewer drainage on its right bank 4km. downstream of water quality site.

Sample Code	Name of the Station	River/ Tributary	State	District	Description of the location
S_1	Tandi	Chenab	Himachal Pradesh	Keylong	Confluence of Chandra and Bhaga
S_2	Udaipur	-do-	-do-	-do-	Confluence point of Miyar-Nallah and Chandrabhaga
S_3	Premnagar	-do-	J&K	Ramban	3 kms away from Premnagar town.
S_4	Dhamkund	-do-	-do-	Doda	59 kms D/S of Premnagar
S_5	Akhnoor	-do-	-do-	Jammu	97 kms D/S of Dhamkund
S_6	Jammu Tawi	Chenab/Tawi	-do-	Jammu	About 5 km upstream of Jammu City



III. Materials And Methods:

Water samples were collected every month, from January 2019 to Dec 2019 from six different stations as mentioned in the above table, in clean and dry polythene bottles. The water samples were collected and preserved for testing of various parameters at 10^{o} C throughout the period of chemical analysis. The water samples were analysed in the Indus Basin River Water Quality Laboratory, Chenab Division, Jammu using standard methods (APHA 23^{rd} Edition). The pH, Conductivity and Dissolved Oxygen of water samples were measured immediately after sampling at the field itself. Samples were subjected to filtration before chemical analysis. The analysis of calcium and magnesium was carried out by EDTA complex metric titration method (APHA 23^{rd} Edition).The Winkler's alkali iodide-azide method was followed for the estimation of DO and BOD.

IV. Results And Discussion

Temperature is an important factor to influence the physico-chemical parameters and the biological reaction in water. Higher values of temperature accelerate the chemical reaction and reduce the solubility of gases and DO. In the present study temperature varied from 2^{o}C to 27^{o}C.

pH LEVEL: The pH of most raw water sources lies within the range of 6.5-8.5. All the water samples analysed during the study period are found to have pH value well within the tolerance limit. The pH values across the river ranges from 8.6 at Jammu Tawi to 6.2 at Premnagar. The last 10 years maximum and minimum recorded values are 8.9 at Jammu Tawi and 5.6 at Tandi.

ELECTRICAL CONDUCTIVITY: Pure water is a poor conductor of electricity. Presence of acids, bases and salts in water make it relatively good conductor of electricity. With increased air pollution, the acid rain also adds to the conductivity of surface water. Greater is the conductivity greater an-ions and cat-ions in the water and greater is the dissolved matter (electrolyte) in it. Electrical conductivity is used as a basic index in judging the suitability of water for potable properties. Present studies revealed that all the samples recorded conductivity values well within the tolerance limit prescribed by ICMR and WHO. Jammu Tawi recorded the highest conductivity value 290 μ mho/cm. The minimum conductivity value of 109 μ mho/cm is recorded at Dhamkund.

The last 10 years maximum and minimum recorded values are 525 μ mho/cm at Jammu Tawi and 40 μ mho/cm at Udaipur. Tolerance limit for conductivity in drinking water is 2300 μ mho/cm.

CALCIUM AND MAGNESIUM: Hardness of water is the traditional measure of capacity of water to react with soap, hard water requiring a considerable amount of soap to produce lather. Scaling of hot water pipes, boilers and other household appliances is due to hard water. In fresh water, the principal hardness causing ions are calcium and magnesium; the ions strontium, iron, barium and manganese also contribute to some extent. It is expressed as an equivalent concentration of calcium carbonate. The permissible limit of hardness as calcium carbonate is 300 mg/l. Our investigation shows all the water samples are much below the permissible limit. The total hardness is considered taking presence of calcium and magnesium ion in water samples. Its permissible limit is 75 to 200 mg/l. Maximum value for calcium was recorded 55.2 mg/l at Jammu Tawi and minimum value 4.0 mg/l at Dhamkund against the last 10 years maximum and minimum values of 68.0 mg/l at Jammu and Tawi and 3.0 mg/l at Dhamkund. Similarly for magnesium the maximum and minimum recorded values during the year are 18.5 mg/l at Jammu Tawi and 1.9 mg/l at Akhnoor against the last 10 years maximum minimum values 38.0 mg/l at Akhnoor and 0.5 mg/l at Premnagar respectively.

TOTAL ALKALINITY: Alkalinity is not a pollutant. It is a total measure of the substances in water that have acid neutralizing capacity. Alkalinity indicates the power of a solution to react with acid and buffer its pH, that is the power to restrict its pH from changing. It is due to salts of weak acids and bicarbonates and is estimated in terms of an equivalent amount of calcium carbonate. No permissive and excessive values of total alkalinity are given by WHO, ISI and ICMR.[6] But according to USPHS, the value of total alkalinity as $CaCO_3$ is 120 mg/l. The average value of bicarbonate alkalinity in the different sources of water samples of the present observation ranges from 224.5 mg/l at Jammu Tawi to 5.5 mg/l at Akhnoor against the last ten years maximum minimum range of 295.2 mg/l at Jammu Tawi to 5.5 mg/l at Akhnoor . The minimum alkalinity value is recorded at Akhnoor whereas the maximum value is at Jammu Tawi indicating that the water having higher alkalinity value has better buffering capacity is important for fish and aquatic life. It is also less vulnerable to acid rain. The alkalinity has no known adverse effect on health; some evidence has been given to indicate its effect in causing heart disease.

SODIUM AND POTASSIUM: Sodium is the chief cat-ion in the extra cellular fluid. About 50% of body sodium is present in the bone, 40% in the extra cellular fluid and the remaining (10%) in the soft tissues whereas potassium is the principal intracellular cat-ion. It is equally important in the extra cellular fluid for specific function such as influencing cardiac muscle activity. According to European Economic Community the limit for sodium is 200mg/l and for potassium is 10mg/l of drinking water. The study reveals the mean value of sodium and potassium content in the water samples are well within the permissible limit along the entire stretch of Chenab River Basin. The maximum and minimum recorded values for sodium during the study period are 11.2 mg/l at Dhamkund and 0.4 mg/l at Premnagar against the last ten years maximum minimum values of 11.2 mg/l at Dhamkund and 0.4 mg/l at Premnagar. Similarly for potassium the range during the study period is 3.4 mg/l at Premnagar to 0.2 mg/l at Akhnoor against the last ten years range of 3.4mg/l at Premnagar to 0.1 mg/l at Premnagar, Dhamkund and Akhnoor.

CHLORIDE: Chloride (Cl^-) ion is one of the major inorganic anions in water and wastewater. Chloride occurs naturally in all types of water. The salty taste produced by chloride concentrations is variable and dependent on the chemical composition of water. The presence of chloride in river water can be attributed to the dissolution of salts in soil, discharge of effluents from chemical industries, sewage discharge, irrigation drainage, contamination from refuse leachates and sea water intrusion in coastal areas. Each of these sources results in local contamination of river water. Chloride concentration is an indicator of sewage pollution in fresh water region. The most important source of chlorides in the waters is the discharge of domestic sewage. Man and other animals excrete very high quantities of chlorides together with nitrogenous compounds. About 8-15 grams of NaCl is excreted by a person per day. Therefore, the chloride concentration serves as an indicator of pollution by sewage. The tolerance limit for chloride is 250 mg/l. In the present study all the samples had chloride concentration below tolerance limit. The values range from 147.0 mg/l at Akhnoor to 1.9 mg/l at Tandi against the last ten years range of 147.0mg/l at Akhnoor to 1.0 mg/l at Premnagar.

SULFATE: The element sulfur exists in various oxidation states ranging from S^{2-} to S^{6+}. The reduced ion, S^{2-}, forms sulphides of low solubility with most metals. Because iron is common and widely distributed, the iron sulfides have a substantial influence on sulfur geochemistry. Sulfur is widely distributed in reduced from in both igneous and sedimentary rocks as metallic sulfides. When sulphide minerals undergo weathering in contact with aerated water, the sulfur is oxidized to yield sulphate ions that go into solution in the water. The concentration of sulfate in most freshwaters is very low. Sulfuric acid is formed when air and water react with sulfur bearing minerals like pyrites. Sulfates are discharged into the aquatic environment in the wastes from many different industries. Atmospheric sulfur dioxide (SO_2), formed by the combustion of fossil fuels and emitted by the metallurgical roasting processes, may also contribute to the sulfate content of surface water. Sulfur trioxide (SO_3), produced by the photolytic or catalytic oxidation of sulphur dioxide, combines with water vapour to form sulfuric acid, which is precipitated as "acid rain" . Aluminium sulfate, which is extensively used as a flocculant for water treatment, may also add to the sulfate content. The tolerance limit for sulphate is 400 mg/l. In the present study all the analysed samples shown sulphate concentration well within tolerance limit. The maximum minimum range in the Chenab River basin for sulphate is 67.3 mg/l at Tandi to 1.1 mg/l at Jammu Tawi against the last ten years maximum minimum range of 191.0 mg/l at Akhnoor to 1.1 mg/l at Jammu Tawi.

DISSOLVED OXYGEN: Dissolved oxygen is one of the most important parameters of water quality assessment which shows metabolic balance and reflects the physical & biological processes prevailing in the water. A high DO level in a river water sample is good because it makes the water better from drinking as well bathing point of view and friendly for aquatic lives. However, high DO levels speed up corrosion in water pipes. For diverse fish population the DO level must ranges from 4-9 mg/l. The river water of Chenab River Basin is good fishing water. However, according to Europian Economic Community the standard value of DO is 5mg/l of drinking water. The DO values of water samples during the study ranges from 6.3 mg/l at Dhamkund and Akhnoor to 10.5 mg/l at Akhnoor against the last ten years range of 12.9 mg/l at Dhamkund to 1.2mg/l at Jammu Tawi.

BIOCHEMICAL OXYGEN DEMAND: The degree of microbial mediated oxygen consumption in water is known as biochemical oxygen demand. This parameter is commonly measured by the quantity of oxygen utilized by suitable micro-organisms during 5 days period at $20^{o}C$. It is not a pollutant but an indicator to what extent the water is polluted. Its value 6.0 mg/l or more in water body is said to be polluted. Present study reveals the value of BOD in the Chenab River Basin ranges from 0.1 mg/l to 2.4 mg/l both at Akhnoor which is well within the tolerance limit. The last ten years range is 0.1 mg/l to 3.3 mg/l

V. Conclusion

The present study reveals that the water quality of Chenab River Basin is quite safe as compared to the physico-chemical parameters point of view at present. However due to increased industrial and human activities along its bank in future a constant monitoring of the water quality of the river is a must to maintain the river water quality.

VI. Applications

The present study is useful in ascertaining the water quality of Chenab River Basin along its entire stretch for its potability for industrial, agricultural and human use.

VII. References

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Table:1

Name of the Sampling Station	pH					Conductivity in µ mho/cm				
	Current Year Study			Last 10 years		Current Year Study			Last 10 years	
	Max	Min	Mean	Max	Min	Max	Min	Mean	Max	Min
Tandi	7.6	6.6	7.2	8.5	5.6	132	120	125	264	100
Udaipur	7.9	6.2	6.9	8.5	6.1	134	78.3	110	300	40
Premnagar	8.5	6.2	7.2	8.5	6.0	224	111	182	370	47
Dhamkund	8.2	6.3	7.1	8.2	6.3	259	109	186	298	109
Akhnoor	8.2	6.5	7.4	8.7	6.5	227	125	162	310	120
Jammu Tawi	8.6	6.8	7.7	8.9	6.8	290	203	242	525	123

Table:2

Name of the Sampling Station	D.O in mg/l					B.O.D.in mg/l				
	Current Year Study			Last 10 years		Current Year Study			Last 10 years	
	Max	Min	Mean	Max	Min	Max	Min	Mean	Max	Min
Tandi	6.6	6.3	6.4	9.8	4.9	-	-	-	-	-
Udaipur	9.8	7.4	6.4	10.2	5.1	-	-	-	-	-
Premnagar	9.2	7.2	8.3	12.9	3.6	-	-	-	-	-
Dhamkund	8.5	6.3	7.4	12.7	5.0	-	-	-	-	-
Akhnoor	10.5	6.3	8.0	12.5	5.8	2.4	0.1	0.9	3.3	0.1
Jammu Tawi	9.8	5.8	7.5	12.1	1.2	2.2	0.2	1.2	1.2	0.2

Table:3

Name of the Sampling Station	Calcium					Magnessium				
	Current Year Study			Last 10 years		Current Year Study			Last 10 years	
	Max	Min	Mean	Max	Min	Max	Min	Mean	Max	Min
Tandi	36.0	14.4	19.8	37.6	13.0	8.8	1.9	5.0	17.5	1.9
Udaipur	37.6	11.2	15.2	46.2	11.2	11.2	1.9	5.0	24.3	0.1
Premnagar	48.0	8.0	23.6	48.0	8.0	10.7	2.4	6.9	18.5	0.5
Dhamkund	37.6	4.0	25.0	48.0	3.0	15.1	2.7	4.4	15.1	1.0
Akhnoor	46.4	11.2	25.0	54.8	9.2	10.7	1.9	5.0	38.0	1.8
Jammu Tawi	55.2	12.0	34.0	68.0	12.0	18.5	3.4	9.6	29.5	1.0

Table:4

Name of the Sampling Station	Carbonate					Bicarbonate				
	Current Year Study			Last 10 years		Current Year Study			Last 10 years	
	Max	Min	Mean	Max	Min	Max	Min	Mean	Max	Min
Tandi	0.0	0.0	0.0	0.0	0.0	67.3	2.2	16.05	134.2	0.2
Udaipur	0.0	0.0	0.0	0.0	0.0	141.5	43.9	69.0	158.6	23.0
Premnagar	0.0	0.0	0.0	0.0	0.0	122.0	31.7	68.0	122.0	25.0
Dhamkund	0.0	0.0	0.0	0.0	0.0	146.4	51.2	82.8	146.4	27.5
Akhnoor	0.0	0.0	0.0	6.5	0.0	114.7	5.5	71.4	126.9	5.5
Jammu Tawi	2.4	0.4	1.4	9.4	0.0	224.5	46.4	120.9	295.2	46.4

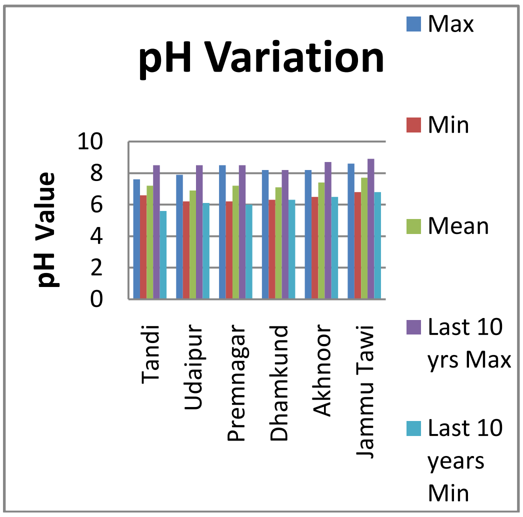
Table:5

Name of the Sampling Station	Chloride in mg/l					Sulphate in mg/l				
	Current Year Study			Last 10 years		Current Year Study			Last 10 years	
	Max	Min	Mean	Max	Min	Max	Min	Mean	Max	Min
Tandi	20.1	1.9	6.9	20.1	1.9	67.3	2.2	16.1	90.8	0.2
Udaipur	22.1	7.0	10.9	22.1	4.1	52.8	2.2	16.1	58.6	2.2
Premnagar	21.1	4.0	14.3	27.8	1.0	43.0	6.3	26.0	90.3	3.4
Dhamkund	37.2	7.0	17.4	44.4	4.3	48.4	7.0	28.2	87.1	2.4
Akhnoor	147.0	8.0	32.9	147.0	5.4	44.5	2.3	21.2	191.0	2.3
Jammu Tawi	43.3	8.1	19.2	43.3	8.1	20.2	1.1	8.1	38.8	1.1

Table:6

Name of the Sampling Station	Sodium in mg/l					Potassium in mg/l				
	Current Year Study			Last 10 years		Current Year Study			Last 10 years	
	Max	Min	Mean	Max	Min	Max	Min	Mean	Max	Min
Tandi	4.7	0.8	2.5	9.1	0.8	1.8	1.3	1.6	2.8	0.1
Udaipur	5.5	1.0	2.8	9.5	1.0	2.0	1.6	1.8	3.3	0.2
Premnagar	9.2	0.4	4.4	9.2	0.4	3.4	0.5	2.1	3.4	0.1
Dhamkund	11.2	0.8	4.5	11.2	0.8	2.3	0.9	1.7	2.8	0.1
Akhnoor	8.9	0.8	3.9	8.9	0.8	2.5	0.2	1.5	2.6	0.1
Jammu Tawi	9.7	4.0	6.4	20.0	0.2	2.1	1.2	1.6	4.7	0.3

Figure-1:



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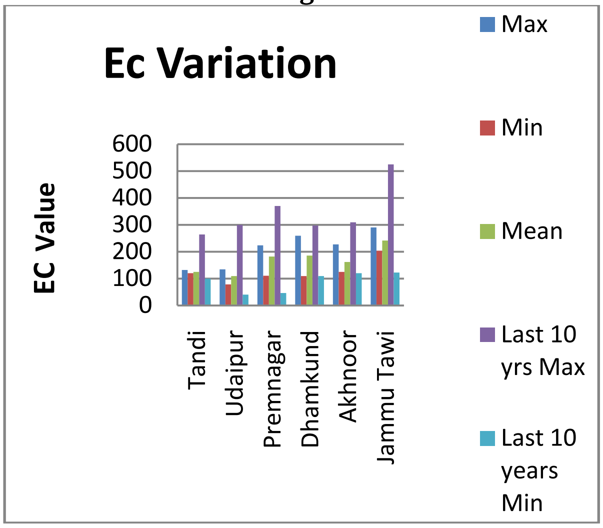

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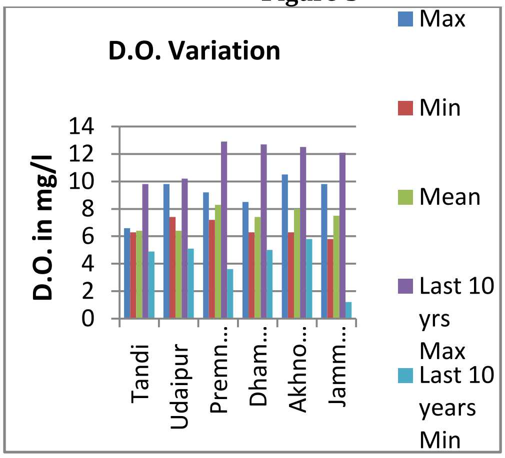

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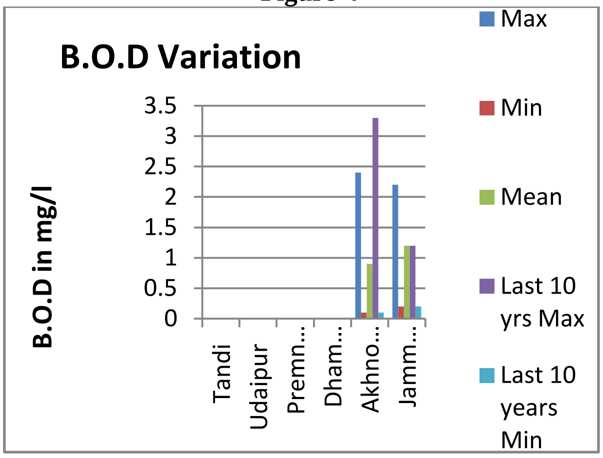

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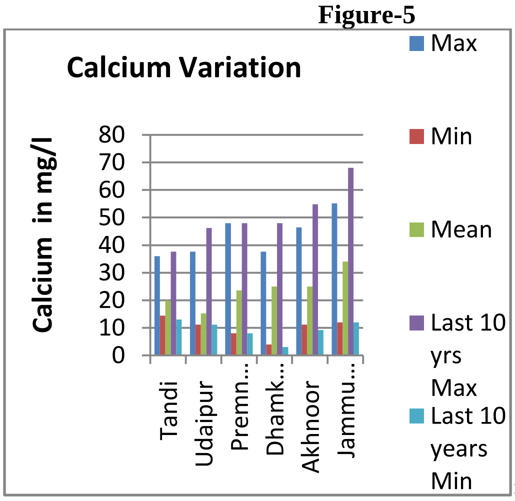

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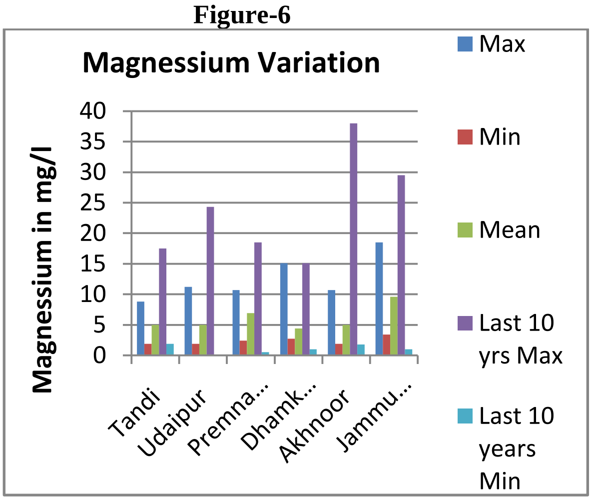

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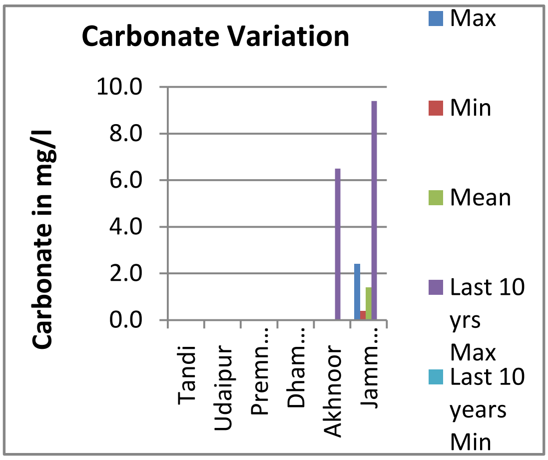

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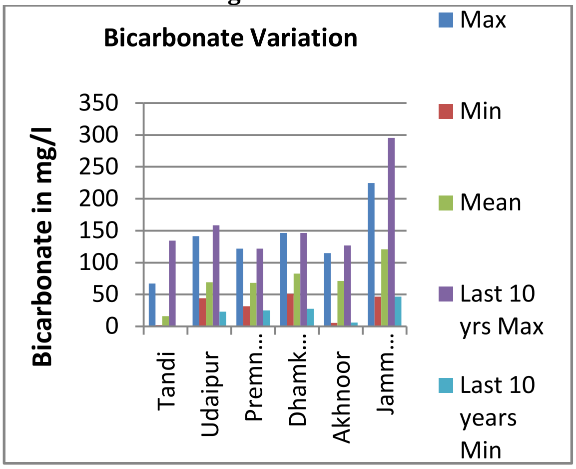

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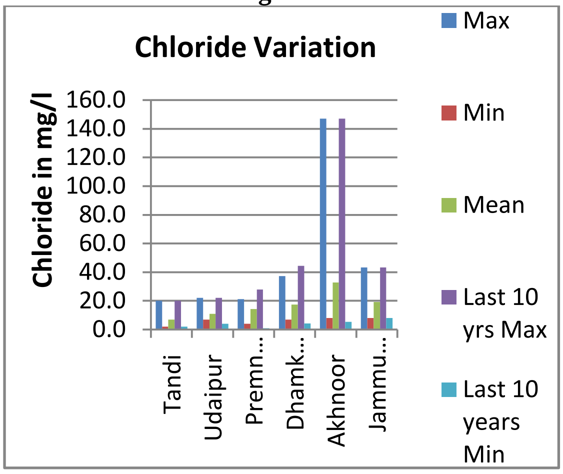

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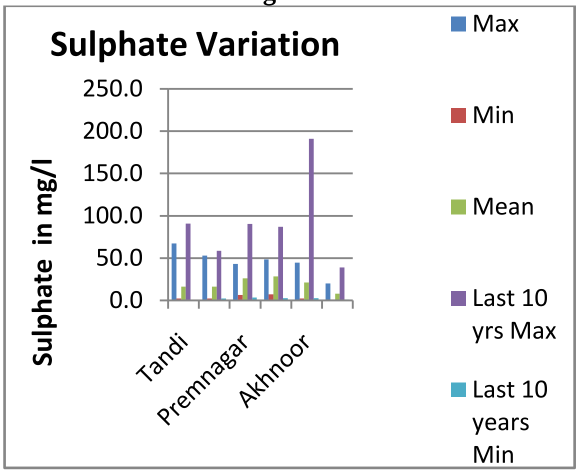

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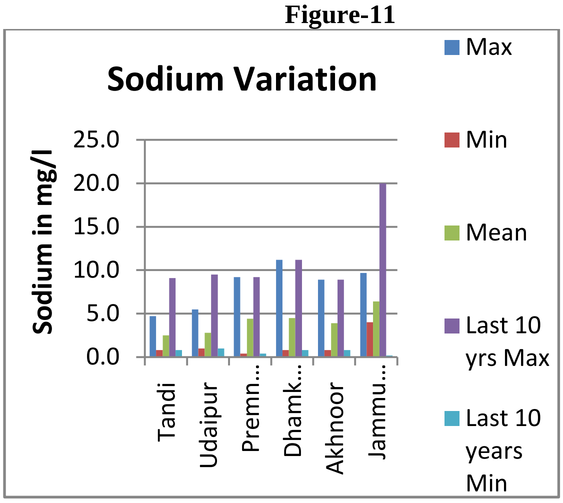

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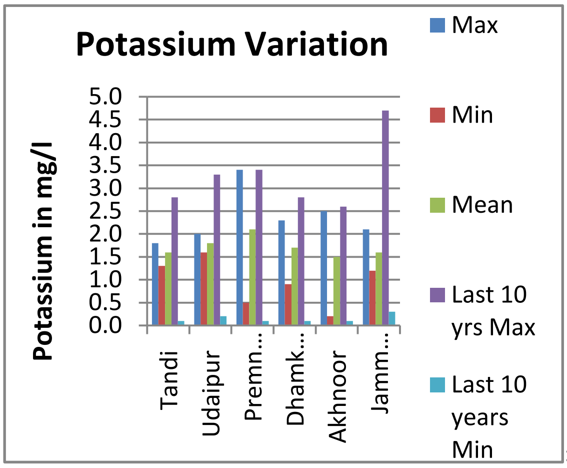

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STUDY OF LONGITUDINAL VARIATION OF WATER QUALITY IN RIVER GHAGHRA IN THE YEAR 2018-19

MIDDLE GANGA DIVISION-1

CENTRAL WATER COMMISSION, LUCKNOW

Prepared by:

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3. Rajat Sharma, Senior Research Assistant

Introduction

Surface water resources in India have a significant role in the existence of human beings, flora and fauna in the region. They are vitally important in our everyday life. The main uses of surface water include usage as drinking-water, other public uses such as bathing and various indoor and outdoor activities, irrigation uses, cattle breeding, various uses in the industries etc. Because of all these uses, especially for drinking and irrigation purposes, it is important to assess and monitor the quality of surface water, mainly rivers as they are the major source of surface water in our country. CWC is the national 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 water quality monitoring stations on various rivers of India for monitoring of 6 in situ parameters, Level-II laboratories for the analysis of 25 physico-chemical plus bacteriological parameters and Level-III/II+ laboratories for the analysis of 41 parameters including heavy metals / toxic parameters and pesticides.

The river Ghaghra is one of the major tributaries of Ganga. It rises in the southern slopes of the Himalayas in Tibet, in the glaciers of Mapchachungo. The river flows south through Nepal as the Karnali river, joins the Sharda river at Brahmaghat in India and form the Ghaghra proper. The total length of Ghaghra river up to its confluence with the Ganga at Revelganj in Bihar is 1,080 kilometres. It is the largest tributary of Ganga by volume and the second longest tributary of the Ganga by length after Yamuna. Being perennial in nature Ghaghra forms a significant role in the day to day activities of the organisms in the basin. The main tributaries of Ghaghra are Sharda, Rapti, Kwano and Sarju.

Study area

River Ghaghra is the major river under the jurisdiction of Middle Ganga Division –I, Lucknow. Middle Ganga Division-I, Lucknow has established a network of 13 water quality monitoring stations under its jurisdiction. The monitoring of surface water is done on monthly basis. Water samples are analysed for physio-chemical and biological parameters apart from the field observations. The samples from the sites are collected as per the guidelines of CWC and analysed in the Middle Ganga Divisional Laboratory situated at MGD-I, Lucknow. The laboratory is of Level II and analyses 25 physico-chemical and bacteriological parameters of river water as per the Standard Methods for the Examination of Water and Wastewater, APHA, 23rd edition.

This division is monitoring the water quality of Ghaghra at 3 sites namely Elginbridge, Ayodhya and Turtipar. All these sites are in the state of Uttar Pradesh. Elginbridge situates at the upstream of the river and is just down to the confluence of river Sharda with Ghaghra. Ayodhya and Turtipar are situated downstream to Elginbridge. All the three sites are situated in the right bank of the Ghaghra. Elginbridge is Trend station i.e. samples are collected once in every month. Ayodhya and Turtipar are flux stations.i.e. Samples are collected thrice (on 1st, 11th and 21st) in a month.

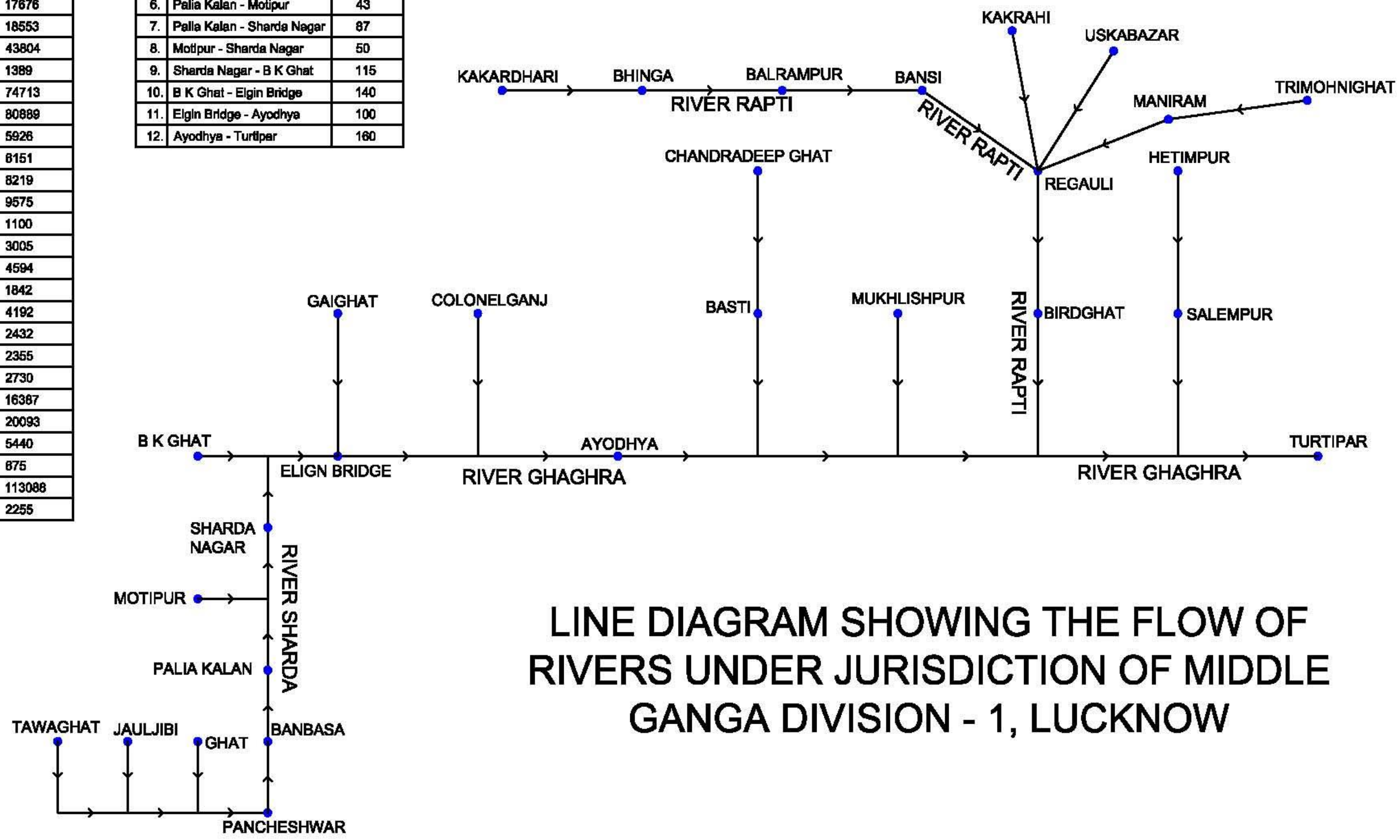
S.no	Station name (U/S to D/S)	Date of starting WQ analysis (dd/mm/yyyy)	District	Type of station	Frequency	Latitude	Longitude	Catchment area(sq.km)
1	Elginbridge	13/01/1964	Barabanki	GDSQ	Once in a month (trend)	27°05'05"	81°29'29"	74713
2	Ayodhya	12/1/1977	Faizabad	GDSQ	Thrice in a month (flux)	26°48'67"	82°12'44"	80889
3	Turtipar	10/3/1963	Ballia	GDSQ	Thrice in a month (flux)	26°10'10"	83°53'53"	113088

Table 1: Details of the Sites in River Ghaghra

Ayodhya is a major site which is famous both historically and as one of the major tourist/pilgrimage destination of India. This study is based on the analysis results of three sites under MGD-I for the water year (June-May) 2018-19 and aims to compare the variation in quality of the water along the length.ie; from upstream to downstream of the river Ghaghra. The analysis results of the samples collected on the first of every month are considered here.

SL. NO.	SITE	CATCHMENT AREA (Sq Km)
1.	Tawaghat	1225
2.	Jauljibi	2150
3.	Ghat	3900
4.	Pancheswar	12293
5.	Banbasa	15820
6.	Palia Kalan	17676
7.	Sharda Nagar	18553
8.	B K Ghat	43804
9.	Motipur	1389
10.	Elgin Bridge	74713
11.	Ayodhya	80889
12.	Kakardhari	5926
13.	Bhinga	8151
14.	Balrampur	8219
15.	Bansi	9575
16.	Chandradeepghat	1100
17.	Basti	3005
18.	Gaighat	4594
19.	Colonelganj	1842
20.	Kakrahi	4192
21.	Uskabazar	2432
22.	Trimohinighat	2355
23.	Maniram	2730
24.	Regauli	16367
25.	Birdghat	20093
26.	Mukhlishpur	5440
27.	Hetimpur	875
28.	Turtipar	113088
29.	Salempur	2255

SL. NO.	SITE DESCRIPTION (From - To)	DISTANCE (Km)
1.	Tawaghat - Jauljibi	50
2.	Jauljibi - Ghat	217
3.	Ghat - Pancheswar	85
4.	Pancheswar - Banbasa	155
5.	Banbasa - Palia Kalan	155
6.	Palia Kalan - Motipur	43
7.	Palia Kalan - Sharda Nagar	87
8.	Motipur - Sharda Nagar	50
9.	Sharda Nagar - B K Ghat	115
10.	B K Ghat - Elgin Bridge	140
11.	Elgin Bridge - Ayodhya	100
12.	Ayodhya - Turtipar	160



LINE DIAGRAM SHOWING THE FLOW OF RIVERS UNDER JURISDICTION OF MIDDLE GANGA DIVISION - 1, LUCKNOW

1. pH

pH is one of the most important parameter monitored in water quality. It is the negative logarithm of hydrogen ion concentration. In natural waters pH normally ranges from 4 to 9 and is contributed mainly by the carbonates and bicarbonates of alkali and alkaline earth metals. All the samples are found to be slightly alkaline in nature with a range of 7.8 to 8.3 during the study period. The maximum pH value for each site is observed in the winter season, during the months of november, december January and february. At Elginbridge, the pH varied from a minimum of 7.8 in july to maximum of 8.3 in november with an average of 8.0. Ayodhya ranged from 7.8 to 8.3 with an average of 8.0. The pH values for Ayodhya is found be constant (7.8) during march to may of 2019. With a range of 7.9 to 8.3 of pH value, Turtipar records an average of 8.1.

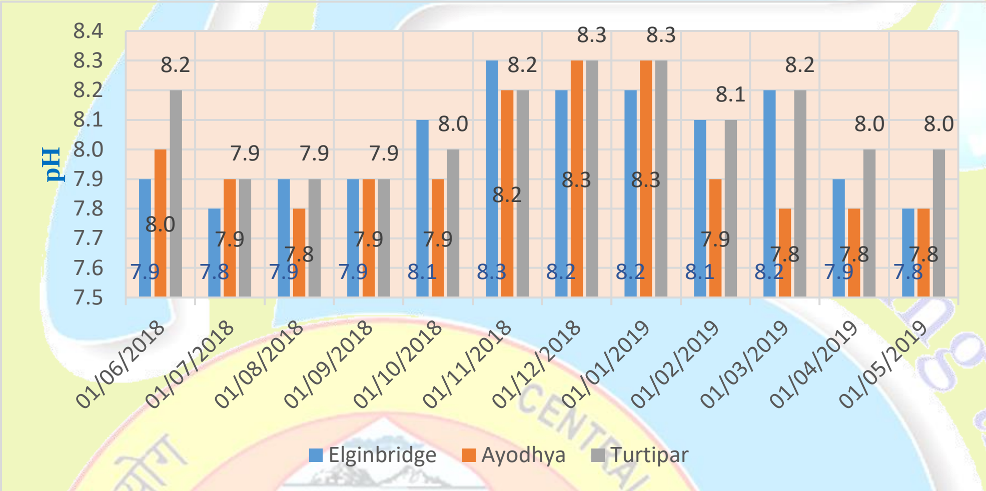
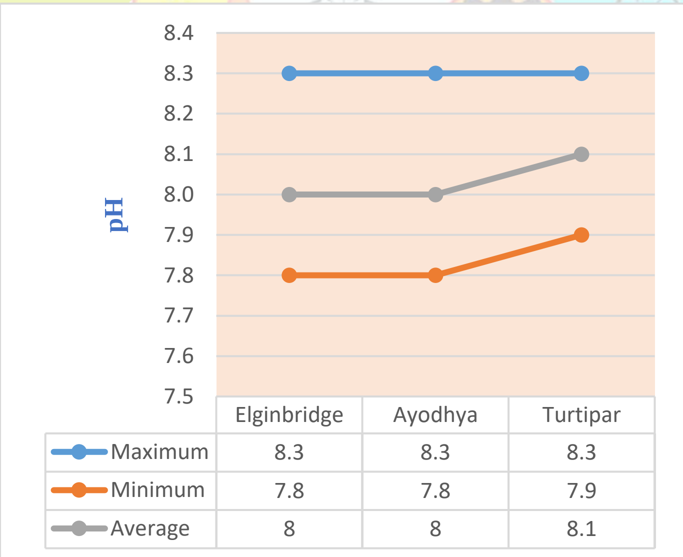


Fig.2: pH Values observed for the Year 2018-19



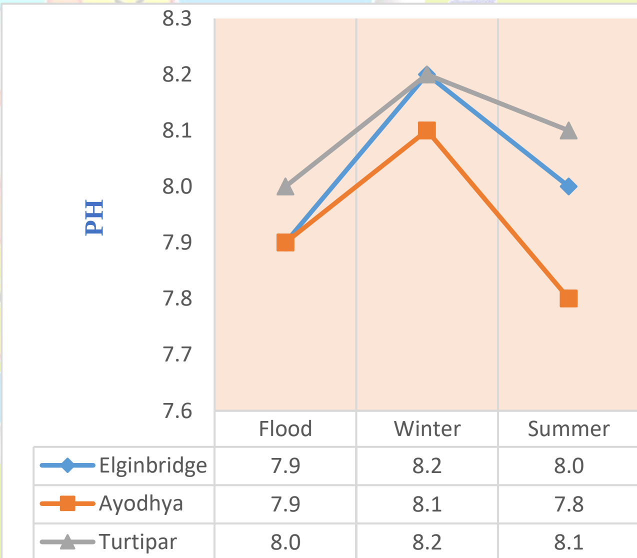


Fig.3: Variation of pH observed for the Year 2018-19

Fig4: Seasonal variation of pH for the Year 2018-19

2. Electrical Conductivity (EC)

It is a measure of the ability of water to conduct electricity. In natural water, EC is contributed by the cations and anions which are formed by the dissociation of various salts in water. EC gives a rough idea about the nature/ pollution level of water. It is expressed in µmhos/cm or µS/cm at 25°C. The EC is measured in the laboratory using digital EC-TDS meter.

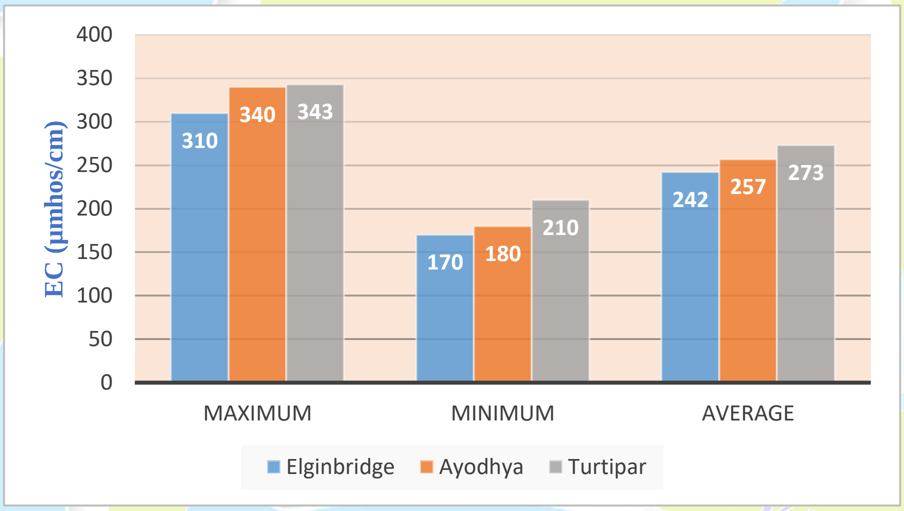


Fig.5: EC Values Observed for the Year 2018-19

The EC value increases from upstream to downstream. The same trend is seen in the annual maximum, minimum and average readings as well as seasonal variation of the parameter. Elginbridge has the minimum observed average of 242µmhos/cm, it increases to 257 µmhos/cm for Ayodhya and 273 µmhos/cm at Turtipar. For all the three sites, the maximum values of EC have been recorded in the winter season (November-February) with a maximum average of 312 µmhos/cm observed at Turtipar while the flood season(june-october) bears the minimum values of EC observed.

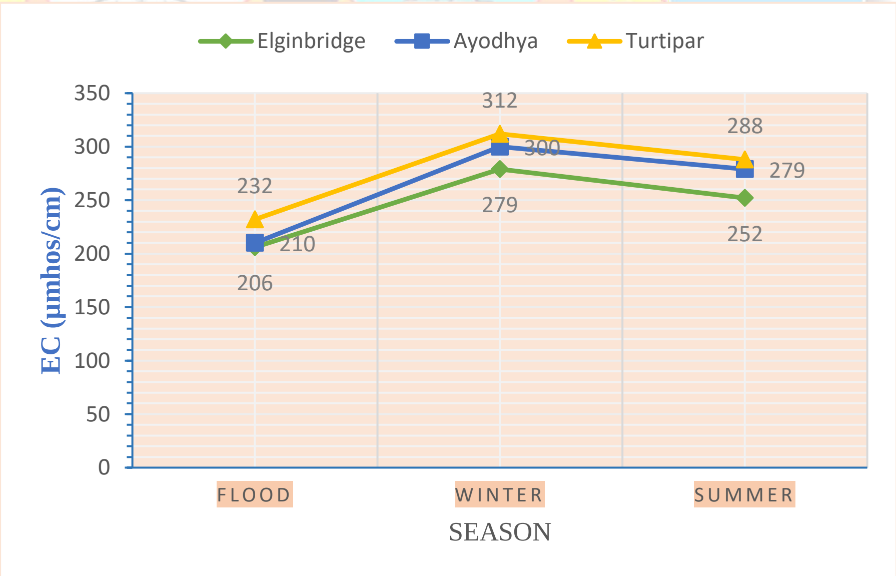


Fig.6: Seasonal variation of EC

3. **Total Dissolved Solids (TDS)**

Total dissolved solids consist of inorganic salts, small amount of organic matter and dissolved materials. The higher concentration of TDS imparts a peculiar taste to water and reduce its potability. Water with TDS values greater than 500 mg/L is not recommended for drinking.

Site Name (From U/S to D/S)	Annual Average		
	Since inception	Past 10 year	2018-19
Elginbridge	169	154	142
Ayodhya	162	158	149
Turtipar	169	166	161

Table 2: Annual average of TDS

The TDS ranged from 102-186 mg/L at Elginbridge, 104-205 mg/L at Ayodhya and 125-195 mg/L at Turtipar. These values are below the permissible limit of drinking water as per IS 10500:2012 by BIS. The annual average of TDS values in the sites of Ghaghra are found to be lesser than the average of last 10 years as well as the average of values since inception.

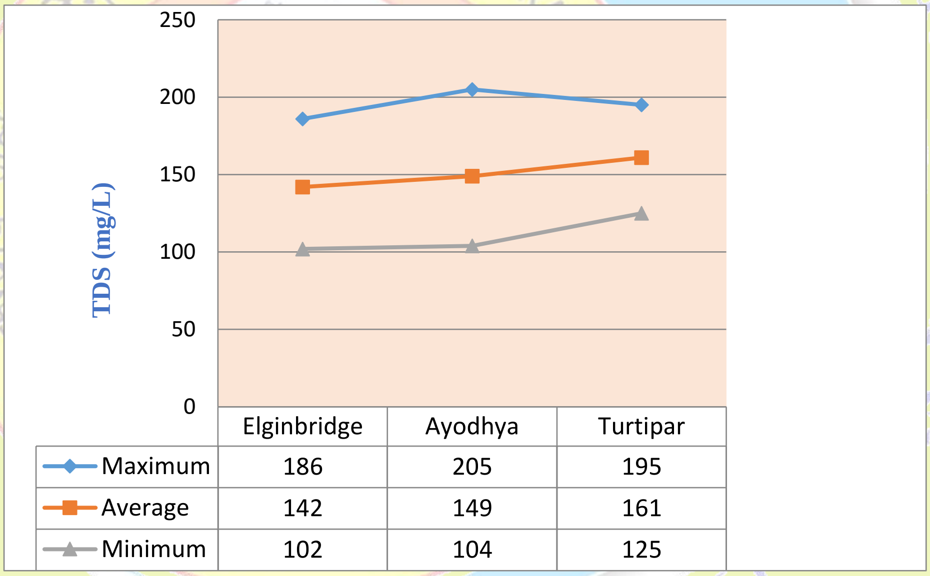
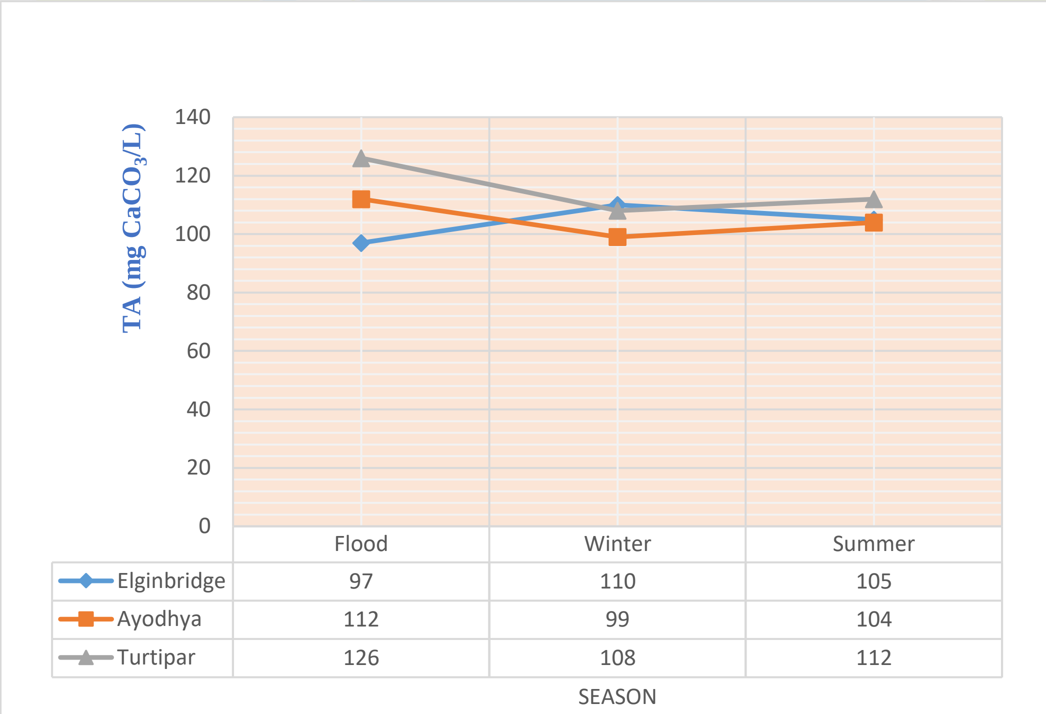


Fig.7: Annual variation of TDS for 2018-19

4. Total Alkalinity (TA)

The alkalinity is a measure of the acid neutralizing capacity of water. In most natural waters bicarbonates and sometimes carbonates are present in appreciable amounts. Their salts get hydrolyzed in solution and produce hydroxyl ions, consequently raising the pH. In the laboratory, TA was estimated by titration method.

During the period of study, carbonate concentration in all the sites of Ghaghra river is observed to be zero. Only the bicarbonate ions account for the total alkalinity of water. The



	Flood	Winter	Summer
Elginbridge	97	110	105
Ayodhya	112	99	104
Turtipar	126	108	112

Fig.8: Seasonal variation of TA

TA (as mg $CaCO_3$/L) value of Elginbridge varies from 88 to 116 with an average of 104 mg $CaCO_3$/L. the maximum value was observed in the month of February, 2019. With a range of 96-138 mg $CaCO_3$/L Ayodhya has an average TA of 106 mg $CaCO_3$/L. Turtipar has recorded a range of 96-155 mg $CaCO_3$/L with a comparatively higher average of 116 mg $CaCO_3$/L. It is also to be noted that the maximum values for the sites Ayodhya and Turtipar were observed during the beginning of flood season.ie; in june, 2018.

5. Total Hardness, Calcium and Magnesium

Calcium and magnesium ions have a major role in the composition of surface water. They form corresponding carbonates, bicarbonates and sulphates and thus contribute towards the total hardness of water. Most of the water samples analysed were found to be hard in nature but do not exceed the permissible limits for drinking or indoor/outdoor usages. The maximum value of TH is 161 mg $CaCO_3$/L observed in june, 2018, maximum of calcium is 34 mg/L in april, 2019 and that of magnesium is 19.2 mg/L estimated in june, 2018 with all the maximum values recorded at Turtipar. The annual average total hardness has an increasing trend from upstream towards the downstream. The calcium and magnesium ions show an increasing trend from flood via winter to the summer season.

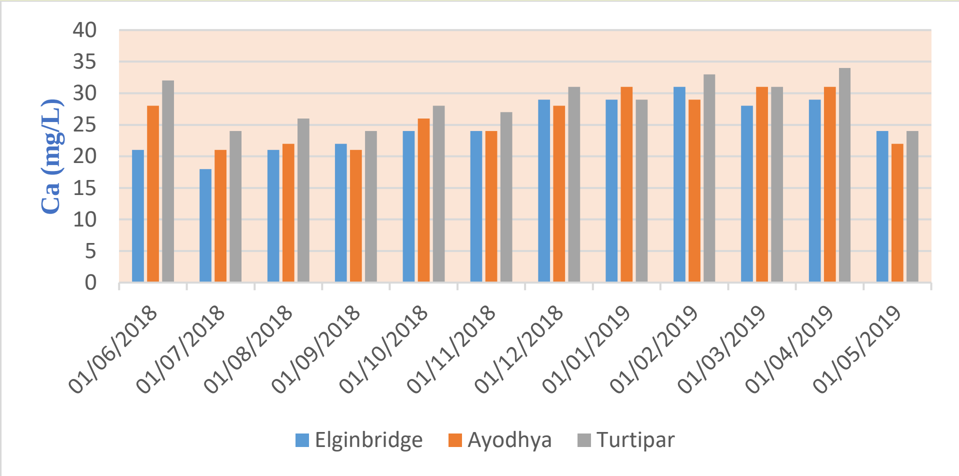


Fig.9 : Calcium concentraions observed for the year 2018-19

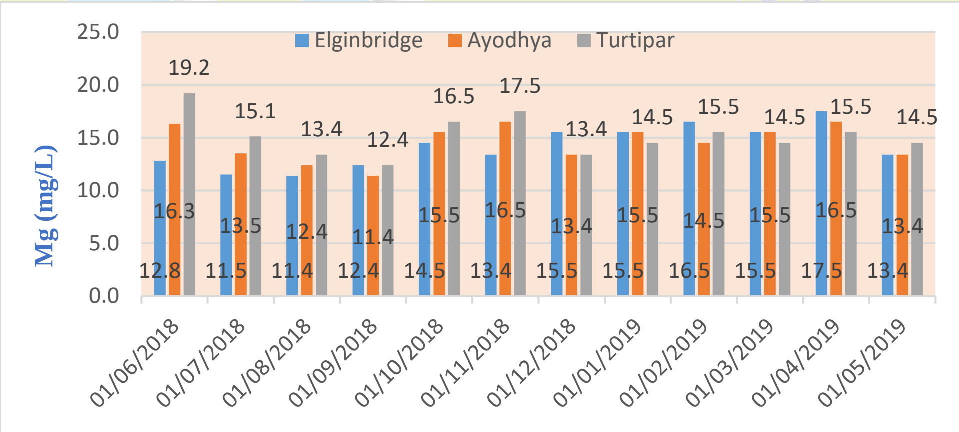


Fig.10 : Magnesium concentraions observed for the year 2018-19

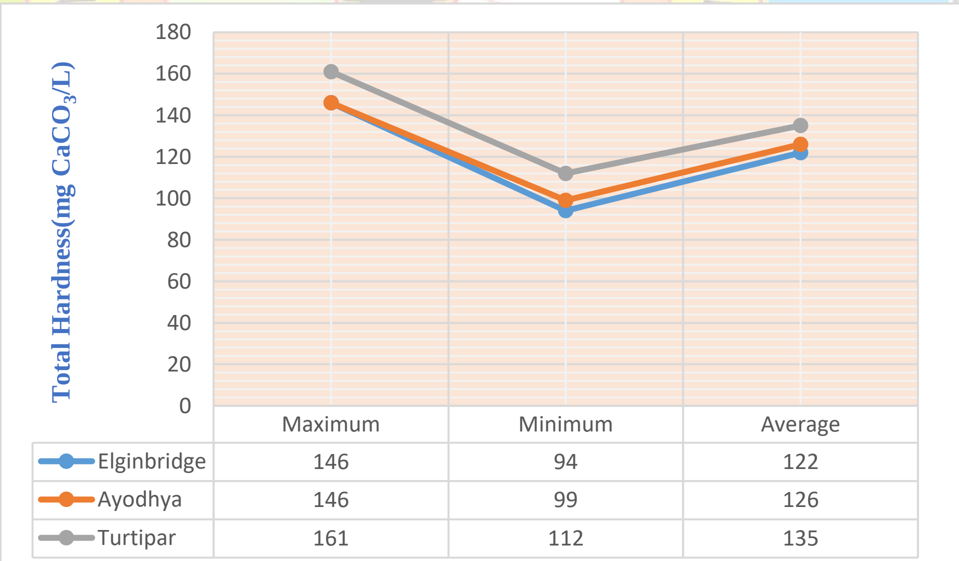


Fig.11: Variation of Total hardness for the year 2018-19

6. <u>Sodium and Potassium</u>

Sodium and potassium are major ions detected in surface water bodies. Both of them, especially sodium has a specific role in determining the suitability of water for irrigation purpose. They are measured in the laboratory using flame emission photometer. The maximum value of sodium detected is 10.0 mg/L whereas that of magnesium is 5.8 mg/L both reported at Turtipar. In all the three sites, the concentration of sodium is more than that of potassium. Both the ions show a higher average concentration in the winter season.

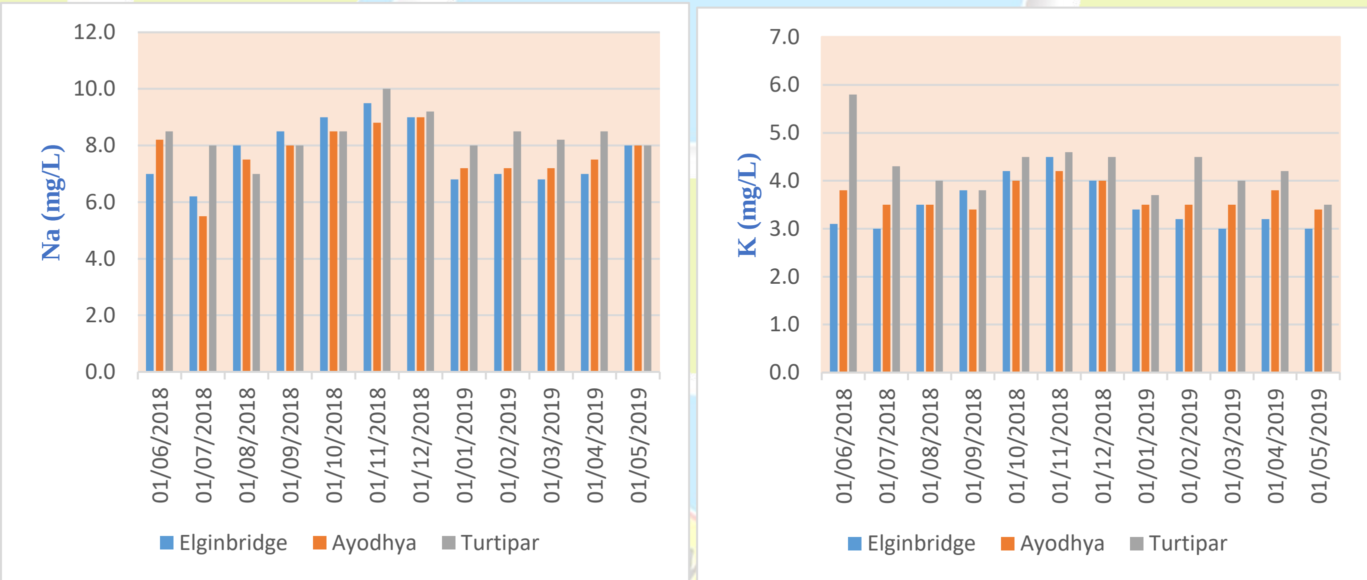


Fig.12 : Sodium and potassium observed for the year 2018-19

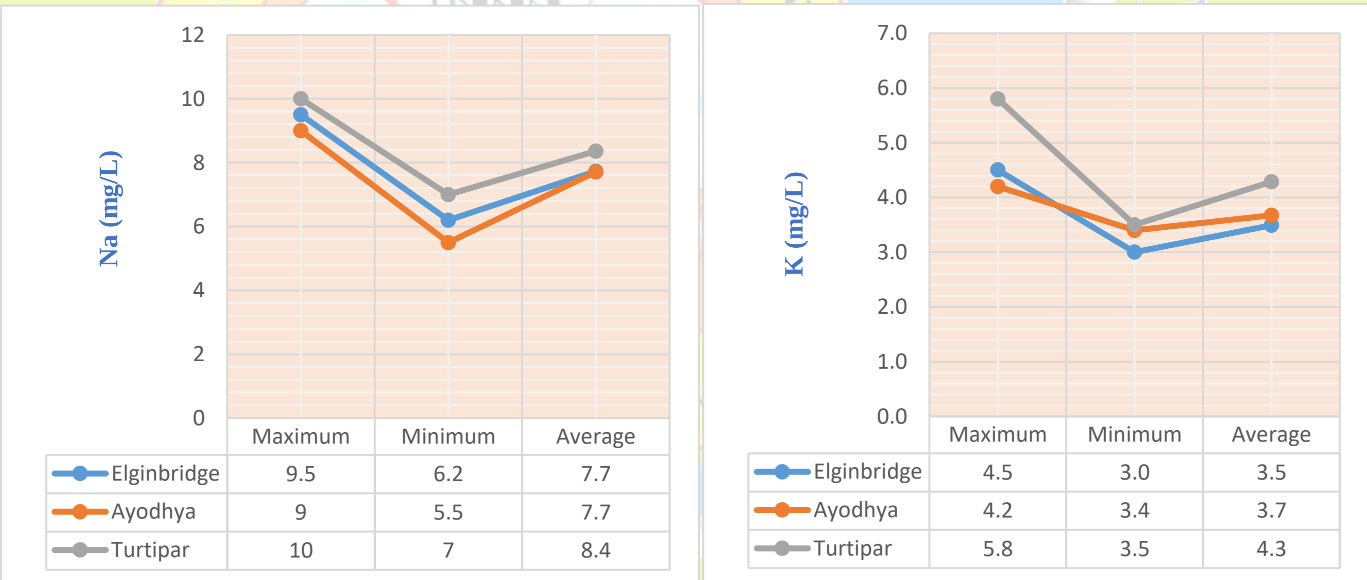
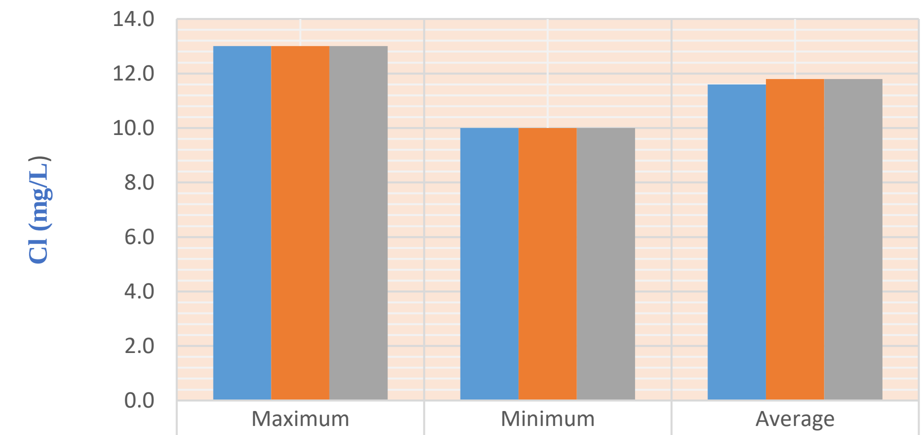


Fig.13: Variation of sodium and potassium for the year 2018-19

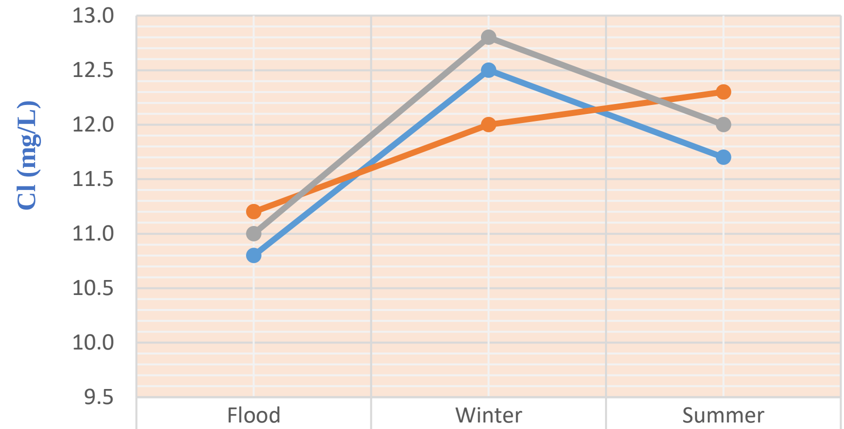
7. <u>Chloride</u>

Chloride is one of the major ions present in surface water. The presence of chloride in natural waters can be attributed to dissolution of salt deposits, discharges of effluents from chemical industries, oil well operations and seawater intrusion in coastal areas. Chloride ion concentration in the study area is found to possess almost the same values. It ranged from 10 mg/L to 13 mg/L.



	Maximum	Minimum	Average
Elginbridge	13.0	10.0	11.6
Ayodhya	13.0	10.0	11.8
Turtipar	13.0	10.0	11.8

Fig.14: Variation of chloride for the year 2018-19



	Flood	Winter	Summer
Elginbridge	10.8	12.5	11.7
Ayodhya	11.2	12.0	12.3
Turtipar	11.0	12.8	12.0

Fig.15: Seasonal variation of chloride for the year 2018-19

8. Sulphate

Sulphate is one of the major anions present in natural water. Sulphates cause scaling in water supplies, and problem of odour and corrosion in waste water treatment due to its reduction to H_2S. The sulphate concentration in the study area has an increasing trend from upstream to downstream in all the months of 2018-19. The values at Turtipar are found to be comparatively higher than the other two sites which are in the upstream. The sulphate concentrations during the study period ranged from 7.8 mg/L at Elginbridge to 22.5 mg/L at Turtipar.

SO_4 (mg/L)	Maximum	Minimum	Average
Elginbridge	14.5	7.8	11.9
Ayodhya	16.0	12.0	14.2
Turtipar	22.5	14.8	17.1

Table 3 : Variation of sulphate for the year 2018-19

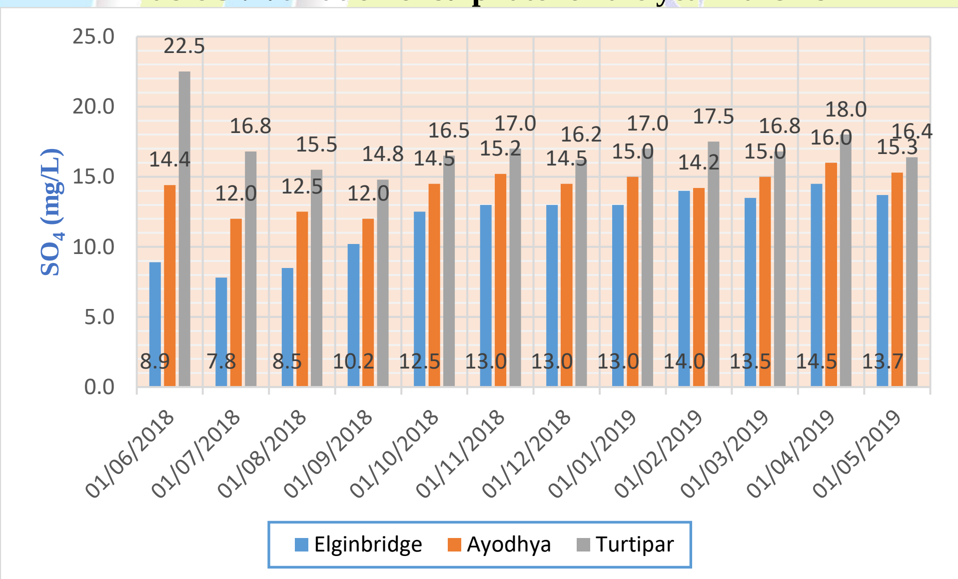


Fig.16: Variation of sulphate for the year 2018-19

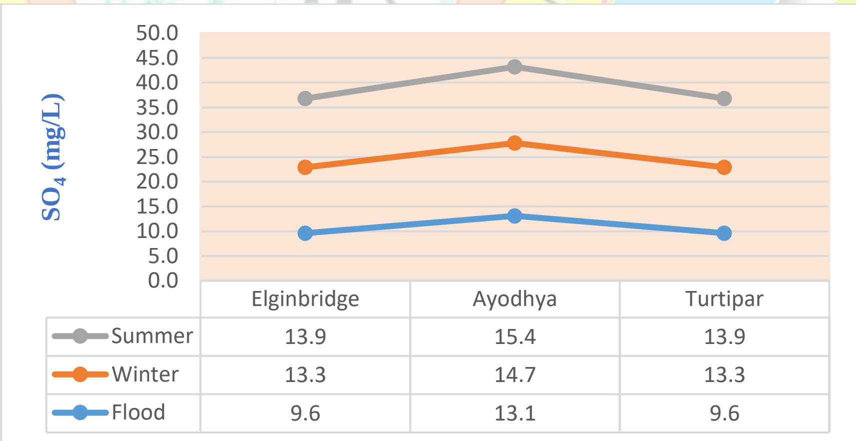


Fig.17: Seasonal variation of sulphate for the year 2018-19

9. Nutrients

The compounds of nitrogen and phosphorous are essential for the plant and animal growth and hence their ions are known as nutrients. In this study, nitrate, nitrite, ammoniacal nitrogen and total phosphates are analysed. The nitrogen compounds' concentration is expressed as mgN/L. All the three sites had shown the same trend as phosphate having higher concentration than the others. The average values of nutrients were found to be minimum in the winter season.

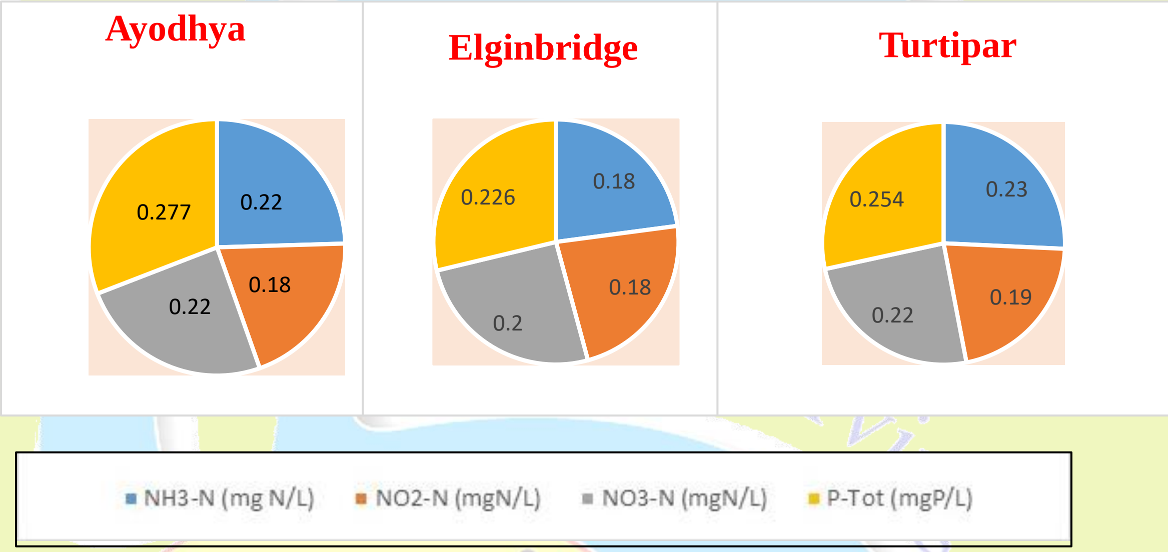


Fig.18 : Average of nutrients for the year 2018-19

Ayodhya	Flood	Winter	Summer	Elginbridge	Flood	Winter	Summer	Turtipar	Flood	Winter	Summer
NH_3-N (mg N/L)	0.20	0.23	0.23	NH_3-N (mg N/L)	0.15	0.20	0.20	NH_3-N (mg N/L)	0.21	0.25	0.24
NO_2-N (mgN/L)	0.16	0.20	0.21	NO_2-N (mgN/L)	0.15	0.20	0.20	NO_2-N (mgN/L)	0.19	0.20	0.18
NO_3-N (mgN/L)	0.18	0.25	0.24	NO_3-N (mgN/L)	0.16	0.22	0.23	NO_3-N (mgN/L)	0.21	0.24	0.21
P-Tot (mgP/L)	0.258	0.282	0.300	P-Tot (mgP/L)	0.204	0.242	0.240	P-Tot (mgP/L)	0.246	0.265	0.253

Table 4 : Seasonal variation of nutrients

The NH_3-N concentrations ranges are 0.12-0.21 at Elginbridge, 0.18-0.22 at Ayodhya and 0.20 -0.27 mgN/L at Turtipar. NO_3-N ranged from 0.14-0.26 at Elginbridge, 0.11-0.24 at Ayodhya and 0.15 -0.28 mgN/L at Turtipar. NO_2-N ranged from 0.11-0.24 at Elginbridge, 0.10-0.22 at Ayodhya and 0.16 -0.24 mgN/L at Turtipar. Total phosphates showed the maximum value of 0.32 mgP/L at Ayodhya in april, 2019.

10.Dissolved oxygen (DO)

Dissolved oxygen (DO) measurement has a significant role in the interpretation of quality of water. It accounts for the suitability of water for living organisms. DO refers to the level of free, non-compound oxygen present in water and it should be analysed in-situ or fixed immediately after sample collection. Any value of DO less than 4.0 mg/L is not recommended for the survival of aquatic life. In CWC, DO is analysed by Winkler azide modification method.

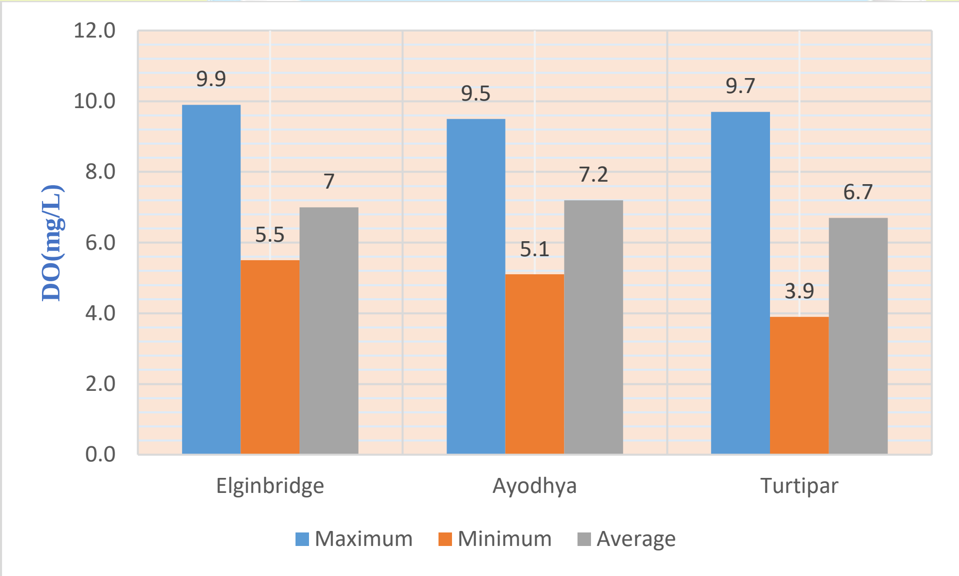


Fig.19: Variation of DO

The maximum and average values of DO for all sites are almost in the same range whereas the minimum value at Turtipar is found to be lesser than the other two. This value of 3.9 mg/L was observed in the month of July, 2018. The lowest values of DO were observed during the flood season whereas the maximum values were recorded during winter of 2018-19 with 9.9 mg/L at Elginbridge in March, 2019.

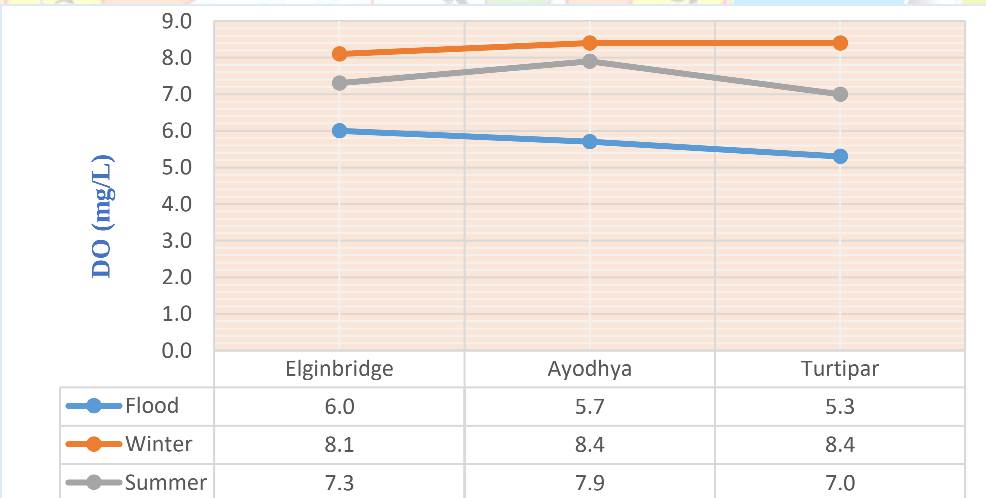


Fig.20: Seasonal variation of DO

11. Biochemical Oxygen Demand (BOD)

BOD is another significant parameter which gives an idea of pollution level of water. Micro-organisms present in water 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. Water having BOD value less than 2 mg/L is considered as free from pollution. BOD analysis is carried out in the laboratory by incubating the samples under specific temperature for a specific period of time and then determining the difference between initial and final DO values.

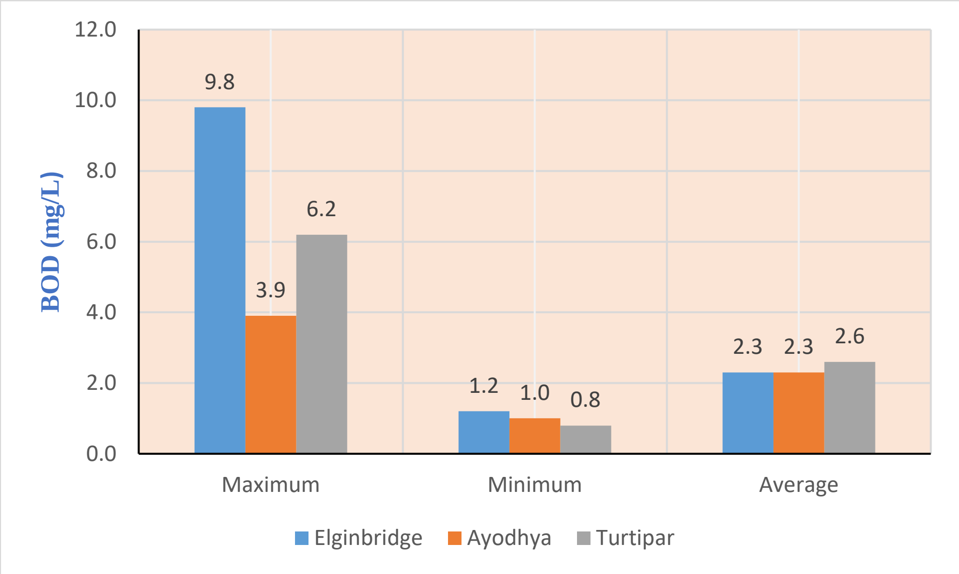


Fig.21: Variation of BOD

Site Name (From U/S to D/S)	Annual Average		
	Since inception	Past 10 year	2018-19
Elginbridge	1.12	1.16	2.30
Ayodhya	0.69	1.19	2.30
Turtipar	1.22	1.30	2.60

Table 5: Variation of annual average of BOD

From the table it is clear that the annual average value of BOD during the period of study is more than the averages since interception and for the past 10 years for all the 3 sites. This shows a deteriorated water quality of the river and indicates extend of pollution caused by man-made activities.

12. Total Coliforms (TC) and Fecal Coliforms (FC)

Coliforms are one of the most useful indicator organisms which are easily detectable. Total Coliforms represent a group of 16 species of bacteria that are found in soil, vegetation, animal wastes and human sewage. Their presence gives an idea about the pollution level of the water bodies. Coliforms are called indicators because their presence give an indication of the possibility of presence of other microorganisms including harmful pathogens. Fecal coliforms represents a sub category of TC with 6 species including the harmful E.coli bacteria.

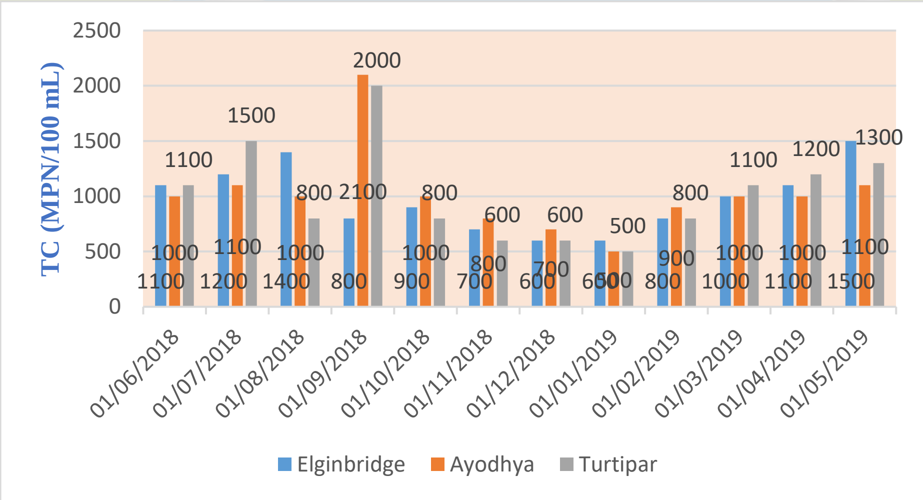


Fig.22: TC values for the year 2018-19

The maximum concentration of total and fecal coliforms for all sites are detected in the month of September, 2018. Winter season showed the minimum values with the month of January having the least values for the water year. The TC value ranges from 500 to 2100 MPN/100 mL and that of FC ranges from 200 to 1000 MPN/100 mL. The maximum values are observed at Ayodhya. Total Coliform value is higher than the tolerance limit.

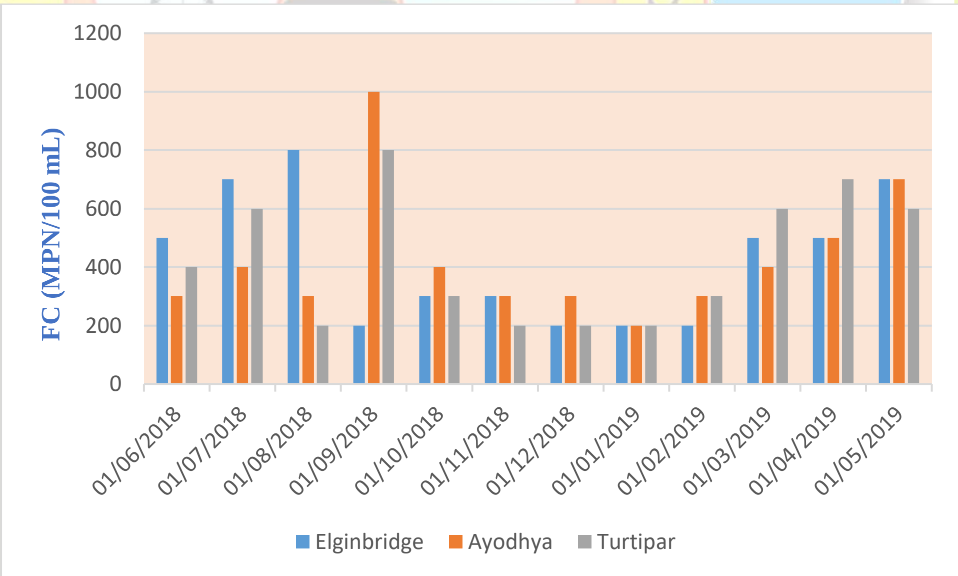


Fig.23: FC values for the year 2018-19

S. No.	Designated-Best-Use	Class of water	Criteria
1.	Drinking Water Source without conventional treatment but after disinfection	A	Total Coliforms Organism MPN/100ml shall be 50 or less pH between 6.5 and 8.5 Dissolved Oxygen 6mg/L or more Biochemical Oxygen Demand 5 days 20°C 2mg/L or less 5.0
2.	Outdoor bathing (Organized)	B	Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5mg/L or more Biochemical Oxygen Demand 5 days 20°C 3mg/L or less
3.	Drinking water source after conventional treatment and disinfection	C	Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 Dissolved Oxygen 4mg/L or more Biochemical Oxygen Demand 5 days 20°C 3mg/L or less
4.	Propagation of Wild life and Fisheries	D	pH between 6.5 to 8.5 Dissolved Oxygen 4mg/L or moreFree Ammonia (as N) 1.2 mg/L or less
5.	Irrigation, Industrial Cooling, Controlled Waste disposal	E	pH betwwn 6.0 to 8.5 Electrical Conductivity at 25°C micro mhos/cm Max.2250 Sodium absorption Ratio Max. 26 Boron Max. 2mg/

*www.cpcb.nic.in/classi.htm

Table 6: Primary Water Quality Criteria for Various Uses (CPCB)

13.Distribution of Major ions in the basin

Most of the major ions show a slightly increasing trend from upstream to downstream of the river.ie; from Elginbridge to Turtipar.

Average value for 2018-19	Chloride (mg/L)	Potassium (mg/L)	Sodium (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Bicarbonate (mg $CaCO_3$/L)	Sulphate (mg/L)
Elginbridge	11.6	3.9	7.7	25	14.2	126	11.9
Ayodhya	11.8	3.7	7.7	26	14.5	129	14.2
Turtipar	11.8	4.3	8.4	29	15.2	142	17.1

Table 7: Result of major ions for the year 2018-19

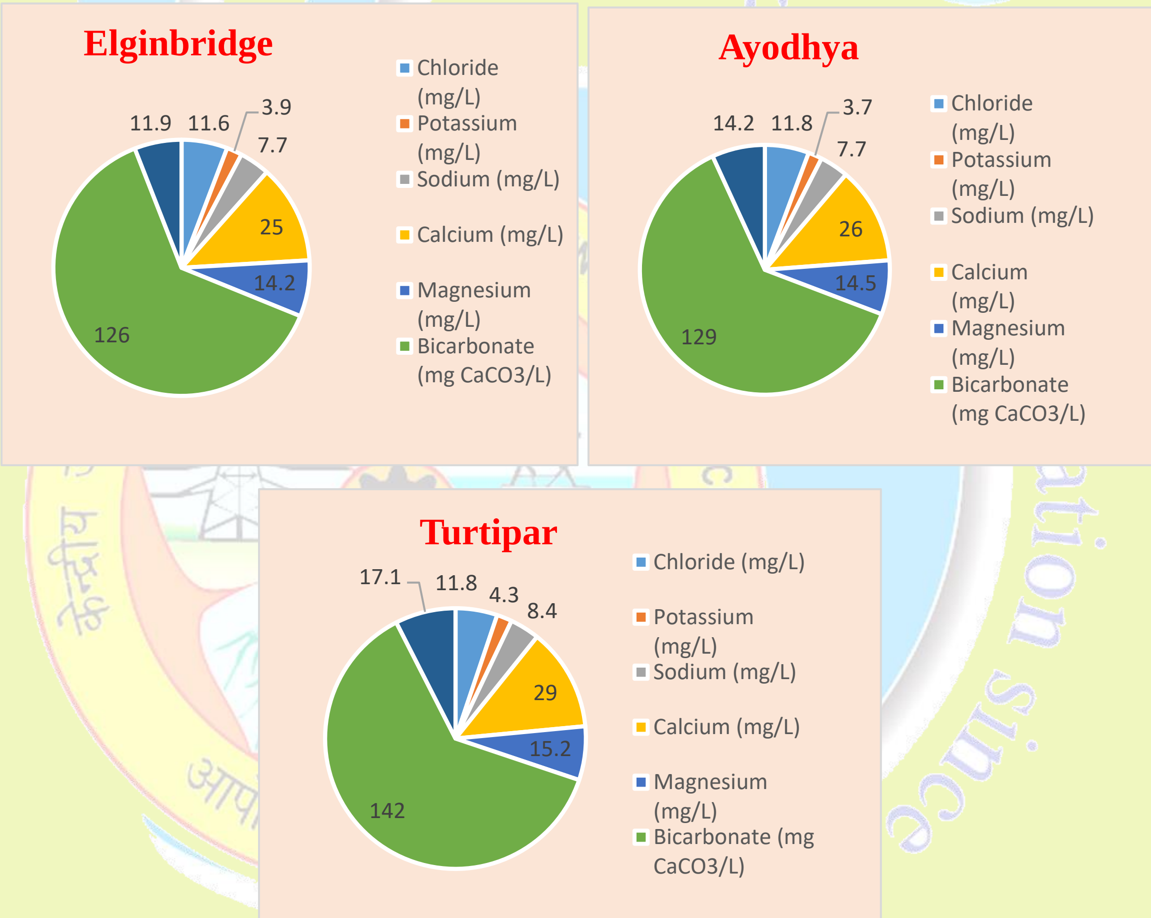


Fig.24: Distribution of Major ions in the basin

From the above diagrams it is clear that the major ion present in the water samples is bicarbonate. Calcium, magnesium, sulphate and chloride ions also persist in the river. The major ion distribution in all three sites is similar which gives an indication that the basic composition of water remains the same along the length of the stream.

Water year 2018-19		Elginbridge			Ayodhya			Turtipar		
S.No	Parameters	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
1	EC (µmhos/cm)	310	170	242	340	180	257	343	210	273
2	pH	8.3	7.8	8	8.3	7.8	8	8.3	7.9	8.1
3	TDS (mg/L)	186	102	142	205	104	149	195	125	161
4	Temp (° C)	30.0	17.0	23.9	28.0	13.0	21.9	30.0	17.0	25.9
5	TA ($mgCaCO_3/L$)	116	88	104	138	96	106	155	96	116
6	B (mg/L)	0.17	0.08	0.13	0.15	0.10	0.12	0.13	0.10	0.11
7	Ca (mg/L)	31	18	25	31	21	26	34	24	29
8	Cl (mg/L)	13.0	10.0	11.6	13.0	10.0	11.8	13.0	10.0	11.8
9	CO_3 (mg/L)	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0
10	F (mg/L)	0.24	0.12	0.19	0.25	0.15	0.2	0.26	0.16	0.22
11	HCO_3 (mg/L)	142	107	126	168	117	129	189	117	142
12	K (mg/L)	8.4	3.0	3.9	4.2	3.4	3.7	5.8	3.5	4.3
13	Mg (mg/L)	17.5	11.4	14.2	16.5	11.4	14.5	19.2	12.4	15.2
14	Na (mg/L)	9.5	6.2	7.7	9.0	5.5	7.7	10.0	7.0	8.4
15	NH_3-N (mg N/L)	0.21	0.12	0.18	0.25	0.18	0.22	0.27	0.20	0.23
16	NO_2-N (mgN/L)	0.22	0.10	0.18	0.24	0.11	0.18	0.24	0.16	0.19
17	NO_3-N (mgN/L)	0.24	0.11	0.2	0.26	0.14	0.22	0.28	0.15	0.22
18	P-Tot (mgP/L)	0.260	0.180	0.226	0.320	0.240	0.277	0.280	0.220	0.254
19	SiO_2 (mg/L)	7.2	6.0	6.7	7.9	7.0	7.5	7.0	5.5	6.4
20	SO_4 (mg/L)	14.5	7.8	11.9	16.0	12.0	14.2	22.5	14.8	17.1
21	BOD (mg/L)	9.8	1.2	2.3	3.9	1.0	2.3	6.2	0.8	2.5
22	COD (mg/L)	22.0	3.0	6.3	13.0	4.0	6.8	14.0	3.0	7.5
23	DO (mg/L)	9.9	5.5	7	9.5	5.1	7.2	9.7	3.9	6.7
24	FC (MPN/100mL)	800	200	425	1000	200	425	800	200	425
25	TC (MPN/100mL)	1500	600	975	2100	500	1017	2000	500	1025
26	TH ($mgCaCO_3/L$)	146	94	122	146	99	126	161	112	135
27	Na% (%)	15	9	12	15	10	12	13	10	12
28	RSC (-)	0.1	0.0	0	0.1	0.0	0	0.1	0.0	0
29	SAR (-)	0.4	0.3	0.3	0.4	0.2	0.3	0.4	0.3	0.3

Table 8: Summary of results for the year 2018-19

Salient Findings of the Study

1. Concentration of most of the chemical parameters are found to be less than the permissible limits of drinking water quality.
2. The normal trend of water quality parameters in the basin is a gradual increase in concentration of the ions from upstream to downstream.
3. pH values are normal in the range of 6.5-8.5 and samples are found to be slightly alkaline in nature.
4. It is of significant notice that the water samples are found to be suitable for drinking water purpose in terms of physico-chemical parameters but impure in terms of biological parameters.
5. The average annual DO in the basin is found to be 4.8 mg/L. it is not suitable for drinking water or outdoor bathing purpose according to CPCB. As per Table 6, Class A water possess a DO concentration of 6 mg/L or more and Class B should have a minimum concentration of 5 mg/L DO. In terms of the annual average DO, the water of Ghaghra comes under Class C category. i.e. water can be used as drinking water source after conventional treatment and disinfection.

6. BOD average of all the sites is 2.5 mg/L and this also brings the quality under Class C type water. Proper treatment is needed before drinking or outdoor bathing usages.

7. An annual overall average of 1006 MPN/100 mL has been recorded for TC during the study period. FC has an average of 425 MPN/100 mL. According to CPCB, the TC values should be less than 50 MPN/100 mL for drinking water purpose and less than 500 MPN/100 mL for the purpose of outdoor bathing. So, the water comes under the Class C.

8. The major ion present in the basin is bicarbonate. Calcium, magnesium, sulphate and chloride ions are also present in higher amounts than others. It is noticeable that the major ion distribution along the longitudinal stretch of the river is same because the basic composition of major ions is same in all the three sites.

9. All the water samples are suitable for irrigation purpose.

Pictures of the Ghaghra River at Elginbridge

Pictures of the Ghaghra River at Ayodhya

Pictures of the Ghaghra River at Turtipar

सत्यमेव जयते

भारत सरकार
Government of India

केन्द्रीय जल आयोग
Central Water Commission

एक प्रतिवेदन
वैनगंगा नदी क्षेत्र के ट्रेंड स्टेशनों के जल गुणवत्ता परिदृश्य पर

A Report on
Water Quality Scenario of Trend station in Wainganga River Basin

जल वर्ष : 2018-19
Water Year: 2018-19

प्रबोधन (मध्य) संगठन
Monitoring (Central) Orgnisation
नागपुर Nagpur

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मई, 2020
May, 2020

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1.0 BASIN DESCRIPTION:

The Wainganga river is one of the tributaries of the river Godavari. Wainganga basin lies between longitude 76^0-10" to 80^0-53"E and Latitude 18^0-48"to 22^0–43"N. Wainganga has three principle branches viz. the Penganga, the Wardha and the Wainganga. The Wainganga rises in the Seoni District of Madhya Pradesh at an elevation of 640 m above the Mean Sea Level. The total length of this river is 754 km upto the confluence with Godavari. In the beginning, it flows for a length of about 275 km in Seoni and Balaghat Districts of Madhya Pradesh. Further it flows for a distance of about 479 km in Bhandara, Chandrapur, and Gadchiroli District of Maharashtra before joining the Godavari. The main tributaries viz. the Kanhan, the Andhari, the Wardha and the Peddavagu join Wainganga at right bank. Wainganga, which is called Pranhita after the confluence of river Wardha, is major tributary of river Godavari. On the left bank, 5 tributaries namely the Bagh, the Chulband, the Garhvi, the Kobragarhi and the Kathani drains into the main river.

The initial reaches of the river basin and the left part of the basin comprises mostly forest area having rural population. There are a few towns in the right part of the basin. These are Nagpur, Chandrapur and Ballarshah. There are mines and cement plants in the middle reaches of the basin. The main occupation of the people in the basin is agriculture and has high cattle population. The Wainganga basin lies in the medium rainfall zone of 900 mm to 1600 mm. Most of the rainfall is received during the south west monsoon from June to October. In winter, the minimum temperature varies from 7 ^{0}C to 13 ^{0}C. The maximum temperature varies from 39^0C to 47^0C during summer. The month of May is the hottest month and the December is the coldest one. A basin map showing Wainganga River and its tributaries is given as Figure 1.

The Monitoring Central Organization, Central Water Commission Nagpur is conducting hydrological observation in Wainganga basin at 24 Stations for water year 2018-19. These sites are maintained under Key Hydrological Stations. Out of these Hydrological Observations sites 15 sites are Water Quality Trend stations. The Waingangā division of Central Water Commission is monitoring the water quality of WaingangāRiver from more than 30 years.

2.0 METHODOLOGY:

2.1 Sampling location: The water quality monitoring for physical, chemical and bacteriological analysis is carried out at all water quality trend stations on river Wainganga.The details of water Quality sampling location is given in Table1. In present study, water quality data observed from 1st June 2018 to 31st May 2019 at the station are compared with designated use class of Inland surface water specifications (BIS 2296-1982) is shown in Table2. The data has been analyzed for 24 important water quality parameters such as Electrical Conductivity (EC), pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand(BOD), Sodium (Na), Potassium (K), Calcium (Ca), Calcium Hardness (CH), Total Hardness (TH), Magnesium (Mg), Iron (Fe),Bicarbonate (HCO_3), Chloride (Cl), Fluoride (F), Sulphate (SO_4), Nitrate (NO_3), Nitrite (NO_2), Ammonical Nitrogen

(NH3-N), Boron (B), Sodium Adsorption Ratio (SAR), Sodium Percentage (Na %), Phosphate (PO_4), Chemical Oxygen Demand (COD) and Total Coliform (TC) &Faecal Coliform (FC).

2.2 Sampling: Sampling and analysis of water samples is done as per the standard norms set by the Water Quality Assessment Authority (WQAA June 2005). The water samples are collected every month during 08.00 AM to 10.00 AM on first working day of the month. These water samples are collected at 30 cm depth from surface without disturbing the bottom sediments, from the point across the river section having maximum depth or maximum flow along the cross section of the river, so that samplemust be representative of the source that

LOCATION OF WATER QUALITY STATIONS IN WAINGANGA BASIN

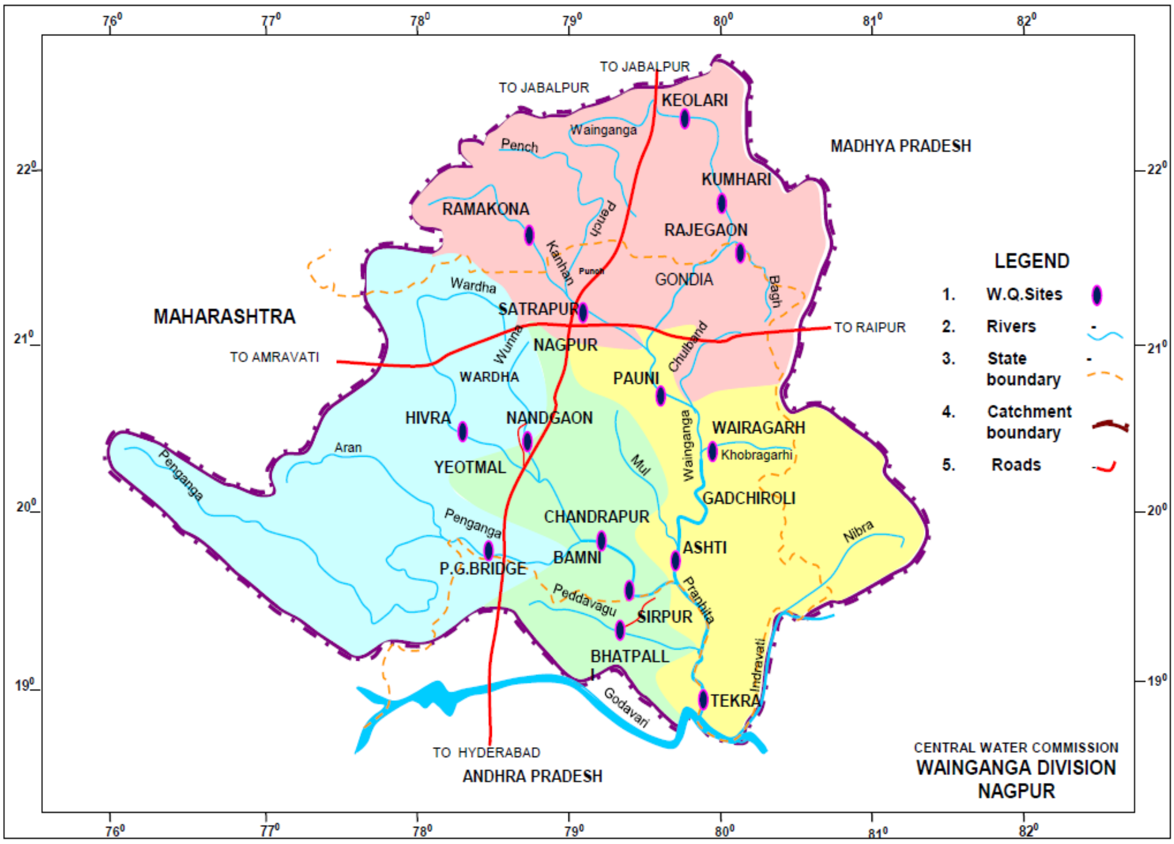

FIGURE 1

is to be evaluated. The samples are collected in clean and pre-rinsed polythene bottles of one liter capacity, filled up to their full capacity without air bubbles. One more sample for bacteriological analysis is also collected in BOD bottles of 300 ml capacity. The collected water samples are preserved and transported as per the standard norms to Waingnaga Water Quality Laboratory, Waingangā Division, Central Water Commission, Nagpur for chemical and bacteriological analysis.

TABLE 1: DETAILS OF WATER QUALITY SITES OF WAINGANGA BASIN

S. No.	Name of site	District	River	State	Catchment Area (Sq. Km.)	Latitude	Longitude	Sites Opening Date	Type of Water Quality Station
1	Keolari	Seoni	Wainganga	Madhya Pradesh	2970	22 ^{0}50"50'	79^{0}54"00'	01.06.2014	Trend
2	Kumhari	Balaghat	Wainganga	Madhya Pradesh	8070	21^{0}53"03'	80^{0}10"36'	01.02.2012	Trend
3	Rajengaon	Balaghat	Bagh	Madhya Pradesh	5380	21^{0}37"32'	80^{0}15"14'	01.02.2014	Trend
4	Ramakona	Chindwada	Kanhan	Madhya Pradesh	2500	21^{0}43"12'	78^{0}49"27'	01.06.2014	Trend
5	Satrapur	Nagpur	Kanhan	Maharashtra	11100	21^{0}13"04'	79^{0}14"06'	09.12.1987	Trend
6	Pauni	Bhandara	Wainganga	Maharashtra	35520	20^{0}47"46'	79^{0}38"32'	12.01.1966	Trend
7	Hivra	Wardha	Wardha	Maharashtra	10240	20^{0}32"54'	78^{0}19"29'	16.12.1987	Trend
8	Nandgaon	Wardha	Wunna	Maharashtra	4580	20^{0}31"01'	78^{0}48"21'	01.01.1988	Trend
9	P.G.Bridge	Yeotmal	Penganga	Maharashtra	18441	19^{0}49"08'	78^{0}34"11'	31.05.1966	Trend
10	Bamni	Chandrapur	Wardha	Maharashtra	46020	19^{0}48"48'	79^{0}22"58'	03.06.1966	Trend
11	Ashti	Gadchiroli	Wainganga	Maharashtra	50990	19^{0}41"05'	79^{0}47"19'	01.06.1966	Trend
12	Wairagarh	Gadchiroli	Khobragarhi	Maharashtra	2600	20^{0}25"19'	80^{0}05"30'	01.10.2014	Trend
13	Bhatpalli	Adilabad	Peddavegu	Maharashtra	3100	19^{0}18"47'	79^{0}27"57'	04.01.1988	Trend
14	Sakmur	Gadchiroli	Wardha	Maharashtra	47500	19^{0}33"41'	79^{0}36"48'	01.06.2014	Trend
15	Tekra	Gadchiroli	Pranhita	Maharashtra	108780	18^{0}57"06'	79^{0}57"45'	15.06.1966	Trend

TABLE 2:
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)

S. 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

*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.

2.3 Analysis of the samples: The collected water samples were analysed for physical, chemical and bacteriological parameters using standard analytical procedure and/or instrumental methods (APHA 23rd edition 2017). The quantitative estimation for the chemical parameters is determined by titrimetric, spectrophotmeteric, flame photometric method and microbiology analysis is done by Most Probable Number method (MPN) as shown in Table- 3.

TABLE 3: DETAILS OF WATER QUALITY ANALYSIS

S. No.	Water Quality Parameters	Method
1	Electrical Conductivity (EC)	Conductivity Cell
2	pH	Potentiometric
3	Dissolved Oxygen (DO)	Winkler Azide Titrimetric
4	Biochemical Oxygen Demand(BOD)	Incubation for 5 days at 20°C
5	Sodium (Na)	Flame Emission Method
6	Potassium (K)	Flame Emission Method
7	Calcium (Ca)	Complexometric Titration
8	Calcium Hardness (CH)	Complexometric Titration
9	Total Hardness (TH)	Complexometric Titration
10	Magnesium (Mg)	Calculation Method
11	Iron (Fe)	Phenanthroline Method
12	Bicarbonate (HCO_3)	Acid Base Titration
13	Chloride (Cl)	Argentometry Titration
14	Fluoride (F)	Ion sensitive Electrode Method
15	Sulphate (SO_4)	NephalometricMethod
16	Nitrate (NO_3)	SulphanilamideMethod
17	Ammonical Nitrogen (NH3-N)	Phenate Methods
18	Boron (B)	Curcuremin Method
19	Sodium Adsorption Ratio (SAR)	Calculation
20	Sodium Percentage (Na %)	Calculation
21	Phosphate (PO_4)	Ascorbic Acid Methods
22	Chemical Oxygen Demand(COD)	Open Reflux and Titration
23	Total Coliform (TC)	Most Probable Number Methods
24	Faecal Coliform (FC)	Most Probable Number Methods

3.0 RESULTS AND DISCUSSION:

3.1 PARAMETERS WISE SUITABILITY OF WATER QUALITY FOR DESIGNATED USE: In the present status report the water quality data of ten year (2009-10 to 2018 - 19) and current one year are given in Figure 2 to 25 and Table 4 to 27.The water quality data of ten years data as shown in Figure 2 (a) to 26 (a) and one year data as shown in Figure 2 (b) to 25 (b).The new sites marked as star have not completed the ten years and opening date of sites are given in table 1. The results and discussion of water quality parameters are given below:

3.1.1 Electrical Conductivity (EC): During the current water year 2018-19, the maximum EC values are in the range from 150 to 2739 µmho/cm, minimum values are in the range of 107 to 423 µmho/cm and average values are in the range of 131 to 938 µmho/cm as shown in Figure 2(b) and Table 4. It is observed from results the average, minimum and maximum values of EC of all sites are under the prescribed limit. However, the maximum values of only Bamni site is above for class D and E.

3.1.2 P^H : During the current water year 2018-19 the maximum values are in the range from 7.8 to 9.0, minimum values are in the range of 6.3 to 8.0 and average values are in the range of 7.5 to 8.3 as shown in Figure 3(b) and Table 5. It is observed from the results average, minimum and maximum P^H values of all sites are prescribed limit. However, the maximum values of PG Bridge, Hivra, Ashti, Sakmur and Keolari sites are above for class A, B, C, D and E.

3.1.3 Dissolve Oxygen (DO): During the current water year 2018-19 the maximum values are in the range from 7.1 to 11.9 mg/L , minimum values are in the range of 0.6 to 6.1 mg/L and average values are in the range of 4.6 to 8.6 mg/Las shown in Figure 4 (b) and Table 6.It is observed from results the maximum DO values of all sites are above prescribed limit. However, the average DO value of Bamni and Satrpur are below class A and the DO value of Hivra is below class B. The minimum DO values of Kumahri, Ramakona, PG Bridge sites are below for class A and Bhatpalli, Nandgaon, Sakmur sites are below class B, Bamni, Hivra, Ashti, Pauni and Satrapur are below class C & D.

3.1.4 Bio-chemical Oxygen Demand (BOD): During the current water year 2018-19 the maximum values are in the range from 2.8 to 120 mg/L , minimum values are in the range of 0.6 to 1.7 mg/L and average values are in the range of 1.4 to 25.8 mg/L as shown in Figure 5 (b) and Table 7. It is observed from results the minimum BOD values of all sites are under the prescribed limit. It is observed from the results average BOD values of Keolari site are is above class A and Bamni, Nandgaon, Hivra, Pauni, Satrapur, Rajegaon and Sakmur are above class B & C. The maximum values of all the sites are above class B & C except Bhatpalli and Ramakona.

3.1.5 Sodium (Na): During the current water year 2018-19 the Maximum values are in the range of 29.8 mg/L to 373.1 mg/L, Minimum values are in the range of 10.1 to 40.8 mg/L and average values are in the range of 17.4 to 102.2 mg/L as shown in Figure 6 (b) and Table 8. The value of Sodium is not prescribed in BIS 2296: 1982.

TABLE 4 : ELECTRICAL CONDUCTIVITY

Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	580	207	345	395	268	323
KUMHARI	726	130	314	386	161	296
RAJEGAON	470	61	212	256	107	196
RAMAKONA	790	181	439	405	206	325
SATRAPUR	1040	180	537	737	258	549
PAUNI	1552	140	355	397	169	281
HIVRA	978	215	460	528	353	454
NANDGAON	820	225	497	610	339	488
P.G.BRIDGE	671	157	436	624	210	451
BAMNI	2887	188	724	2739	423	938
ASHTI	887	117	305	308	171	261
WAIRAGARH	199	36	128	150	110	131
BHATPALLI	798	235	518	576	235	448
SAKMUR	954	203	543	829	235	534
TEKRA	605	163	399	454	224	355

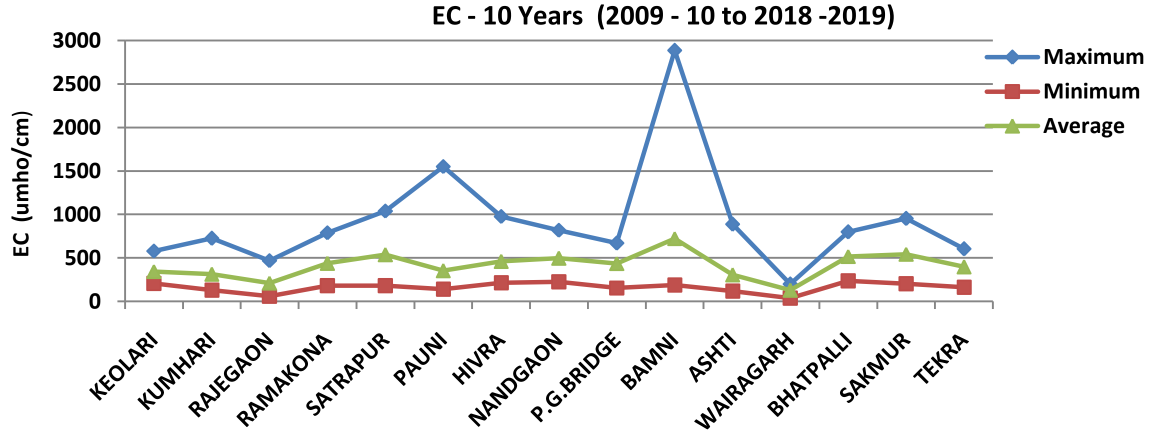

Figure 2 (a)

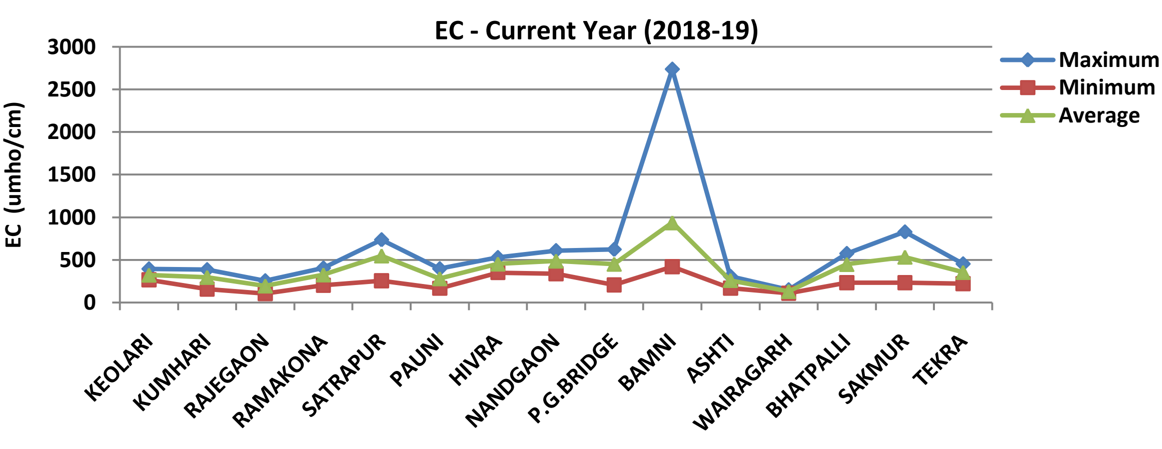

Figure 2 (b)

TABLE 5 : pH						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	8.9	7.6	8.2	8.9	7.7	8.3
KUMHARI	8.6	6.3	8.0	8.2	6.9	7.8
RAJEGAON	8.5	6.7	7.9	7.8	7.2	7.5
RAMAKONA	8.7	7.6	8.1	8.1	7.7	8.0
SATRAPUR	8.8	6.3	8.1	8.1	6.3	7.6
PAUNI	8.8	6.4	8.0	8.5	7.5	7.9
HIVRA	8.8	6.9	8.3	8.7	7.7	8.1
NANDGAON	8.9	7.5	8.2	8.5	7.5	8.0
P.G.BRIDGE	9.0	7.5	8.4	8.9	7.9	8.3
BAMNI	8.8	7.1	8.1	8.2	7.1	7.8
ASHTI	9.8	7.3	8.4	9.0	7.6	8.1
WAIRAGARH	8.3	6.7	7.7	7.9	7.2	7.6
BHATPALLI	8.9	7.6	8.3	8.5	8.0	8.1
SAKMUR	8.7	7.2	8.2	8.7	7.9	8.3
TEKRA	8.9	6.6	8.3	8.4	7.7	8.1

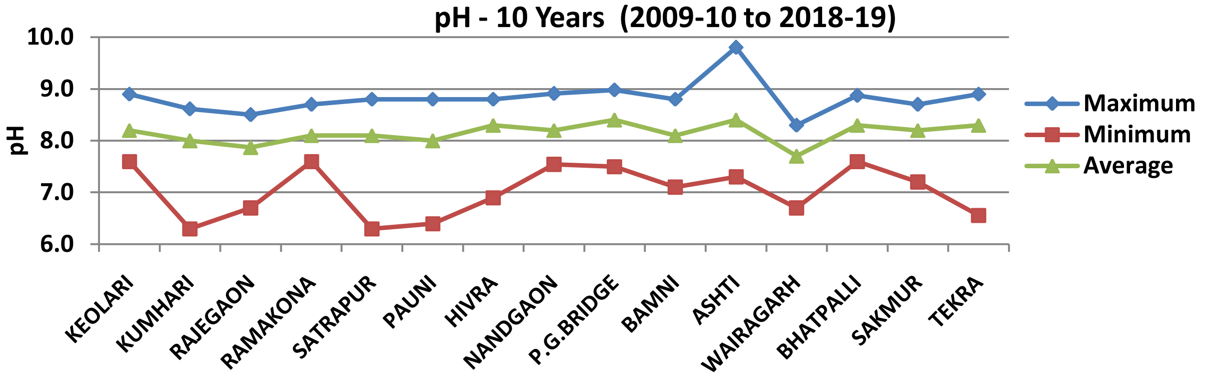

Figure : 3 (a)

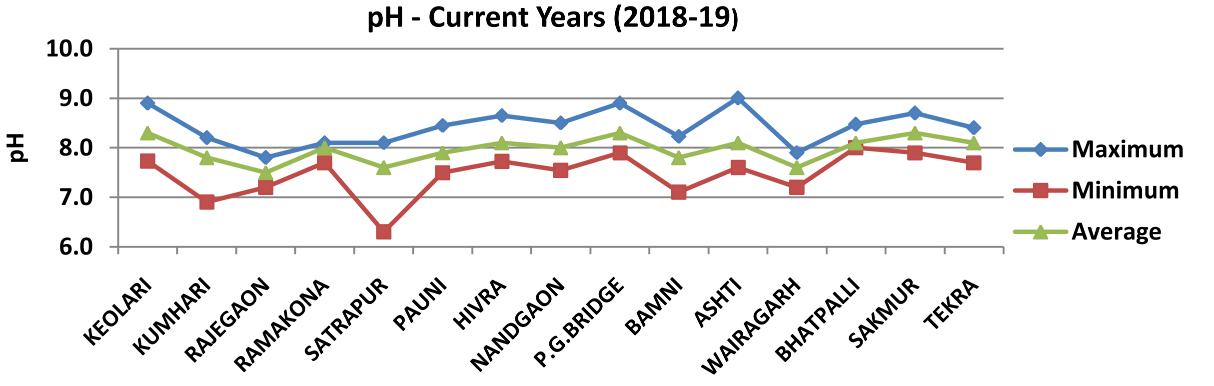

Figure 3 (b)

TABLE 6 : DISSOLVED OXYGEN						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	13.4	0.0	7.2	11.9	6.0	8.6
KUMHARI	11.7	0.0	7.3	10.2	5.2	8.2
RAJEGAON	8.9	4.8	6.8	8.7	5.0	6.9
RAMAKONA	11.2	0.0	7.0	8.6	5.6	6.9
SATRAPUR	11.4	1.7	7.2	8.4	1.7	5.2
PAUNI	9.5	3.0	6.8	8.0	3.0	6.3
HIVRA	9.0	1.1	6.3	7.1	1.1	4.6
NANDGAON	8.8	1.1	6.1	7.5	4.6	6.0
P.G.BRIDGE	9.8	5.0	7.4	8.7	5.0	7.2
BAMNI	8.5	0.0	5.6	7.4	1.6	5.0
ASHTI	9.5	0.6	6.9	8.3	0.6	6.2
WAIRAGARH	9.2	1.4	6.8	8.0	6.1	6.7
BHATPALLI	11.5	0.9	7.2	10.6	4.0	7.4
SAKMUR	11.4	1.5	6.2	11.4	4.1	7.1
TEKRA	10.2	4.7	7.0	8.8	6.1	7.1

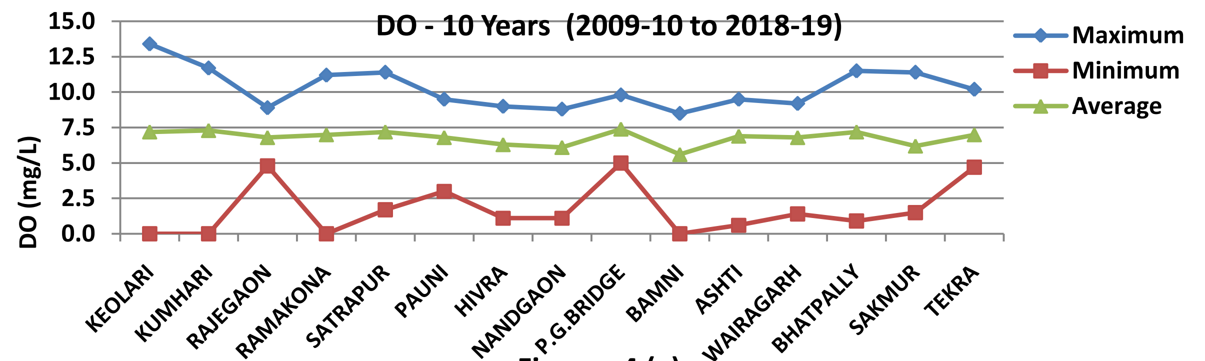

Figure: 4 (a)

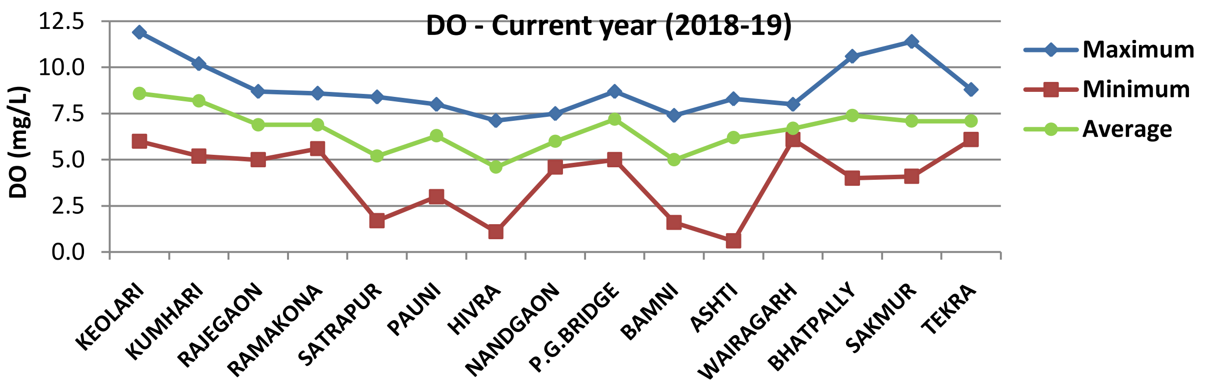

Figure: 4 (b)

TABLE 7 : BIOCHEMICAL OXYGEN DEMAND						
Site Name (From U/s to D/s)	**10 Years (2009-10 to 2018-19)**			**Current year (2018-2019)**		
	Maximum	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**
KEOLARI	45.0	0.9	7.3	6.5	1.1	2.7
KUMHARI	45.0	0.4	3.0	3.4	1.1	1.7
RAJEGAON	75.0	0.6	3.0	75.0	1.1	9.9
RAMAKONA	25.0	0.9	3.8	2.8	1.1	2.0
SATRAPUR	110.0	0.3	7.1	110.0	1.7	25.8
PAUNI	55.0	1.0	4.8	55.0	1.2	7.5
HIVRA	70.0	0.6	5.8	70.0	1.3	19.6
NANDGAON	105.0	0.6	7.0	60.0	0.6	17.1
P.G.BRIDGE	50.0	0.5	2.7	4.4	1.2	2.0
BAMNI	225.0	0.5	13.4	120.0	1.0	21.7
ASHTI	40.0	0.3	2.0	2.8	0.6	1.8
WAIRAGARH	25.0	0.4	2.4	3.1	0.8	1.4
BHATPALLI	85.0	0.4	3.8	2.8	1.0	2.0
SAKMUR	80.0	1.0	10.8	35.0	1.2	5.8
TEKRA	45.0	0.4	2.7	3.4	1.0	1.8

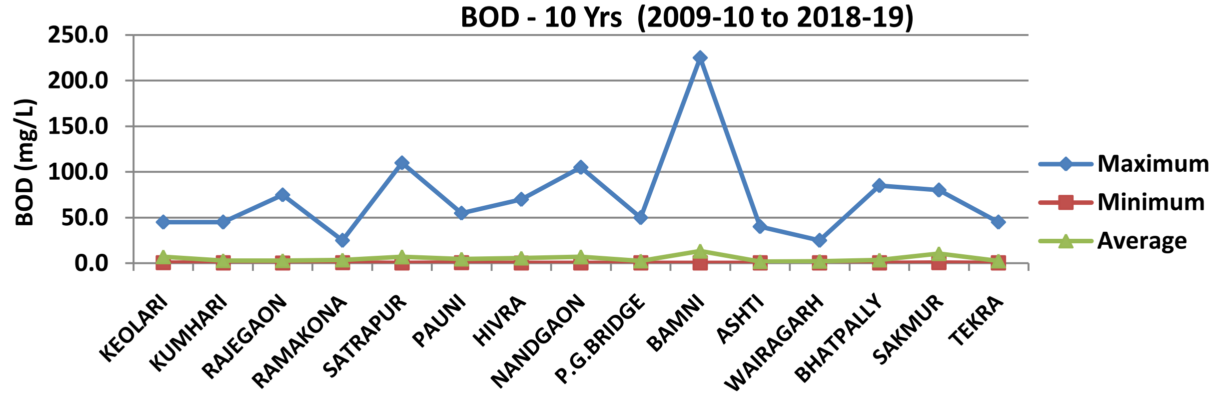

Figure: 5 (a)

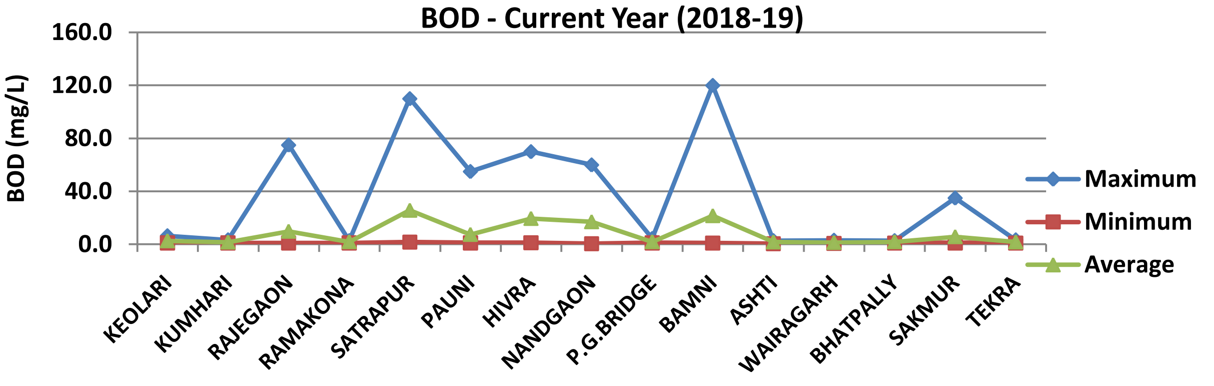

Figure: 5 (b)

TABLE 8 : SODIUM						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	70.0	9.5	20.8	70.0	14.0	29.5
KUMHARI	51.3	1.3	18.9	35.0	10.3	21.2
RAJEGAON	38.8	1.9	14.3	38.8	12.7	19.3
RAMAKONA	54.0	10.9	26.4	54.0	10.9	24.4
SATRAPUR	87.6	2.7	41.0	64.0	10.1	49.1
PAUNI	61.9	4.3	23.5	42.0	12.8	24.9
HIVRA	152.0	8.2	44.0	74.4	40.8	54.5
NANDGAON	94.2	10.3	34.9	60.0	25.2	37.3
P.G.BRIDGE	67.6	4.1	29.9	67.6	12.8	35.6
BAMNI	373.1	3.0	63.4	373.1	32.7	102.2
ASHTI	54.3	4.0	22.3	45.7	11.5	22.1
WAIRAGARH	29.8	6.6	13.2	29.8	10.8	17.4
BHATPALLI	105.6	9.9	43.0	61.5	19.3	39.6
SAKMUR	117.0	14.0	47.2	98.9	16.4	57.4
TEKRA	72.6	2.4	31.4	48.0	19.9	33.0

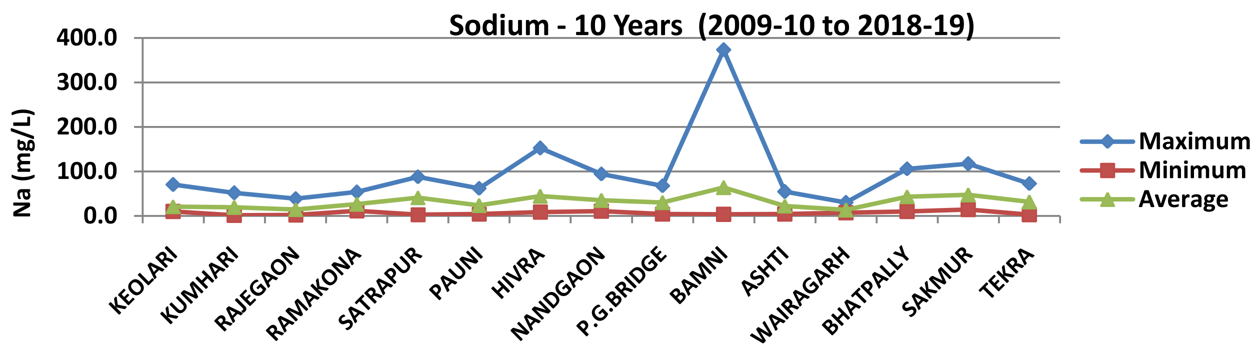

Figure: 6 (a)

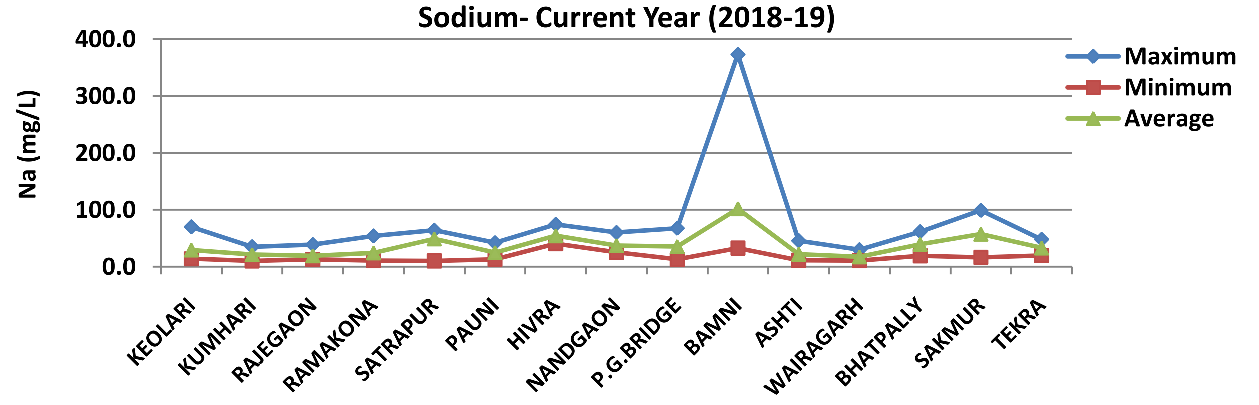

Figure: 6 (b)

3.1.6 Potassium (K): During the current water year 2018-19 the maximum values of K are in the range of 12.0 to 65.7 mg/L, minimum values are in the range of 1.2 to 3.0 mg/L and average values are in the range of 3.8 to 17.4 mg/Las shown in Figure 7 (b) and Table 9. The value of Potassium is not prescribed in BIS 2296: 1982.

3.1.7 Calcium (Ca): During the current water year 2018-19 the maximum values of Ca are in the range of 42.5 to 163.5 mg/L, minimum values are in the range of 3.2 to 8.0 mg/L and average values are in the range of 16.3 to 76.4 mg/L as shown in Figure 8 (b) and Table 10. The value of calcium is not prescribed in BIS 2296: 1982.

3.1.8 Calcium Hardness as $CaCO_3$(CH) : During the current water year 2018-19 the maximum values of CH are in the range of 106 to 409 mg/L , minimum values are in the range of 8.1 to 20.3 mg/L and average values are in the range of 41.4 to 191.3 mg/L as shown in Figure 9 (b) and Table 11. It is observed from the results minimum values and average value CH of all sites are under the prescribed limit for class A .The maximum values of Tekra, Bamni, P.G.Bridge, Nandgaon, Ashti, Pauni, Satrapur, Kumhari, Sakmur and Keolari are above class A.

3.1.9 Total Hardness as $CaCO_3$(TH) : During the current water year 2018-19 the maximum values of TH are in the range of 120.0 to 621.0 mg/L , minimum values are in the range of 51.0 to 220.0 mg/L , and average values are in the range of 73.0 to 310.0 mg/Las shown in Figure 10 (b) and Table12. It is observed from the results minimum TH values of all sites are under the prescribed limit. The average TH values of all sites are under the prescribed limit except Bamnisite is above class A, The maximum values of Bamni, Hivra, Ashti, Kumhari, sakmur are above class A.

3.1.10 Magnesium (Mg) : During the currentwater year 2018-19 the maximum values are in the range of 15.7 to 77.9 mg/L , minimum values are in the range of 1.1 to 5.9 mg/L and average values are in the range of 7.7 to 29.8 mg/Las shown in Figure 11 (b) and Table 13. It is observed from the results the average, minimum and maximum Mg values of all sites are under the prescribed limit for class A.

3.1.11 Iron (Fe): During the current water year 2018-19 the maximum values of Iron are in the range of 0.254 to 2.819 mg/L, minimum values are in the range of 0.000 to 0.000 mg/L and average values are in the range of 0.085 to 0.512 mg/L as shown in Figure 12 (b) and Table 14. It is observed from the results the minimum Fe values are within prescribed limit for Class A and C. The average Fe values of Keolari, Rajegaon, Ramkona, Nandgaon, Wairagarh sites are under the prescribed limit and remaining other sites are above prescribed limit for class A and average values of all sites are below Class C. The maximum

TABLE 9 : POTASSIUM						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	39.7	0.8	2.4	39.7	1.2	5.9
KUMHARI	21.4	0.6	2.1	21.4	1.2	4.0
RAJEGAON	12.0	1.0	2.4	12.0	1.8	3.8
RAMAKONA	31.4	1.3	3.0	31.4	2.1	9.1
SATRAPUR	38.7	1.1	3.2	38.7	2.7	6.9
PAUNI	39.1	0.9	3.5	17.1	1.7	4.6
HIVRA	37.1	1.0	3.4	37.1	3.0	6.6
NANDGAON	49.5	0.9	3.4	49.5	2.0	8.5
P.G.BRIDGE	44.7	1.0	3.2	44.7	2.1	7.0
BAMNI	65.7	1.2	8.0	65.7	3.0	17.4
ASHTI	20.3	0.8	2.7	20.3	1.7	4.9
WAIRAGARH	13.1	1.0	2.4	13.1	1.4	4.5
BHATPALLI	38.3	0.9	2.7	38.3	2.0	6.2
SAKMUR	40.8	0.4	4.9	40.8	2.6	8.5
TEKRA	20.6	1.1	3.1	20.6	2.0	4.9

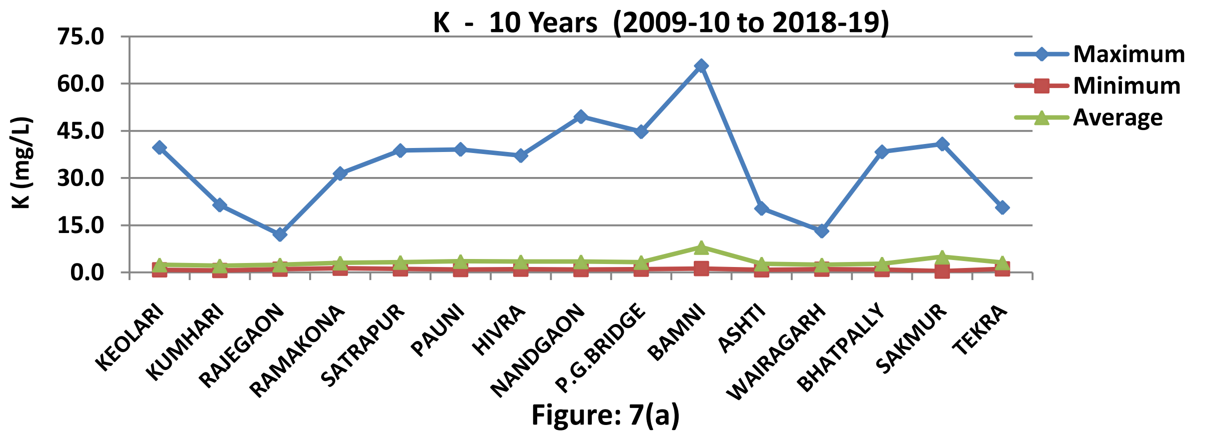

Figure: 7(a)

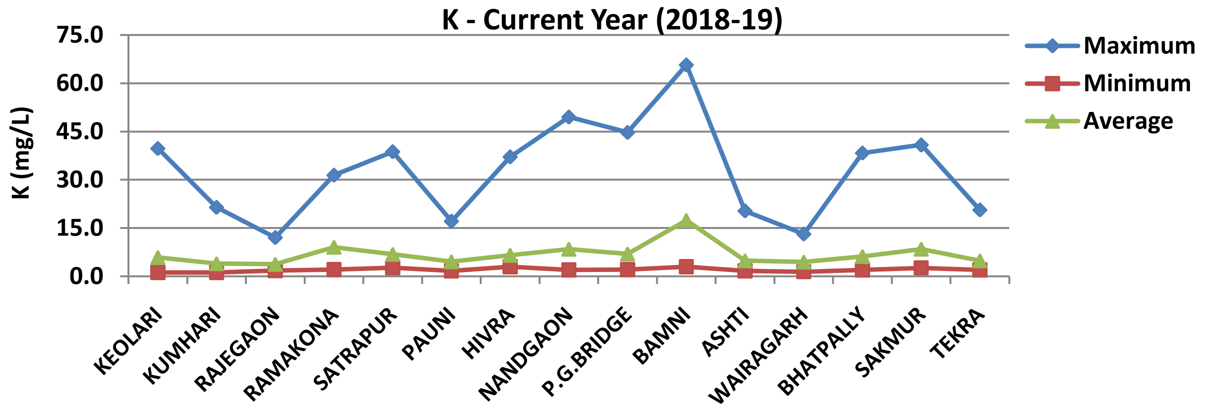

Figure: 7 (b)

TABLE 10 : CALCIUM						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	100.0	3.2	40.4	100.0	3.2	40.2
KUMHARI	146.0	4.3	40.4	146.0	4.3	47.9
RAJEGAON	60.3	4.4	27.8	50.0	4.4	26.7
RAMAKONA	77.5	5.5	46.5	77.5	5.5	43.8
SATRAPUR	100.0	5.7	47.1	100.0	5.7	55.3
PAUNI	95.0	6.7	35.2	95.0	6.7	33.0
HIVRA	74.7	6.3	32.4	60.0	6.3	27.8
NANDGAON	110.0	4.4	42.8	110.0	6.3	47.0
P.G.BRIDGE	94.5	6.0	36.9	90.0	6.0	38.1
BAMNI	248.4	8.0	58.1	163.5	8.0	76.4
ASHTI	82.5	4.9	29.1	82.5	4.9	31.0
WAIRAGARH	42.5	4.6	18.2	42.5	4.6	16.3
BHATPALLI	96.3	5.1	38.1	77.5	5.1	38.0
SAKMUR	128.0	7.6	41.7	128.0	7.6	46.7
TEKRA	85.0	6.1	34.5	85.0	6.1	35.2

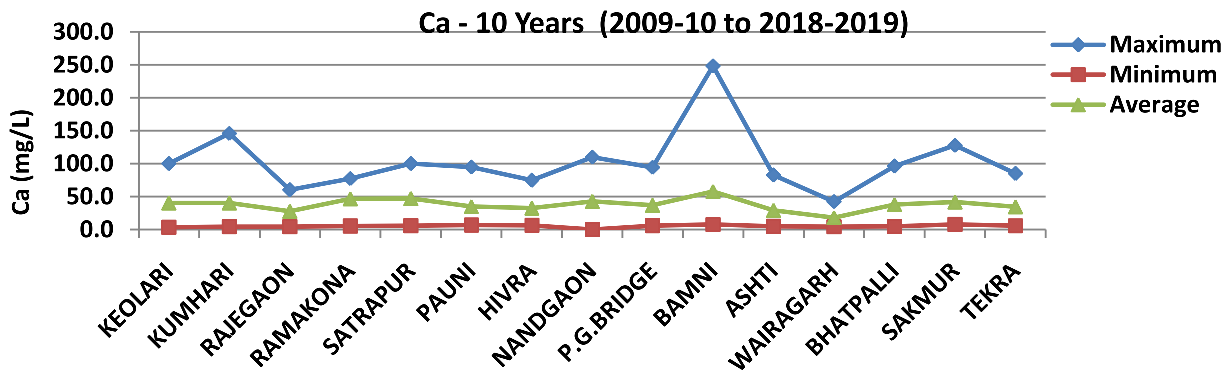

Figure: 8 (a)

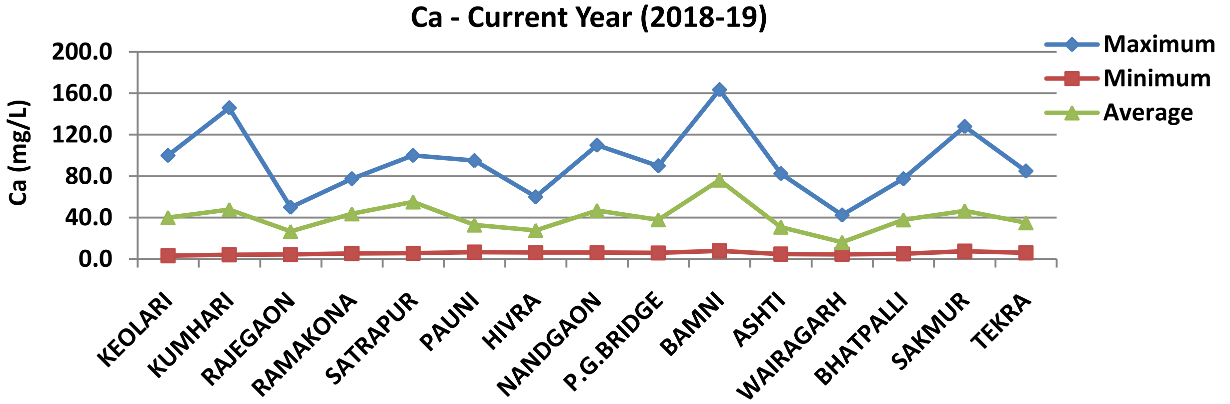

Figure: 8 (b)

TABLE 11 : CALCIUM HARDNESS

Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	250.0	8.1	101.1	250.6	8.1	101.3
KUMHARI	365.0	10.8	101.1	365.2	10.8	120.5
RAJEGAON	150.0	11.1	69.5	125.1	11.1	67.4
RAMAKONA	193.8	13.8	116.4	193.8	13.8	110.5
SATRAPUR	250.0	14.2	117.8	250.3	14.2	138.2
PAUNI	237.5	16.6	88.0	237.5	16.6	82.1
HIVRA	186.8	15.8	81.0	150.6	15.8	70.4
NANDGAON	275.0	16.1	107.1	275.0	16.1	117.5
P.G.BRIDGE	236.3	14.9	92.3	225.8	14.9	95.1
BAMNI	621.0	20.1	145.3	409.6	20.3	191.3
ASHTI	206.3	12.2	72.8	206.3	12.2	77.6
WAIRAGARH	106.3	11.6	45.5	106.3	11.6	41.4
BHATPALLI	240.8	12.7	95.1	194.1	12.7	94.8
SAKMUR	320.0	19.0	104.2	320.6	19.0	117.3
TEKRA	212.5	15.3	86.2	212.5	15.7	88.1

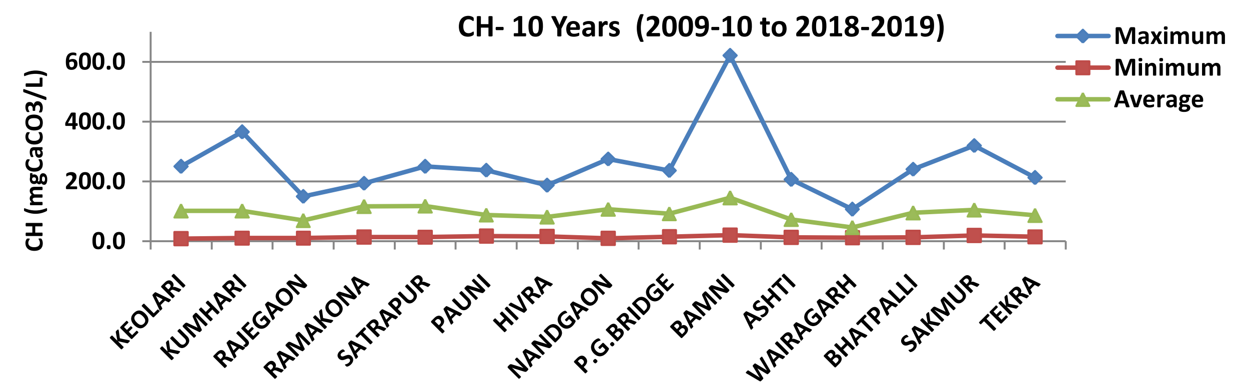

Figure : 9 (a)

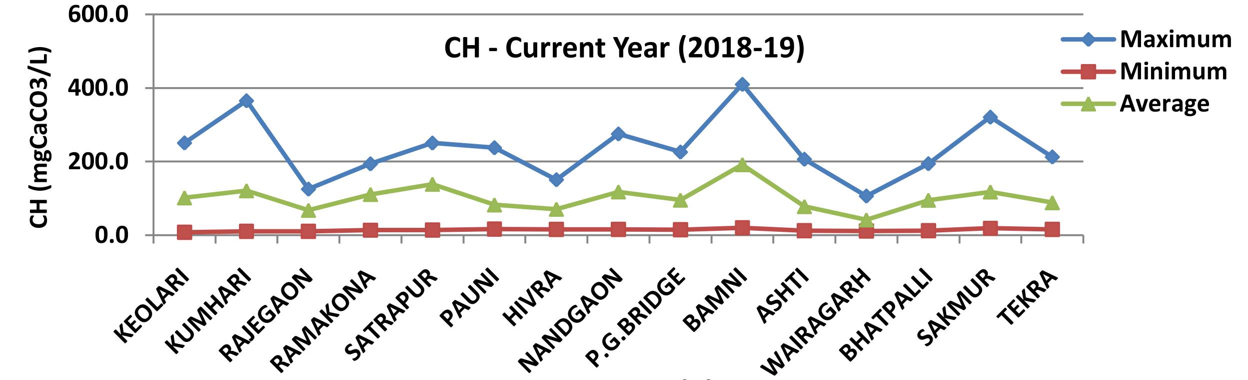

Figure : 9 (b)

TABLE 12 : TOTAL HARDNESS						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	299.1	82.2	167.1	299.0	82.0	166.0
KUMHARI	387.4	64.3	161.8	387.0	86.0	171.0
RAJEGAON	226.0	44.3	111.9	147.0	69.0	112.0
RAMAKONA	280.9	99.9	185.7	209.0	144.0	178.0
SATRAPUR	437.3	106.5	211.6	299.0	190.0	248.0
PAUNI	279.5	80.3	148.8	279.0	91.0	134.0
HIVRA	340.4	86.9	172.0	340.0	87.0	175.0
NANDGAON	406.9	93.0	200.8	309.0	191.0	241.0
P.G.BRIDGE	368.5	42.7	193.3	249.0	127.0	199.0
BAMNI	880.8	58.2	257.3	621.0	220.0	310.0
ASHTI	307.8	59.2	128.4	308.0	86.0	129.0
WAIRAGARH	120.8	32.9	70.3	120.0	51.0	73.0
BHATPALLI	393.5	100.3	202.8	239.0	100.0	201.0
SAKMUR	329.0	115.1	199.6	329.0	171.0	222.0
TEKRA	375.1	73.4	162.4	234.0	122.0	158.0

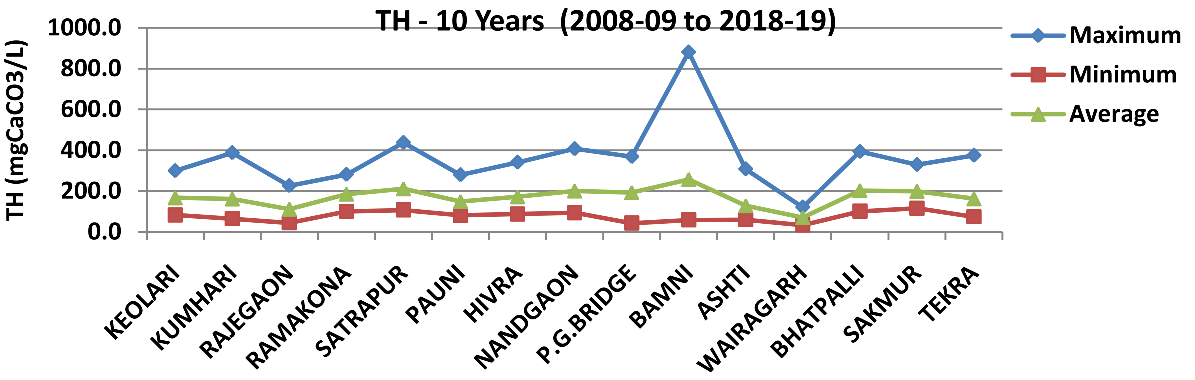

Figure :10 (a)

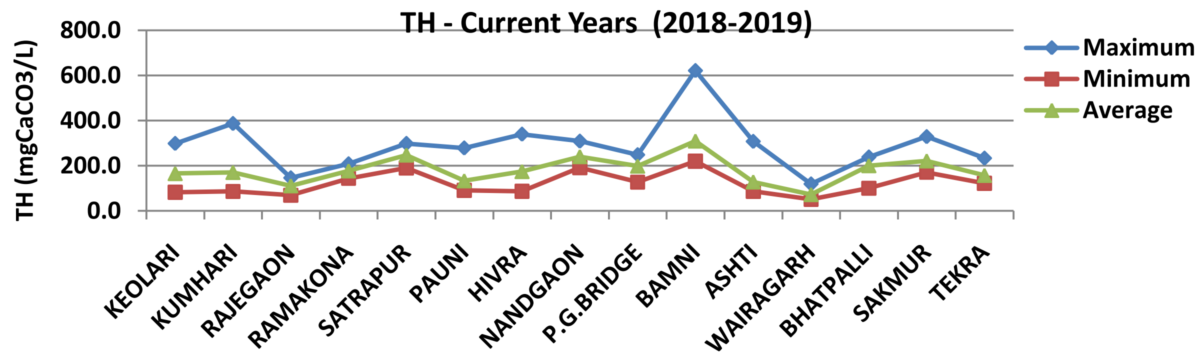

Figure : 10 (b)

TABLE 13 : MAGNESIUM						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	48.6	1.6	15.8	24.4	1.7	15.7
KUMHARI	32.3	3.9	14.6	18.8	5.1	12.2
RAJEGAON	31.9	0.9	10.2	15.7	2.5	10.8
RAMAKONA	31.3	3.6	16.6	31.3	3.6	16.4
SATRAPUR	56.9	3.0	22.5	51.8	3.0	26.4
PAUNI	41.6	1.7	14.6	21.2	1.7	12.3
HIVRA	77.9	1.7	21.8	77.9	1.7	25.2
NANDGAON	70.3	2.4	22.5	70.3	3.5	29.8
P.G.BRIDGE	54.7	1.5	24.2	39.9	1.5	24.9
BAMNI	107.8	3.8	26.9	66.6	5.9	28.6
ASHTI	36.2	1.1	13.4	24.4	1.1	12.5
WAIRAGARH	19.3	0.0	5.9	19.3	3.3	7.7
BHATPALLI	53.8	2.5	25.9	53.8	2.5	26.1
SAKMUR	54.1	2.2	22.9	54.1	2.2	25.2
TEKRA	71.4	2.0	18.3	29.1	2.0	16.7

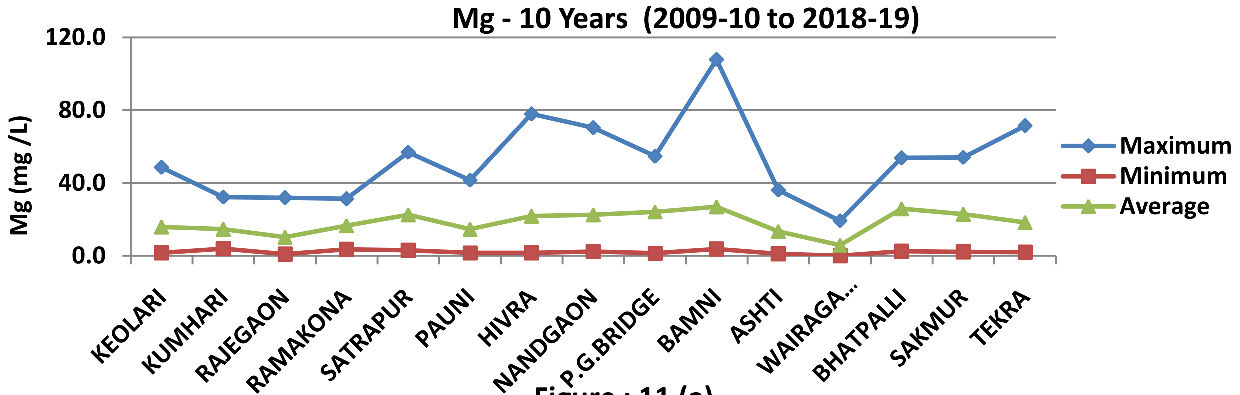

Figure : 11 (a)

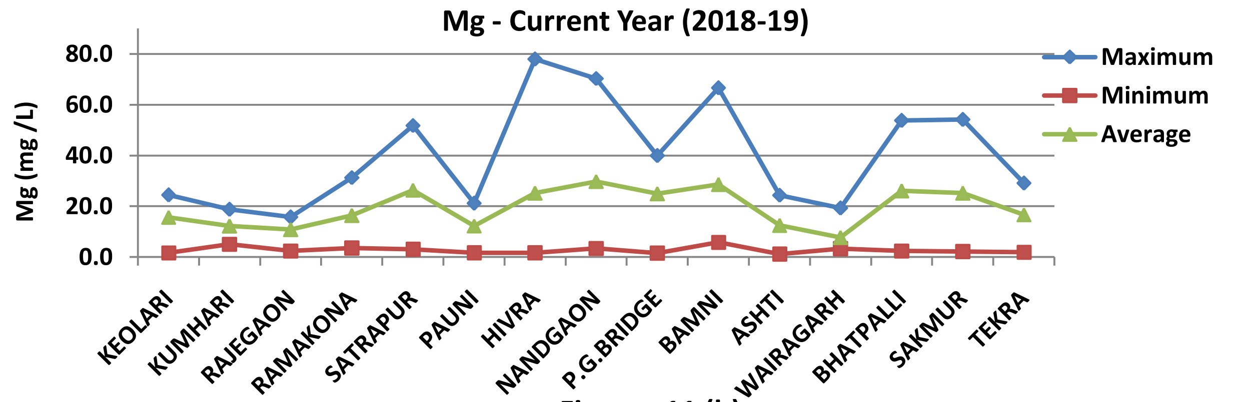

Figure : 11 (b)

TABLE 14 : IRON						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	0.426	0.000	0.112	0.254	0.000	0.085
KUMHARI	2.819	0.000	0.204	2.819	0.000	0.512
RAJEGAON	2.318	0.000	0.291	0.439	0.000	0.155
RAMAKONA	1.786	0.000	0.211	0.340	0.000	0.124
SATRAPUR	1.927	0.000	0.241	1.927	0.000	0.348
PAUNI	2.237	0.000	0.236	2.237	0.000	0.422
HIVRA	2.209	0.000	0.219	2.209	0.000	0.495
NANDGAON	1.814	0.000	0.980	0.266	0.000	0.092
P.G.BRIDGE	7.249	0.000	0.209	2.088	0.000	0.387
BAMNI	2.409	0.000	0.228	2.082	0.000	0.376
ASHTI	2.409	0.000	0.198	2.409	0.000	0.449
WAIRAGARH	1.647	0.000	0.222	0.404	0.000	0.122
BHATPALLI	2.131	0.000	0.183	1.921	0.000	0.351
SAKMUR	1.931	0.000	0.118	1.932	0.000	0.375
TEKRA	2.038	0.000	0.104	2.038	0.000	0.382

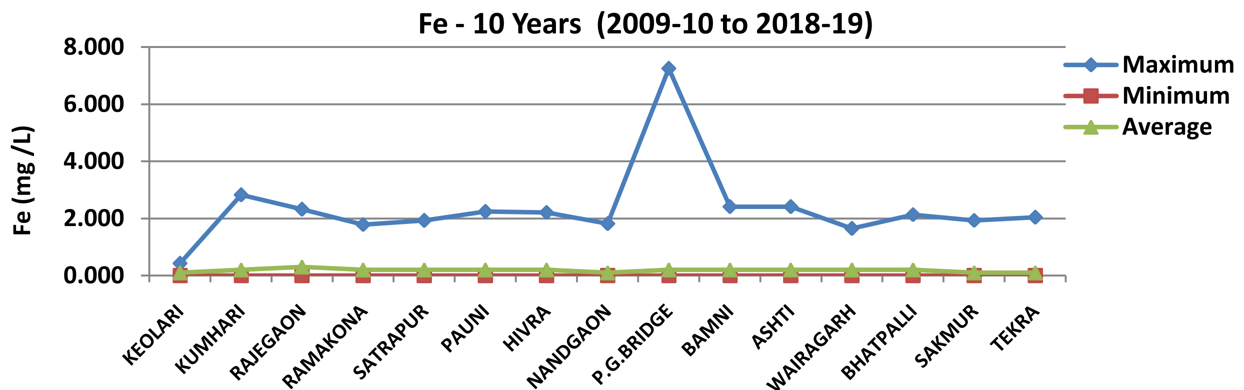

Figure :12 (a)

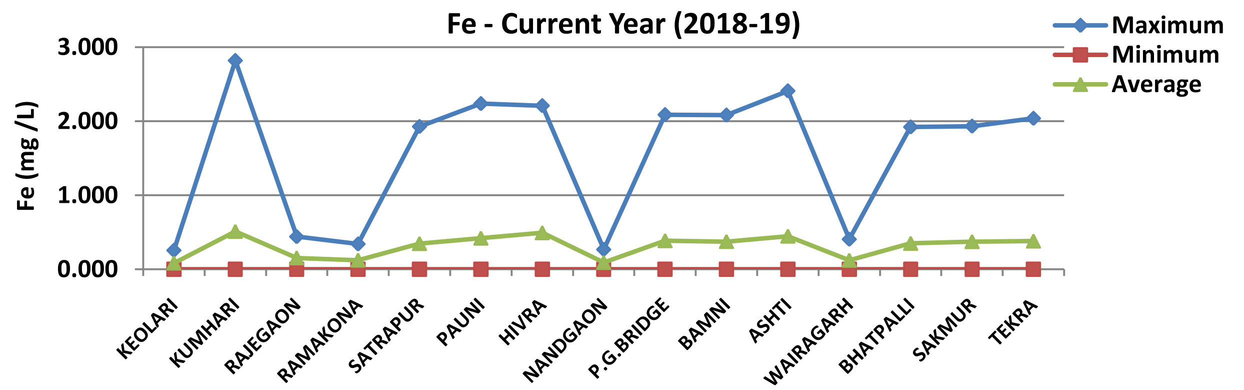

Figure : 12 (b)

Fe values of all sites are also above the prescribed limit for class A except Keolari, Nandgaon are within limit, however the maximum values of all sites under the prescribed limit of Class C.

3.1.12 Bicarbonate (HCO_3): During the current water year 2018-19 the maximum values are in the range of 174.2 to 412.6 mg/L, minimum values are in the range of 68.3 to 229.4 mg/L and average values are in the range of 107.1 to 297.2 mg/Las shown in Figure 13 (b) and Table 15. The value of Bicarbonate is not prescribed in BIS 2296: 1982.

3.1.13 Chloride (Cl): During the current water year 2018-19 the maximum values of Cl are in the range of 17.2 to 409.2 mg/L, minimum values are in the range of 2.7 to 32.8 mg/L and average values are in the range of 9.3 to 106.6 mg/L as shown in Figure 14 (b) and Table16. It is observed from the results the average and minimum Cl values of all sites are under the prescribed limit for class A and maximum Cl values of all sites are also under the prescribed limit for class A except Bamni site is above Class A and below class C & E.

3.1.14 Fluoride (F) : During the current water year 2018-19 the maximum values ofFluoride are in the range of 0.34 to 0.77 mg/L, minimum values are in the range of 0.10 to 0.36 mg/L, and average values are in the range of 0.29 to 0.60 mg/L as shown in Figure 15 (b) and Table17. It is observed from the results the average, minimum and maximum F values of all sites are under the prescribed limit for class A, B & C.

3.1.15 Sulphate(SO_4): During the current water year 2018-19 the maximum values of SO_4 are in the range of 10.8 to 626.4, mg/L, minimum values are in the range of 2.0 to 36.1 mg/L and average values are in the range of 6.3 to 123.6. mg/Las shown in Figure 16 (b) and Table18. It is observed from the results the average, minimum and maximum SO_4 values of all sites are under the prescribed limit for class A,C& E except Bamni site The maximum SO_4 value of Bamni are above class A & C and below class E.

3.1.16 Nitrate (NO_3): During the current water year 2018-19 the maximum values of NO_3 are in the range of 10.7 to 57.5 mg/L, minimum values are in the range of 0.0 to 2.0 mg/L and average values are in the range of 6.2 to 16.5 mg/Las shown in Figure 17 (b) and Table 19. It is observed from the results the average, minimum and maximum NO_3 values of all sites are under the prescribed limit for class A and class C except Keolari.

3.1.17 Ammonia (NH_3N): During the current water year 2018-19 the maximum values of NH_3N are in the range of 0.8 to 5.2, minimum values are in the range of 0.0 to 0.3 and average values are in the range of 0.4 to 1.7 as shown in Figure 18 (b) and Table 20. It is observed from the results minimum NH_3N values of all sites are within prescribed limit for class D. However, the average values of NH_3N values all sites are within prescribed limit

TABLE 15 : BICARBONATE						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	313.1	90.0	196.8	313.1	90.0	198.4
KUMHARI	355.3	60.4	190.1	342.3	136.6	208.2
RAJEGAON	266.4	32.0	123.8	266.4	107.4	145.1
RAMAKONA	266.4	32.0	123.8	266.5	192.8	228.7
SATRAPUR	395.0	60.3	234.4	366.0	160.3	266.5
PAUNI	310.0	80.0	181.6	299.8	104.9	164.7
HIVRA	484.0	80.7	243.4	361.2	209.8	266.5
NANDGAON	419.6	109.8	237.6	381.8	222.1	270.7
P.G.BRIDGE	450.0	65.9	227.0	345.9	166.5	246.2
BAMNI	485.6	96.8	259.6	412.6	229.4	297.2
ASHTI	282.0	73.8	155.4	238.3	115.3	157.4
WAIRAGARH	174.2	37.0	88.8	174.2	68.3	107.1
BHATPALLI	450.6	120.0	283.2	351.0	217.8	289.1
SAKMUR	359.0	134.3	217.9	345.0	134.3	215.2
TEKRA	398.0	95.0	198.2	243.5	156.2	203.8

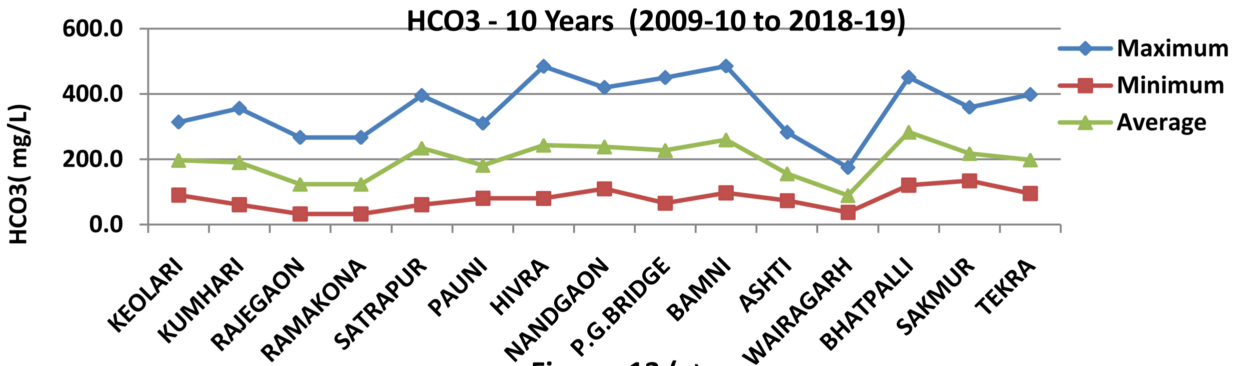

Figure: 13 (a)

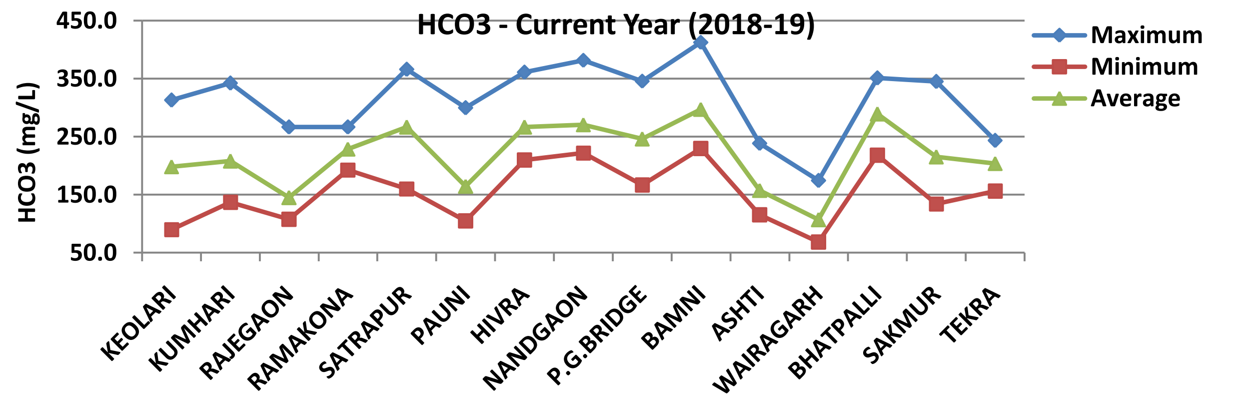

Figure : 13 (b)

TABLE 16 : CHLORIDE						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	26.1	5.1	14.5	26.1	8.1	15.9
KUMHARI	77.7	2.8	16.6	56.1	7.1	14.0
RAJEGAON	67.5	2.0	11.0	20.4	3.7	9.3
RAMAKONA	24.9	4.0	15.1	22.2	10.8	17.2
SATRAPUR	112.2	3.6	40.2	78.1	20.3	46.0
PAUNI	62.5	3.6	19.5	39.0	8.1	19.3
HIVRA	97.4	7.8	24.1	49.4	21.6	31.3
NANDGAON	74.6	7.8	32.9	63.1	22.2	38.9
P.G.BRIDGE	113.3	4.0	25.2	44.2	10.9	28.4
BAMNI	500.3	2.1	82.9	409.9	32.8	106.6
ASHTI	78.8	2.9	17.5	38.0	8.1	16.0
WAIRAGARH	17.7	2.7	9.5	17.0	2.7	10.0
BHATPALLI	204.0	5.8	18.3	61.8	10.8	20.5
SAKMUR	161.2	8.0	46.3	161.2	17.2	57.5
TEKRA	68.2	3.2	23.5	29.0	9.4	21.0

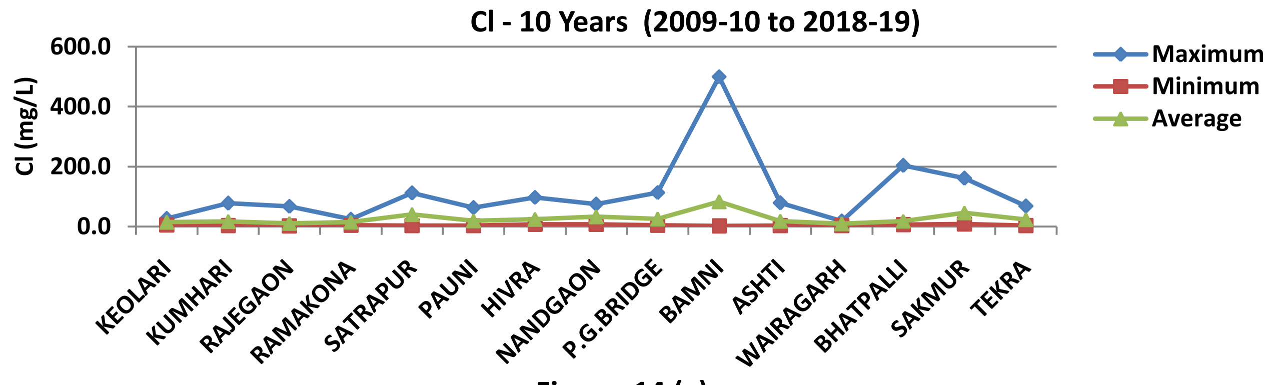

Figure: 14 (a)

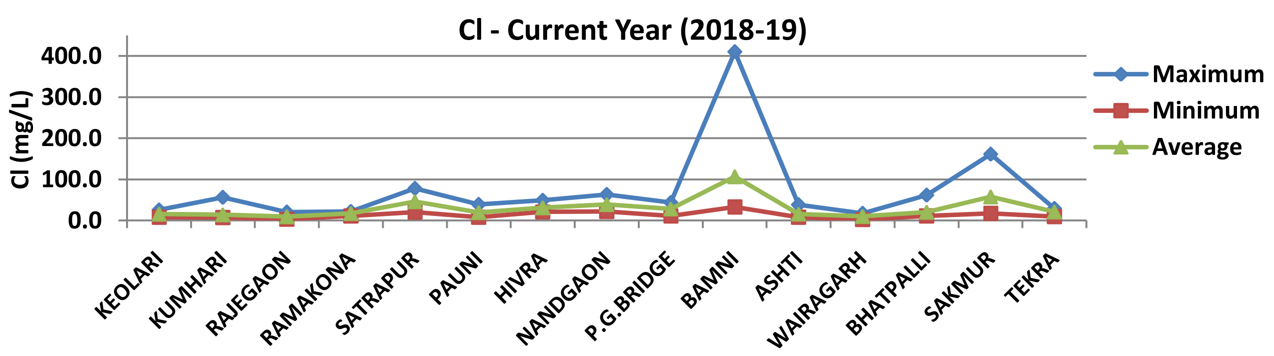

Figure: 14 (b)

TABLE 17 : FLUORIDE						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	1.09	0.00	0.32	0.44	0.19	0.31
KUMHARI	0.73	0.00	0.34	0.46	0.17	0.36
RAJEGAON	1.22	0.00	0.21	0.34	0.10	0.29
RAMAKONA	1.90	0.00	0.54	0.65	0.34	0.46
SATRAPUR	3.00	0.00	0.53	0.67	0.27	0.51
PAUNI	1.16	0.00	0.31	0.45	0.21	0.33
HIVRA	1.67	0.00	0.47	0.51	0.29	0.44
NANDGAON	1.86	0.00	0.41	0.57	0.28	0.41
P.G.BRIDGE	1.54	0.00	0.48	0.57	0.23	0.40
BAMNI	1.40	0.00	0.56	0.59	0.33	0.48
ASHTI	2.65	0.00	0.42	0.45	0.22	0.33
WAIRAGARH	0.66	0.00	0.11	0.36	0.10	0.29
BHATPALLI	2.52	0.00	0.73	0.77	0.36	0.60
SAKMUR	1.63	0.00	0.40	0.61	0.27	0.44
TEKRA	1.86	0.00	0.44	0.55	0.26	0.47

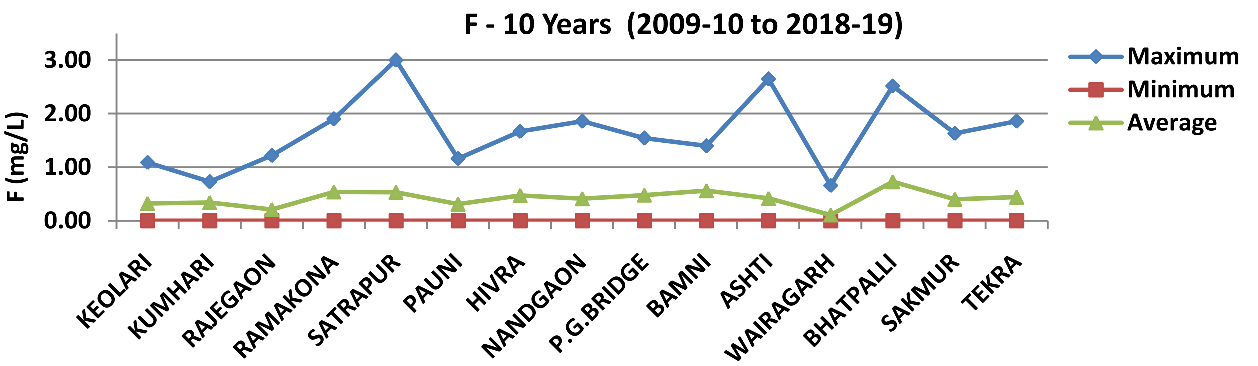

Figure : 15(a)

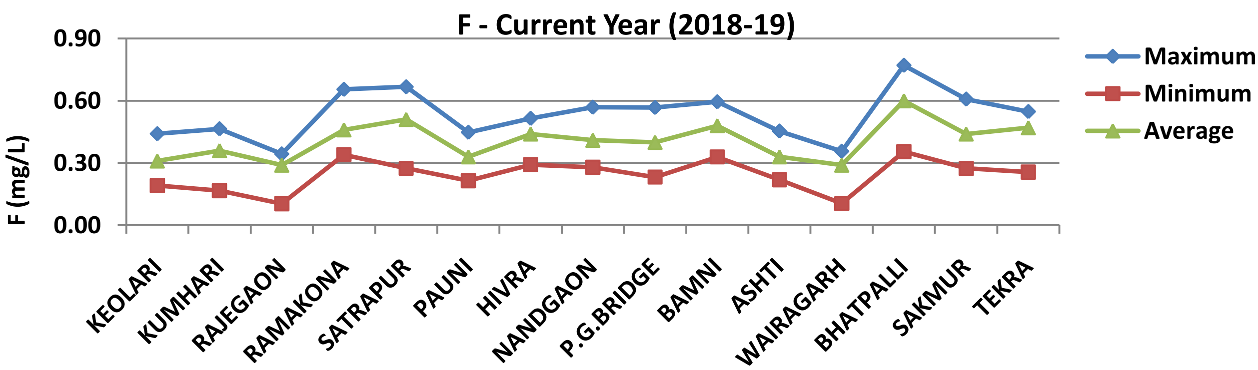

Figure : 15 (b)

TABLE 18 : SULPHATE						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	68.0	1.0	10.9	34.3	3.7	13.4
KUMHARI	189.6	0.1	11.9	10.8	2.0	6.3
RAJEGAON	49.0	0.9	15.1	31.6	3.6	16.5
RAMAKONA	84.6	2.5	24.8	39.4	10.1	24.8
SATRAPUR	161.1	1.0	33.0	139.5	22.2	55.5
PAUNI	75.0	0.1	14.4	18.4	9.3	13.9
HIVRA	104.6	0.5	16.7	39.1	10.9	20.0
NANDGAON	85.6	1.2	20.2	38.9	18.4	30.7
P.G.BRIDGE	89.6	0.4	16.6	27.9	6.3	20.7
BAMNI	626.4	1.4	44.9	626.4	36.1	123.6
ASHTI	164.9	0.3	13.1	16.8	3.4	12.3
WAIRAGARH	37.9	1.0	8.5	15.2	5.4	9.7
BHATPALLI	42.8	0.2	16.8	22.5	3.0	18.3
SAKMUR	171.3	2.4	41.5	132.7	19.6	64.1
TEKRA	78.0	1.6	18.9	36.2	15.9	22.9

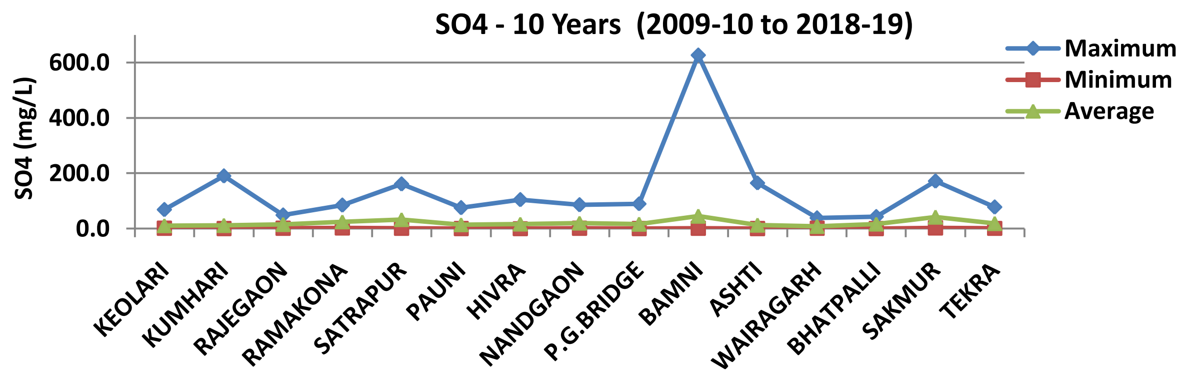

Figure :16 (a)

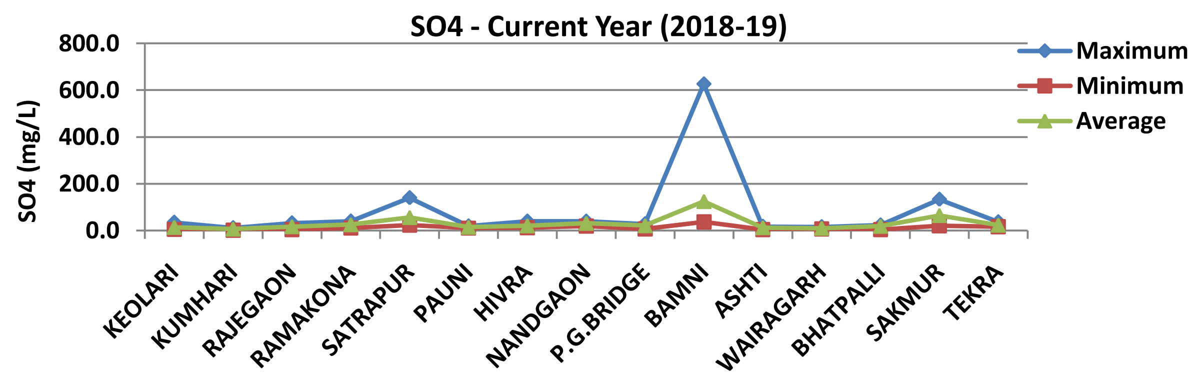

Figure : 16 (b)

TABLE 19 : NITRATE						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	57.5	0.5	6.5	57.5	1.6	16.5
KUMHARI	28.2	0.0	3.6	28.2	0.0	8.7
RAJEGAON	14.3	0.0	3.2	10.7	1.6	6.5
RAMAKONA	14.2	0.3	5.8	13.4	1.6	6.8
SATRAPUR	21.0	0.0	3.2	16.2	0.0	8.9
PAUNI	17.6	0.0	2.6	17.6	0.0	7.8
HIVRA	17.8	0.0	3.6	17.8	0.0	8.2
NANDGAON	17.1	0.0	3.3	17.1	2.0	9.4
P.G.BRIDGE	28.2	0.0	4.3	28.2	0.0	11.8
BAMNI	28.2	0.0	4.3	28.2	0.0	13.7
ASHTI	12.9	0.0	2.4	12.9	0.0	6.2
WAIRAGARH	21.1	0.8	4.3	21.1	1.4	8.2
BHATPALLI	28.2	0.0	3.6	28.2	0.0	8.6
SAKMUR	28.8	0.0	5.5	28.8	0.0	11.1
TEKRA	17.4	0.0	2.5	17.4	0.0	8.2

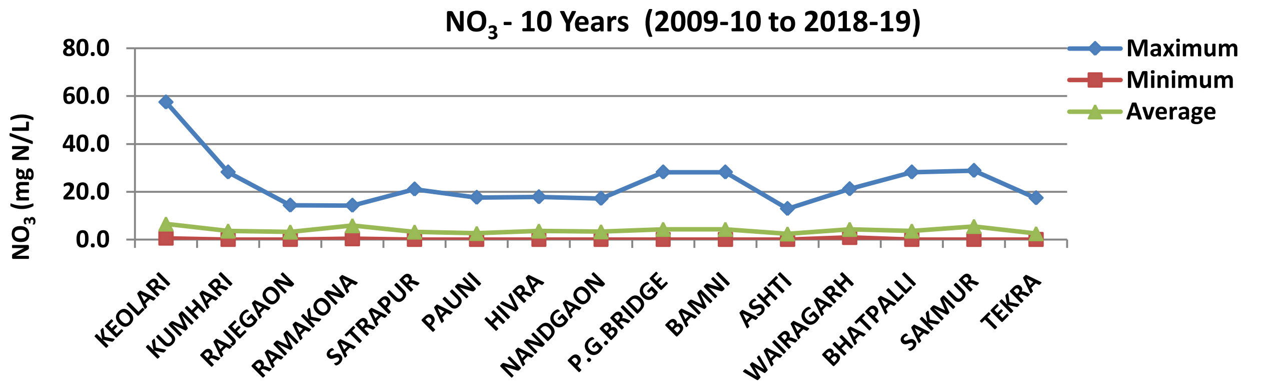

Figure : 17 (a)

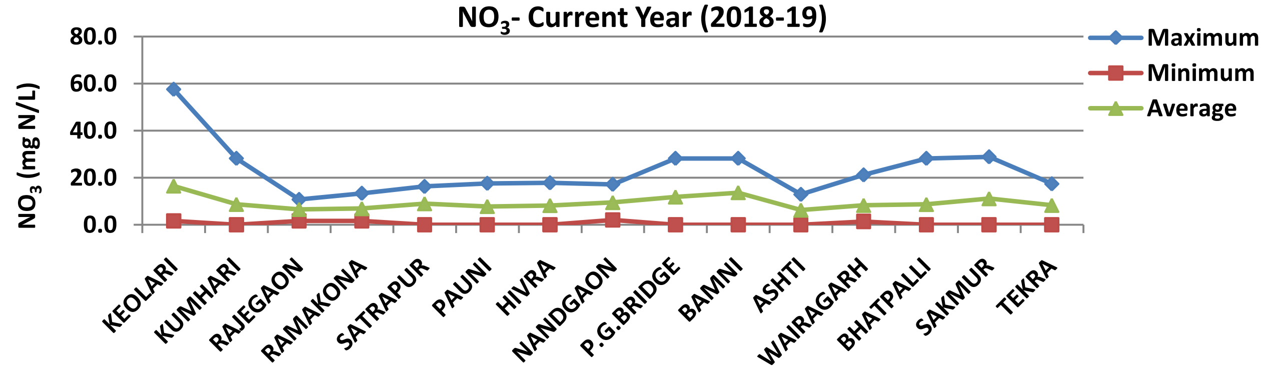

Figure : 17 (b)

TABLE 20 : AMMONICAL NITROGEN

Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	3.4	0.0	0.3	3.4	0.0	0.4
KUMHARI	3.2	0.0	0.4	3.2	0.1	0.8
RAJEGAON	3.4	0.0	0.3	3.4	0.1	1.0
RAMAKONA	1.0	0.0	0.2	0.8	0.0	0.4
SATRAPUR	5.2	0.0	0.4	5.2	0.3	1.2
PAUNI	4.1	0.0	0.3	4.1	0.1	1.0
HIVRA	2.3	0.0	0.3	2.4	0.2	1.0
NANDGAON	2.0	0.0	0.2	0.9	0.2	0.6
P.G.BRIDGE	2.2	0.0	0.3	2.2	0.1	0.7
BAMNI	8.4	0.0	0.5	4.3	0.3	1.7
ASHTI	2.5	0.0	0.3	2.1	0.1	0.7
WAIRAGARH	1.5	0.0	0.2	1.5	0.0	0.4
BHATPALLI	2.2	0.0	0.3	2.2	0.1	0.6
SAKMUR	3.6	0.0	0.4	3.6	0.2	0.9
TEKRA	1.3	0.0	0.3	1.3	0.0	0.4

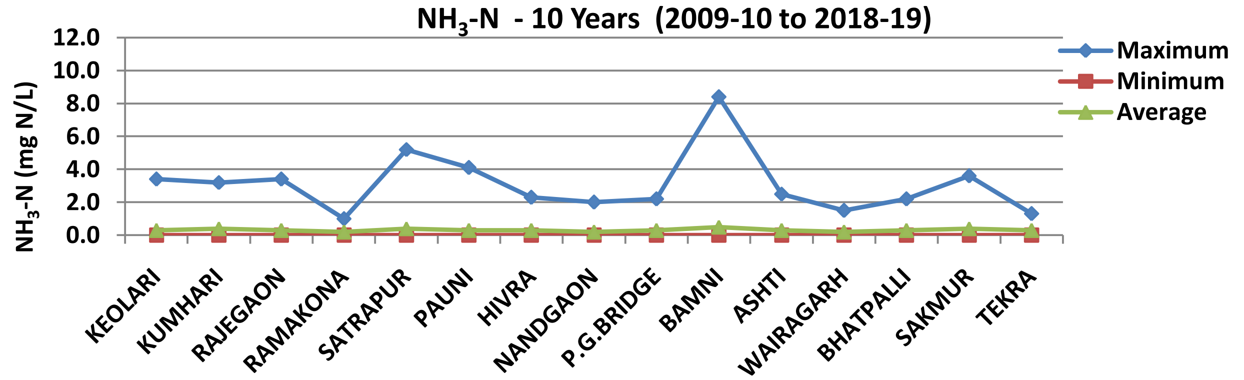

Figure : 18 (a)

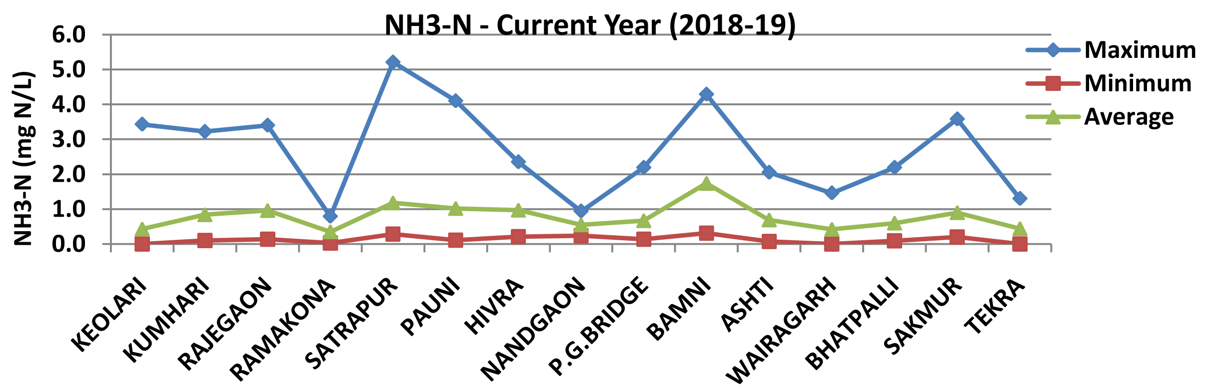

Figure : 18 (b)

for class D except Bamni. The maximum values of NH_3N values of all sites are above prescribed limit except Ramakona and Nandgaon and for class D.

3.1.18 Boron (B) : During thecurrent water year 2018-19 the maximum Boron values are in the range of 0.63 to 2.75 mg/L, minimum values are in the range of 0.0 to 0.04 mg/L and average values are in the range of 0.33 to 0.66 mg/Las shown in Figure 19 (b) and Table 21. The Boron average and minimum values are with-in limit as prescribed in class E. The Boron maximum value are most of the sites are under the prescribed limit for class E exceptBhatpalli, Bamni, Rajegaon,Kumhari and Sakmur.

3.1.19 Sodium Adsorption Ratio (SAR): During the current water year 2018-19 the maximum values SAR are in the range of 1.29 to 5.05, minimum values are in the range of 0.20 to 1.02 and average values are in the range of 0.62 to 1.85 as shown in Figure 20 (b) and Table 22. It is observed from the results maximum, minimum and Average SAR values of all sites are within prescribed limit and below class E.

3.1.20 Sodium Percent (Na %) : During the current water year 2018-19 the maximum values of Na % are in the range of 29.84 to 58.92 mg/L , minimum values are in the range of 7.44 to 26.31 mg/L and average values are in the range of 20.76 to 40.67 mg/Las shown in Figure 21 (b) and Table 23. It is observed from the results maximum, minimum and averageNa % values of all sites are within prescribed limit and below class E.

3.1.21 Phosphate (PO_4): During the current water year 2018-19 the maximum values of PO_4 are in the range of 0.488 to 3.722 mg/L, minimum values of all sites in the range of0.000 to 0.394 and average values are in the range of 0.160 to 1.791 mg/L as shown in Figure 22 (b) and Table 24. The value of PO_4 is not prescribed in BIS 2296: 1982.

3.1.22 Total Coliform (TC) :During the current water year 2018-19 the maximum TC values of are in the range of 1100 to 16000 MPN/100 ml, minimum values are in the range of 20 to 2400 MPN/100 ml and average values are in the range of 531 to 9578 MPN/100 ml as shown in Figure 23 (b) and Table 25. It is observed from the results maximum TC values of all sites are above class C except Tekra, Ramakona and Keolari. The minimum TC values of all sites are above class A except Tekra and Sakmur. However, all values are within Class B. The average TC values of all sites are above class A and TC values of all sites are below class B except Bamni, Nandgaon, Pauni, Satrapur and Wairagarh.

TABLE 21 : BORON						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	1.61	0.00	0.42	1.21	0.00	0.42
KUMHARI	2.22	0.00	0.31	2.18	0.03	0.61
RAJEGAON	2.84	0.00	0.39	2.75	0.03	0.66
RAMAKONA	1.56	0.00	0.46	0.86	0.04	0.49
SATRAPUR	2.63	0.00	0.43	0.96	0.04	0.35
PAUNI	1.31	0.00	0.41	1.17	0.04	0.47
HIVRA	1.71	0.00	0.40	1.20	0.03	0.36
NANDGAON	2.32	0.00	0.49	1.74	0.03	0.52
P.G.BRIDGE	1.89	0.00	0.31	0.99	0.02	0.34
BAMNI	2.36	0.00	0.41	2.31	0.03	0.62
ASHTI	1.71	0.00	0.34	0.89	0.03	0.38
WAIRAGARH	1.80	0.00	0.31	0.63	0.02	0.37
BHATPALLI	2.68	0.00	0.40	2.71	0.03	0.56
SAKMUR	2.27	0.00	0.38	2.28	0.02	0.48
TEKRA	2.16	0.00	0.29	0.94	0.02	0.33

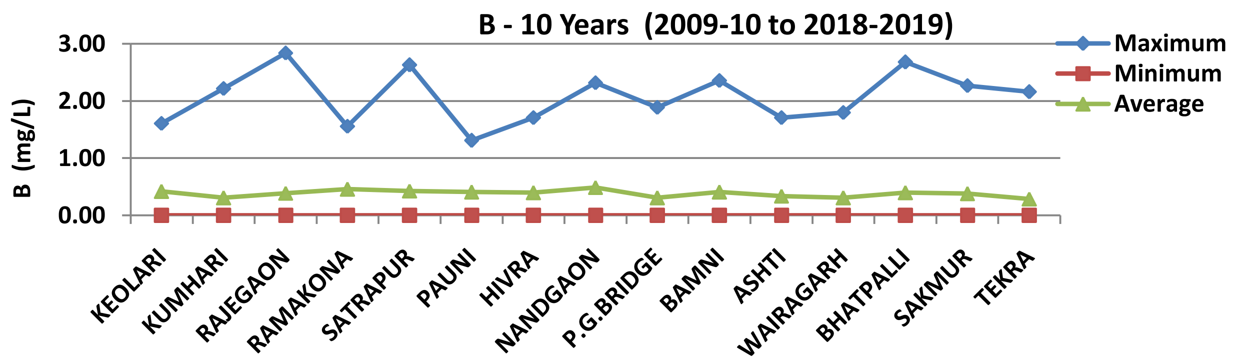

Figure : 19 (a)

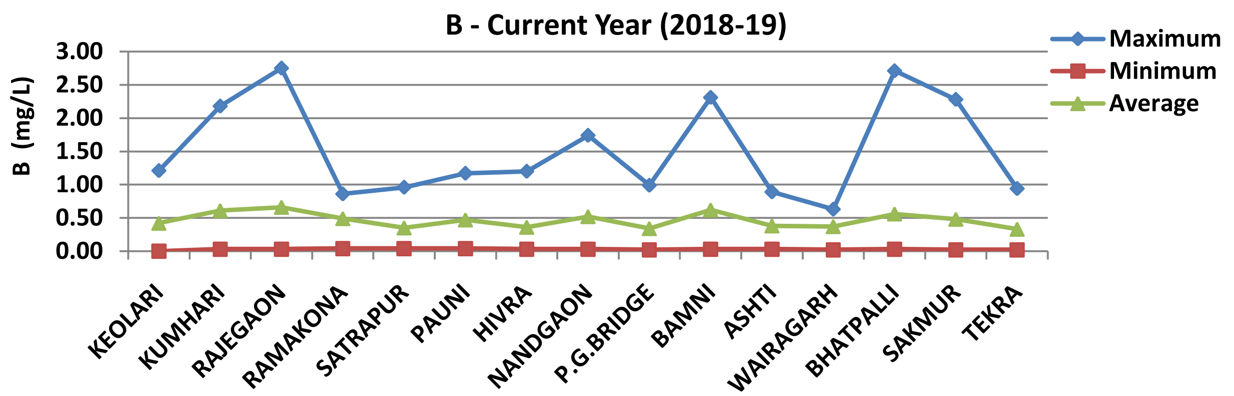

Figure : 19 (b)

TABLE 22 : SODIUM ADSORPTION RATIO						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	2.83	0.29	0.71	2.83	0.39	0.89
KUMHARI	1.54	0.11	0.76	1.54	0.21	0.62
RAJEGAON	1.57	0.14	0.63	1.29	0.41	0.66
RAMAKONA	2.11	0.46	0.81	1.86	0.28	0.71
SATRAPUR	2.91	0.16	1.26	1.79	0.20	1.21
PAUNI	2.36	0.27	0.90	1.38	0.45	0.77
HIVRA	4.30	0.31	1.50	2.52	1.02	1.57
NANDGAON	2.71	0.34	1.11	1.46	0.46	0.88
P.G.BRIDGE	2.13	0.27	0.93	1.94	0.26	0.96
BAMNI	6.54	0.13	1.76	5.05	0.55	1.85
ASHTI	2.53	0.21	0.93	1.51	0.22	0.73
WAIRAGARH	1.76	0.36	0.71	1.41	0.31	0.77
BHATPALLI	3.48	0.47	1.35	1.94	0.40	1.04
SAKMUR	3.11	0.51	1.48	2.36	0.33	1.41
TEKRA	2.67	0.11	1.10	1.71	0.47	0.95

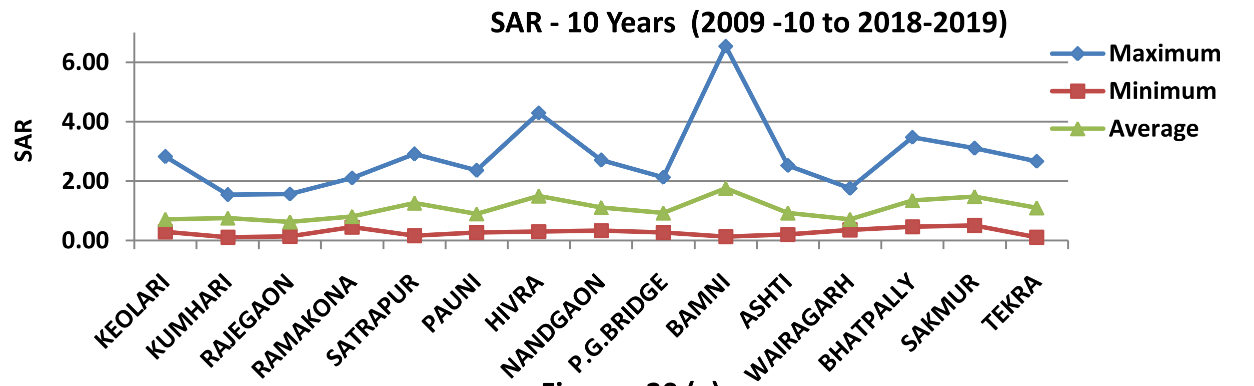

Figure : 20 (a)

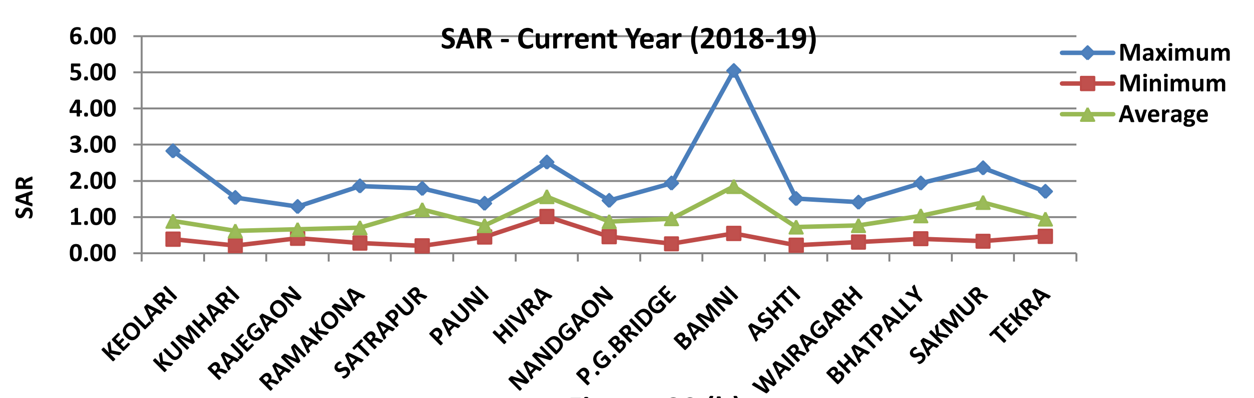

Figure :20 (b)

TABLE 23 : % SODIUM						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	50.73	10.31	21.00	50.73	13.05	27.09
KUMHARI	44.18	2.96	20.58	44.18	8.41	22.64
RAJEGAON	44.11	5.18	21.80	40.59	17.04	26.22
RAMAKONA	39.26	11.52	23.10	38.89	11.52	20.76
SATRAPUR	51.57	4.50	28.40	35.46	7.67	28.91
PAUNI	48.72	8.30	25.00	46.37	20.24	28.40
HIVRA	58.92	11.20	34.30	58.92	26.31	40.67
NANDGAON	49.60	11.50	26.60	29.84	15.68	24.50
P.G.BRIDGE	41.73	7.90	24.40	41.80	10.62	26.77
BAMNI	63.61	2.90	31.10	55.39	16.62	35.83
ASHTI	54.18	7.40	26.90	50.01	7.44	27.69
WAIRAGARH	52.57	12.30	29.10	52.57	15.83	33.33
BHATPALLI	55.38	11.00	31.00	55.38	14.68	29.59
SAKMUR	50.24	12.80	32.20	50.24	12.68	34.49
TEKRA	59.36	2.90	28.40	42.28	12.60	26.56

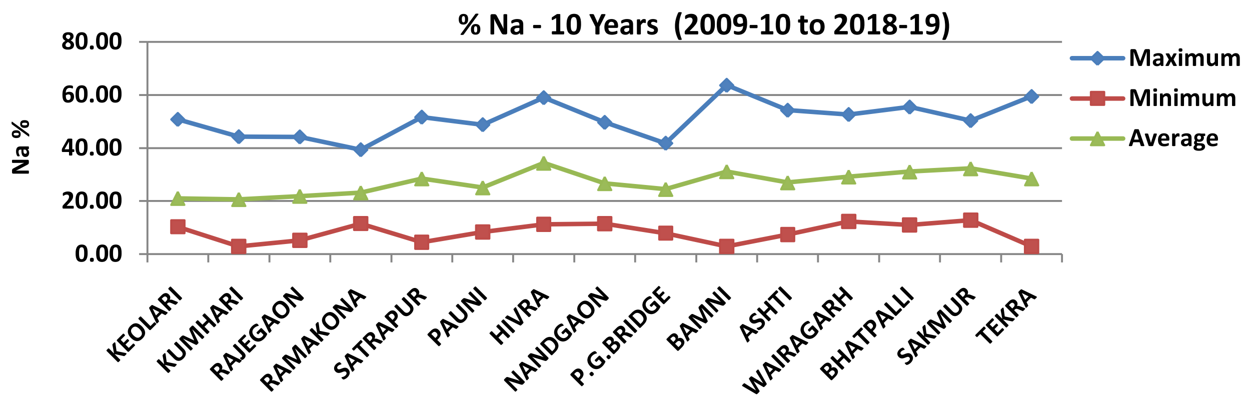

Figure : 21 (a)

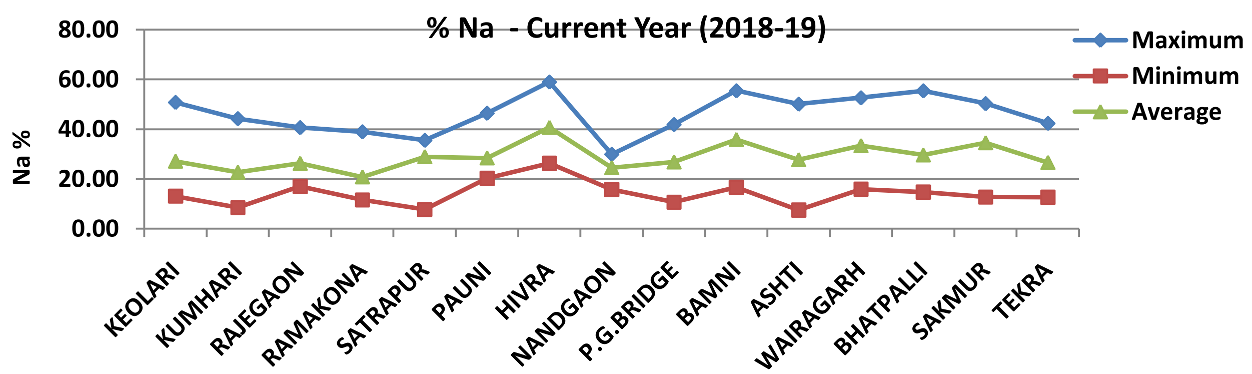

Figure : 21 (b)

TABLE 24 : PHOSPHATE						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	2.412	0.000	0.522	1.748	0.037	0.390
KUMHARI	2.776	0.012	0.318	2.776	0.027	0.552
RAJEGAON	4.876	0.000	0.391	0.488	0.000	0.160
RAMAKONA	5.505	0.015	0.466	3.240	0.394	1.791
SATRAPUR	9.426	0.000	0.370	1.866	0.022	0.352
PAUNI	2.237	0.000	0.312	1.630	0.012	0.321
HIVRA	2.209	0.000	0.428	2.646	0.008	0.508
NANDGAON	2.743	0.000	0.218	1.407	0.026	0.382
P.G.BRIDGE	2.758	0.003	0.226	2.225	0.026	0.347
BAMNI	4.527	0.000	0.356	2.270	0.036	0.484
ASHTI	2.411	0.000	0.229	2.411	0.011	0.501
WAIRAGARH	2.122	0.014	0.314	2.120	0.014	0.544
BHATPALLI	3.781	0.000	0.370	2.978	0.009	0.491
SAKMUR	4.195	0.029	0.488	3.209	0.035	0.583
TEKRA	3.722	0.000	0.269	3.722	0.036	0.733

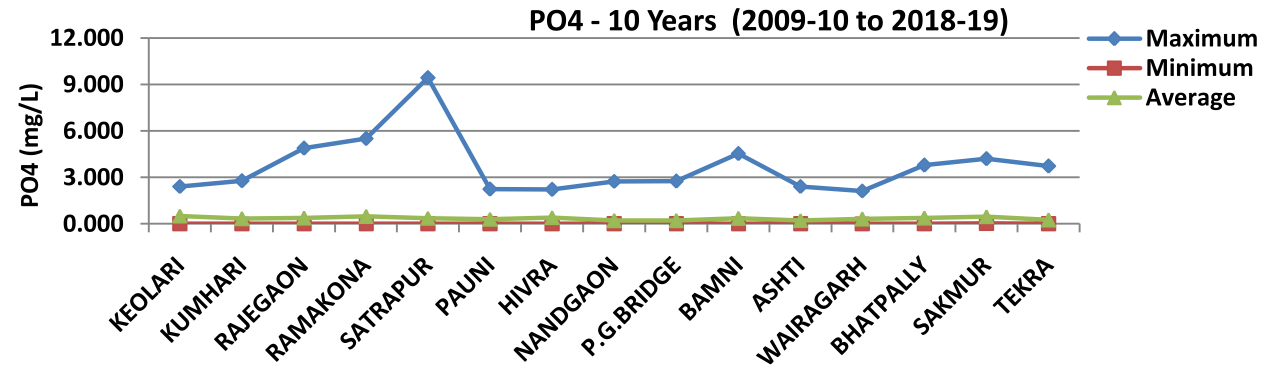

Figure : 22 (a)

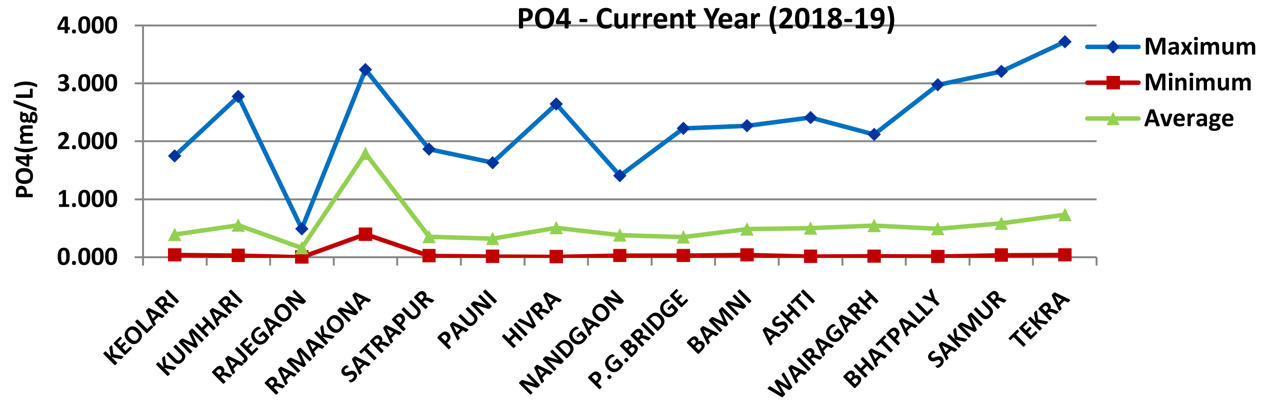

Figure : 22 (b)

TABLE 25 : TOTAL COLIFORM						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	16000	20	2268	3500	210	1467
KUMHARI	120000	20	3663	16000	130	2109
RAJEGAON	120000	20	5688	5000	260	1903
RAMAKONA	16000	20	2227	1100	300	648
SATRAPUR	120000	40	13938	16000	210	5134
PAUNI	120000	40	9149	16000	340	7853
HIVRA	120000	20	4865	9000	170	1922
NANDGAON	120000	40	8794	16000	2400	9578
P.G.BRIDGE	120000	40	1355	3000	300	1355
BAMNI	120000	20	7743	16000	80	5973
ASHTI	120000	20	3064	9000	260	1766
WAIRAGARH	16000	20	2883	9000	170	5223
BHATPALLI	120000	40	5470	16000	500	2925
SAKMUR	16000	20	950	5000	20	1307
TEKRA	120000	20	1975	1700	40	531

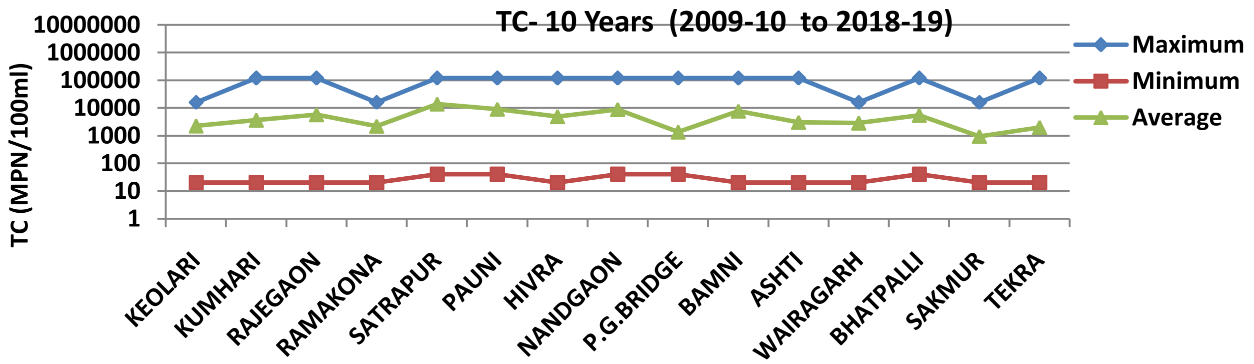

Figure :23 (a)

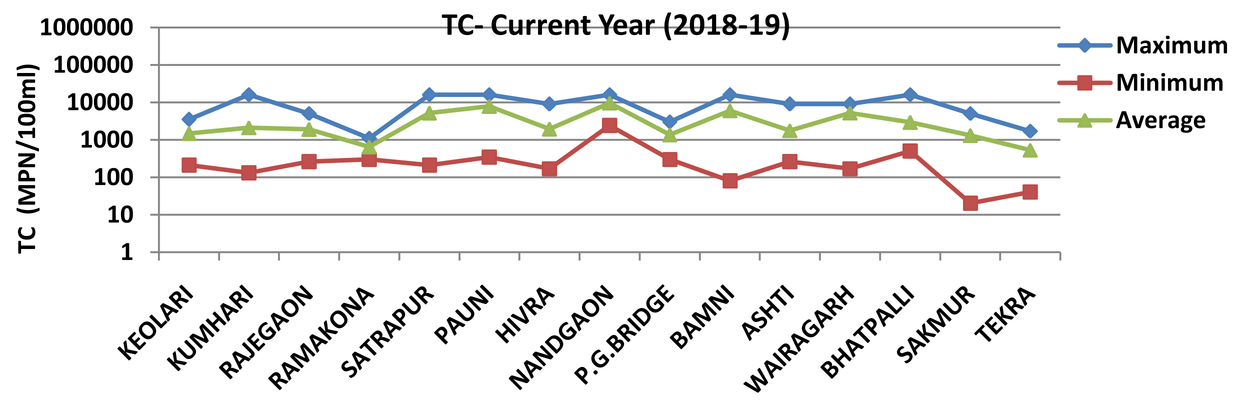

Figure: 23 (b)

3.1.23 Faecal Coliform(FC): During the current water year 2018-19 the maximum FC values of are in the range of 700 to 16000 MPN/100 ml, minimum values are in the range of 20 to 170 MPN/100 ml and average values are in the range of 146 to 4852 MPN/100 ml as shown in Figure 24 (b) and Table26.

3.1.24 Chemical Oxygen Demand (COD): During the current water year 2018-19 the maximum values of COD are in the range of 74.5 to 240.0 mg/L, minimum values are in the range of 3.8 to 30.0 mg/L and average values are in the range of 44.1 to 89.4 mg/L as shown in Figure 25 (b) and Table 27.The value of COD is not prescribed in BIS 2296: 1982.

TABLE 26 : FAECAL COLIFORM						
Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	16000	20	833	2800	40	663
KUMHARI	120000	40	1700	2800	40	678
RAJEGAON	5000	20	334	5000	80	1037
RAMAKONA	16000	20	618	3000	130	786
SATRAPUR	47000	20	1994	5000	170	1174
PAUNI	16000	20	1050	3000	90	1698
HIVRA	17250	20	473	2200	40	398
NANDGAON	47000	20	1796	16000	130	4852
P.G.BRIDGE	75500	20	1035	800	20	237
BAMNI	16000	20	1771	16000	40	2463
ASHTI	17250	40	549	900	90	329
WAIRAGARH	3000	20	278	3000	80	642
BHATPALLI	17250	20	679	5000	110	974
SAKMUR	3500	20	229	1300	20	217
TEKRA	27100	20	369	700	20	146

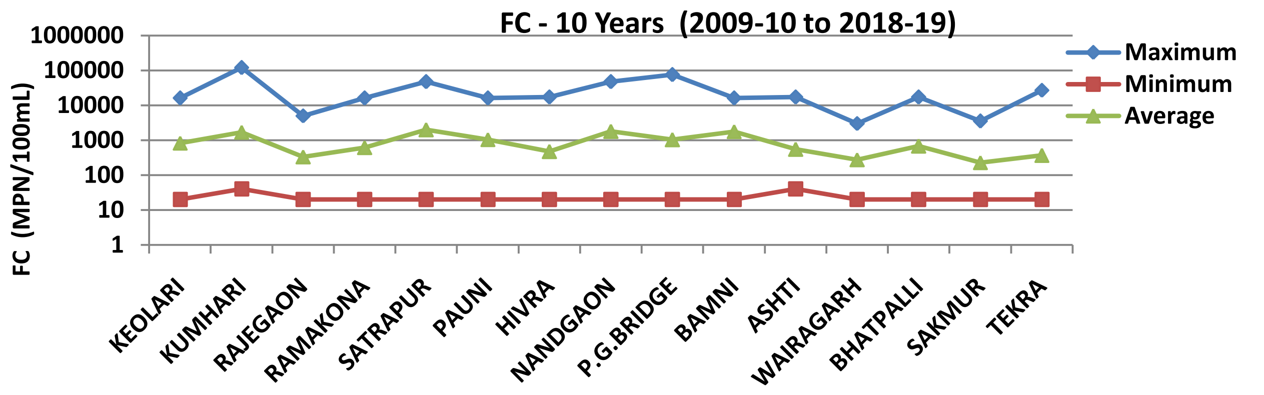

Figure : 24 (a)

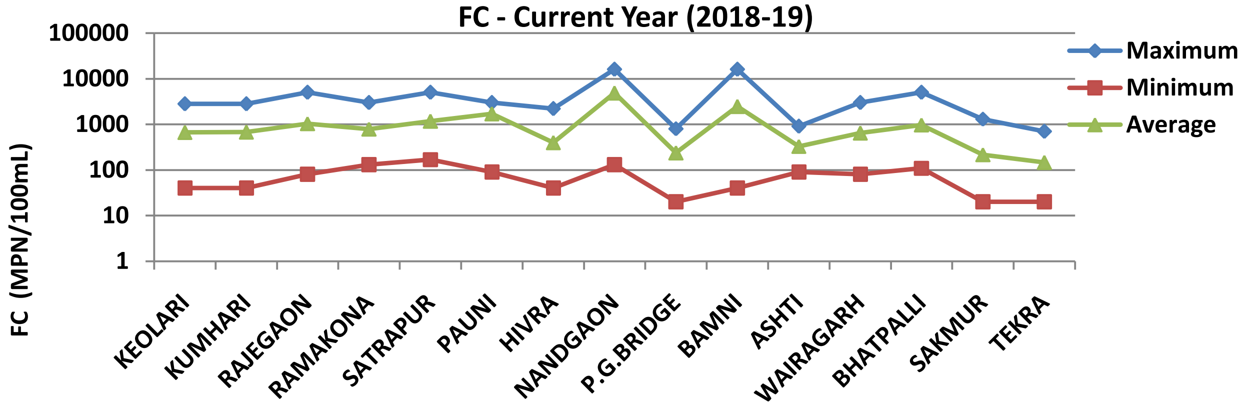

Figure: 24 (b)

TABLE 27 : CHEMICAL OXYGEN DEMAND

Site Name (From U/s to D/s)	10 Years (2009-10 to 2018-19)			Current year (2018-2019)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
KEOLARI	323.0	6.8	55.2	152.4	11.8	61.3
KUMHARI	349.0	4.8	47.4	152.4	4.8	55.3
RAJEGAON	379.0	11.0	50.1	82.4	16.0	44.1
RAMAKONA	316.0	5.6	53.3	156.8	11.8	57.1
SATRAPUR	617.1	12.9	59.1	180.0	21.0	79.7
PAUNI	301.4	3.6	53.6	180.0	5.4	46.4
HIVRA	384.0	9.2	56.7	160.0	9.2	56.9
NANDGAON	434.0	4.7	55.7	140.0	30.0	65.6
P.G.BRIDGE	394.0	5.4	54.2	124.0	5.4	56.5
BAMNI	443.0	6.0	75.1	240.0	26.0	89.4
ASHTI	305.8	7.4	49.3	114.0	7.4	51.5
WAIRAGARH	394.0	2.3	55.6	74.5	23.5	45.7
BHATPALLI	415.0	3.4	52.2	105.9	5.8	48.8
SAKMUR	372.0	3.8	55.0	107.5	9.4	49.0
TEKRA	378.0	3.8	48.0	95.2	3.8	45.0

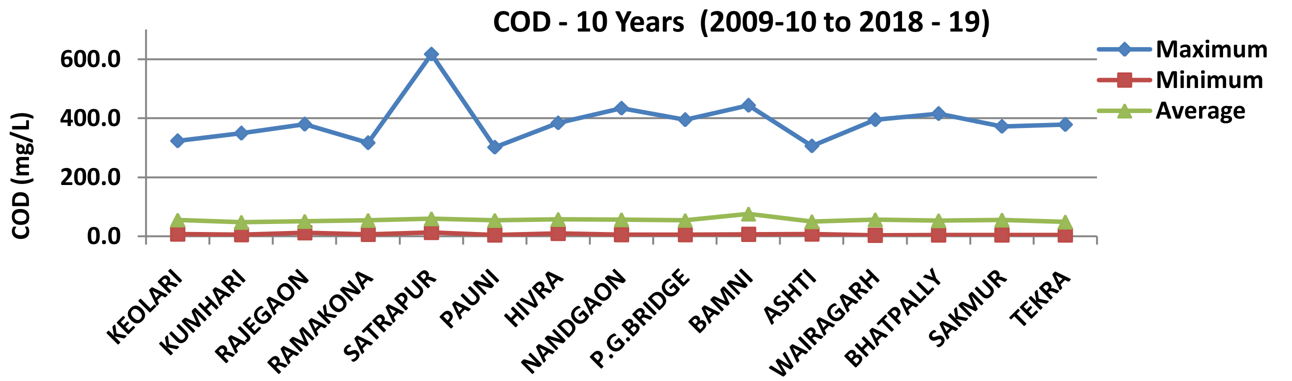

Figure: 25 (a)

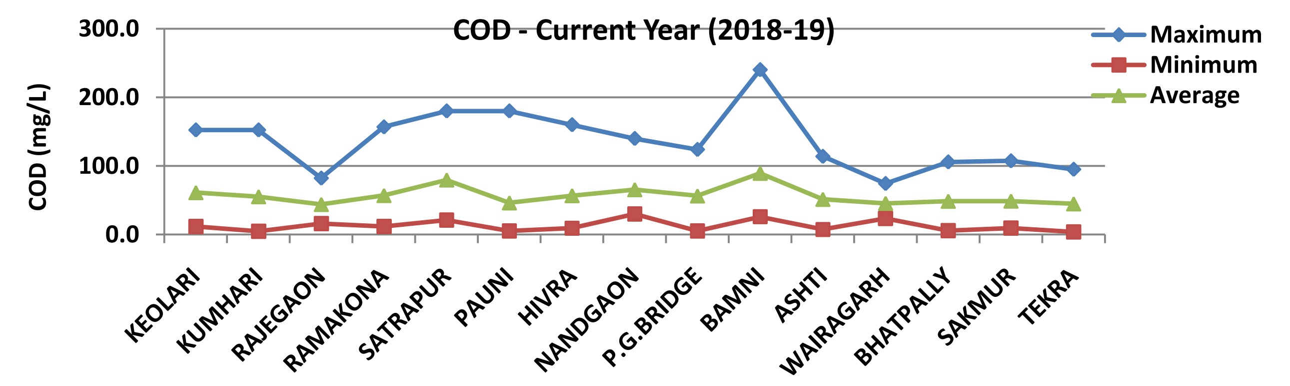

Figure : 25 (b)

3.2 SUITABILITY OF WATER QUALITY FOR DRINKING AND IRRIGATION AT WATER QUALITY MONITRING STATIONS: The consumption of contaminated water disturbs human health and causes of various diseases. The good quality of water, whether utilize for drinking, domestic purposes, recreational, agriculture or and industrial purposes has a vital effect on human and animals health. Water of poor quality can act as source of disease outbreaks. Initiatives to manage the safety of water do not only maintain public health, but often encourage socioeconomic growth and well-being as well. The important water quality parameters such as pH, EC, DO, BOD,TDS, CH, TH, Mg, Fe, Cl, F, SO_4, NO_3, TC & FC, B, Na% and RSC are analyzed and obtained data compared with Class A (Drinking water source without conventional treatment but after disinfections), Class C (Drinking water source with conventional treatment followed by disinfections and Class E (Irrigation, industrial cooling and controlled waste disposal) of BIS: 2296-1982 as given in Table 2. On the basis of results discuss the suitability of drinking water quality at each station under Wainganga River Basin are given in Table 28 to 41:

3.2.1 Keolari :

Table 28 : Water Quality Monitoring Station : Keolari				
River : Wainganga			**Year : 2018-19**	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	7.7 to 8.9	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	323 to 395	**E : 2250**
3	**DO**	mg/L, Min	6.0 to 11.9	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.1 to 6.5	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	210 to 3500	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	161 to 237	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	82.0 to 299.0	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	8.1 to 250.6	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	1.7 to 24.4	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 0.254	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	8.1 to 26.1	**A : 250 C & E : 600**
12	**Fluoride**	as F, mg/L, Max	0.19 to 0.44	**A & C : 1.5**
13	**Sulphate**	as SO_4,mg/L, Max	3.7 to 34.3	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	1.6 to 57.5	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	40 to 2800	-
16	**Boron**	as B, mg/L, Max	0.00 to 1.21	**E : 2.0**
17	**Sodium percent,**	Max	13.05 to 50.7	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.39 to 2.83	**E : 26**

- ❖ The water of Keolari water quality monitoring station is not suitable for Class – A with reference CH, TC and also not suitable for Class – C with reference to pH, BOD and NO3.
- ❖ The water of Keolari Water quality monitoring station is suitable for Class – E with reference to above parameters except pH.

3.2.2 Kumhari :

Table 29 : **Water Quality Monitoring Station :** Kumhari				
River : Wainganga			**Year : 2018-19**	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	6.9 to 8.2	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	161 to 386	**E : 2250**
3	**DO**	mg/L, Min	5.2 to 10.2	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.1 to 3.4	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	130 to 16000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	97 to 232	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	86.0 to 387.0	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	10.8 to 365.2	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	5.1 to 18.8	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 2.819	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	7.1 to 56.1	**A : 250 C & E : 600**
12	**Fluoride**	as F, mg/L, Max	0.17 to 0.46	**A & C : 1.5**
13	**Sulphate**	as SO_4,mg/L, Max	2.0 to 10.8	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	0.0 to 28.2	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	40 to 2800	-
16	**Boron**	as B, mg/L, Max	0.03 to 2.18	**E : 2.0**
17	**Sodium percent,**	Max	8.41 to 44.18	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.21 to 1.54	**E : 26**

- ❖ The water of Kumhari water quality monitoring station is not suitable for Class - A with reference to DO,CH, TH , Fe, NO_3 and also not suitable for Class - C in reference of BOD and TC.

- ❖ The water of Kumhari water quality monitoring station is suitable for Class - E with reference to above parameters except B.

3.2.3 Rajegaon :

Table 30 : **Water Quality Monitoring Station :** Rajegaon				
River : Bagh			**Year :** 2018-19	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	7.2 to 7.8	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	107 to 256	**E : 2250**
3	**DO**	mg/L, Min	5.0 to 8.7	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.1 to 75.0	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	260 to 5000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	64 to154	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	69.0 to 147.0	**A : 300**

8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	11.1 to 125.1	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	2.5 to 15.7	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 0.439	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	3.7 to 20.4	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.10 to 0.34	**A & C : 1.5**
13	**Sulphate**	as SO_4,mg/L, Max	3.6 to 31.6	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	1.6 to 10.7	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	80 to 5000	-
16	**Boron**	as B, mg/L, Max	0.03 to 2.75	**E : 2.0**
17	**Sodium percent,**	Max	17.04 to 40.59	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.41 to 1.29	**E : 26**

- The water of Rajegaon water quality monitoring station is not suitable for Class - A with reference to DO,Fe and also not suitable for Class - C with reference of BOD and TC.

- The water of Rajegaon Water quality monitoring station is suitable for Class - E with reference to above parameters except B .

3.2.4 Ramakona :

Table 31 : Water Quality Monitoring Station : Ramakona

River : Kanhan **Year :** 2018-19

S. No.	Constituents	Unit	Result Range during year	Remark's (BIS 2296: 1982)
1	**pH**	-	7.7 to 8.1	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	206 to 405	**E : 2250**
3	**DO**	mg/L, Min	5.6 to 8.6	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.1 to 2.8	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	300 to 1100	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	124 to 243	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	144 to 209	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	13.8 to 193.8	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	3.6 to 31.3	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 0.340	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	10.8 to 22.2	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.34 to 0.65	**A & C : 1.5**
13	**Sulphate**	as SO_4,mg/L, Max	10.1 to 39.4	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	1.6 to 13.4	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	130 to 3000	-
16	**Boron**	as B, mg/L, Max	0.04 to 0.86	**E : 2.0**
17	**Sodium percent,**	Max	11.52 to 38.89	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.28 to 1.86	**E : 26**

- The water of Ramakona water quality monitoring station is not suitable for Class - A with reference to DO, Fe, BOD, TC, However the water is suitable for Class - C with reference to all above parameters.

❖ The water of Ramakona water quality monitoring station is suitable for Class - E with reference to all above parameters.

3.2.5 Satrapur :

Table 32 : Water Quality Monitoring Station : Satrapur				
River : Kanhan			**Year :** 2018-19	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	6.3 to 8.1	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	258 to 737	**E : 2250**
3	**DO**	mg/L, Min	1.7 to 8.4	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.7 to 110.0	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	210 to 16000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	155 to 442	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	190 to 299	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	14.2 to 250.3	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	3.0 to 51.8	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 1.927	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	20.3 to 78.1	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.27 to 0.67	**A & C : 1.5**
13	**Sulphate**	as SO_4,mg/L, Max	22.2 to 139.5	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	0.0 to 16.2	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	170 to 5000	-
16	**Boron**	as B, mg/L, Max	0.04 to 0.96	**E : 2.0**
17	**Sodium percent,**	Max	7.67 to 35.46	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.20 to 1.79	**E : 26**

❖ The water of Satrapur water quality monitoring station is not suitable for Class - A with reference to CH and also not suitable for Class - C in reference to pH, DO, BOD and TC.

❖ The water of Satrapur water quality monitoring station is suitable for Class – E with reference to above parameters except pH.

3.2.6 Pauni :

Table 33 : Water Quality Monitoring Stations : Pauni				
River : Wainganga			**Year :** 2018-19	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	7.5 to 8.5	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	169 to 397	**E : 2250**
3	**DO**	mg/L, Min	3.0 to 8.0	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.2 to 55.0	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	340 to 16000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	101 to 238	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	91 to 279	**A : 300**

8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	16.6 to 237.5	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	1.7 to 21.2	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 2.237	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	8.1 to 39.0	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.21 to 0.45	**A & C : 1.5**
13	**Sulphate**	as SO_4,mg/L, Max	9.3 to 18.4	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	0.0 to 17.6	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	90 to 3000	-
16	**Boron**	as B, mg/L, Max	0.04 to 1.17	**E : 2.0**
17	**Sodium percent,**	Max	20.2 to 46.37	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.45 to 1.38	**E : 26**

❖ The water of Pauni water quality monitoring station is not suitable for Class - A with reference to CH, Fe and also not suitable for Class - C in reference to DO, BOD TC.

❖ The water of Pauni water quality monitoring station is suitable for Class – E with reference to all above parameters

3.2.7 Hivra :

Table 34 : Water Quality Monitoring Stations : Hivra				
River : Wardha			**Year :** 2018-19	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	7.7 to 8.7	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	353 to 528	**E : 2250**
3	**DO**	mg/L, Min	1.1 to 7.1	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.3 to 70.0	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	170 to 9000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	212 to 317	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	87 to 340	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	15.8 to 150.6	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	1.7 to 77.9	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 2.209	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	21.6 to 49.4	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.29 to 0.51	**A & C : 1.5**
13	**Sulphate**	as SO_4,mg/L, Max	10.9 to 39.1	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	0.0 to 17.8	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	40 to 2200	-
16	**Boron**	as B, mg/L, Max	0.03 to 1.20	**E : 2.0**
17	**Sodium percent,**	Max	26.31 to 58.92	**E : 60**
18	**Sodium Absorption Ratio**	Max	1.02 to 2.52	**E : 26**

❖ The water of Hivra water quality monitoring station is not suitable for Class - A with reference to TH, Fe and also not suitable for Class - C in reference to pH, DO, BOD, and TC.

❖ The water of Hivra water quality monitoring station is suitable for Class – E with reference to above parameters except pH.

3.2.8 Nandgaon :

Table 35 : Water Quality Monitoring Stations : Nandgaon				
River : Wunna			**Year :** 2018-19	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	7.5 to 8.5	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	339 to 610	**E : 2250**
3	**DO**	mg/L, Min	4.6 to 7.5	**A : 6 C : 5**
4	**BOD**	mg/L, Max	0.6 to 60.0	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	2400 to 16000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	203 to 366	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	191 to 309	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	16.1 to 275.0	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	3.5 to 70.3	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 0.266	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	22.2 to 63.1	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.28 to 0.57	**A & C : 1.5**
13	**Sulphate**	as SO_4,mg/L, Max	18.4 to 38.9	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	2.0 to 17.1	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	130 to 1600	-
16	**Boron**	as B, mg/L, Max	0.03 to 1.74	**E : 2.0**
17	**Sodium percent,**	Max	15.68 to 29.84	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.46 to 1.46	**E : 26**

- The water of Nandgaon water quality monitoring station is not suitable for Class - A with reference to DO CH,TH and also not suitable for Class - C in reference to BOD and TC.

- The water of Nandgaon water quality monitoring station is suitable for Class - E with reference to all above parameters.

3.2.9 P.G.Bridge :

Table 36 : Water Quality Monitoring Stations : P.G.Bridge				
River : Penganga			**Year :** 2018-19	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	7.9 to 8.9	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	210 to 624	**E : 2250**
3	**DO**	mg/L, Min	5.0 to 8.7	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.2 to 4.4	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	300 to 3000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	126 to 376	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	127 to 249	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	14.9 to 225.8	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	1.5 to 39.9	**A : 100**

10	**Iron**	as Fe, mg/L, Max	0.000 to 2.088	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	10.9 to 44.2	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.23 to 0.57	**A & C : 1.5**
13	**Sulphate**	as SO_4,mg/L, Max	6.3 to 27.9	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	0.0 to 28.2	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	20 to 800	-
16	**Boron**	as B, mg/L, Max	0.02 to 0.99	**E : 2.0**
17	**Sodium percent,**	Max	10.62 to 41.80	**E : 60**

❖ The water of P.G. Bridge water quality monitoring station is not suitable for Class - A with reference to DO, TH, TC, Fe and also not suitable for Class - C in reference to BOD and TC.

❖ The water of P.G. Bridge water quality monitoring station is suitable for Class - E with reference to above parameters.

3.2.10 Bamni :

Table 37 : Water Quality Monitoring Stations : Bamni				
River : Wardha			**Year :** 2018-19	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	7.1 to 8.2	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	423 to 2739	**E : 2250**
3	**DO**	mg/L, Min	1.6 to 7.4	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.0 to 120.0	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	80 to 16000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	254 to 1643	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	220 to 621	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	20.3 to 409.6	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	5.9 to 66.6	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 2.082	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	32.8 to 409.9	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.33 to 0.59	**A & C : 1.5**
13	**Sulphate**	as SO_4,mg/L, Max	36.1 to 626.4	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	0.0 to 28.2	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	40 to 16000	-
16	**Boron**	as B, mg/L, Max	0.03 to 2.31	**E : 2.0**
17	**Sodium percent,**	Max	16.62 to 55.39	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.55 to 5.05	**E : 26**

❖ The water of Bamni water quality monitoring station is not suitable for Class - A with reference to CH, TH, Fe, Cl and also not suitable for Class - C in reference to DO, BOD, SO_4 and TC.

❖ The water of Bamni water quality monitoring station is suitable for Class – E with reference to all above parameters except EC & B .

3.2.11 Ashti :

Table 38 : Water Quality Monitoring Stations : Ashti				
River : Wainganga			**Year :** 2018-19	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	7.6 to 9.0	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	171 to 308	**E : 2250**
3	**DO**	mg/L, Min	0.6 to 8.3	**A : 6 C : 5**
4	**BOD**	mg/L, Max	0.6 to 2.8	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	260 to 9000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	103 to 185	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	86 to 308	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	12.2 to 206.3	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	1.1 to 24.4	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 2.409	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	8.1 to 38.0	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.22 to 0.45	**A & C : 1.5**
13	**Sulphate**	as SO_4, mg/L, Max	3.4 to 16.8	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	0.0 to 12.9	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	90 to 900	-
16	**Boron**	as B, mg/L, Max	0.03 to 0.89	**E : 2.0**
17	**Sodium percent,**	Max	7.44 to 50.01	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.22 to 1.51	**E : 26**

- The water of Ashti water quality monitoring station is not suitable for Class - A with reference to CH, TH, Fe and also not suitable for Class - C in reference to pH, DO, BOD and TC.

- The water of Ashti water quality monitoring station is suitable for Class - E with reference toall above parameters except pH.

3.2.12 Wairagarh :

Table 39 : Water Quality Monitoring Stations : Wairagarh				
River : Khobragarhi			**Year :** 2018-19	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	7.2 to 7.9	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	110 to 150	**E : 2250**
3	**DO**	mg/L, Min	6.1 to 8.0	**A : 6 C : 5**
4	**BOD**	mg/L, Max	0.8 to 3.1	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	170 to 9000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	66 to 90	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	51 to 120	**A : 300**

8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	11.6 to 106.3	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	3.3 to 19.3	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 0.404	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	2.7 to 17.0	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.10 to 0.36	**A & C : 1.5**
13	**Sulphate**	as SO_4, mg/L, Max	5.4 to 15.2	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	1.4 to 21.1	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	80 to 3000	-
16	**Boron**	as B, mg/L, Max	0.02 to 0.63	**E : 2.0**
17	**Sodium percent**	Max	15.83 to 52.57	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.31 to 1.41	**E : 26**

❖ The water of Wairagarh water quality monitoring station is not suitable for Class - A with reference to Fe, NO_3 and also not suitable for Class - C in reference to BOD and TC.

❖ The water of Wairagarh water quality monitoring station is suitable for Class – E with reference to all above parameters.

3.2.13 : Bhatpalli :

Table 40 : Water Quality Monitoring Stations : Bhatpalli

River : Peddavagu**Year :** 2018-19

S. No.	Constituents	Unit	Result Range during year	Remark's (BIS 2296: 1982)
1	**pH**	-	8.0 to 8.5	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	235 to 576	**E : 2250**
3	**DO**	mg/L, Min	4.0 to 10.6	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.0 to 2.8	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	500 to 16000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	141 to 346	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	100 to 239	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	12.7 to 194.1	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	2.5 to 53.8	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 1.921	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	10.8 to 61.8	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.36 to 0.77	**A & C : 1.5**
13	**Sulphate**	as SO_4, mg/L, Max	3.0 to 22.5	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	0.0 to 28.2	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	110 to 5000	-
16	**Boron**	as B, mg/L, Max	0.03 to 2.71	**E : 2.0**
17	**Sodium percent**	Max	14.68 to 55.38	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.40 to 1.94	**E : 26**

❖ The water of Bhatpalli water quality monitoring station is not suitable for Class - A with reference to DO, BOD, Fe, NO_3 and also not suitable for Class - C in reference to TC.

❖ The water of Bhatpalli Water Quality monitoring station is suitable for Class - E with reference to all above parameters except B.

3.2.14 Sakmur:

Table 41 : Water Quality Monitoring Stations : Sakmur				
River : Wardha			**Year :** 2018-19	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	7.9 to 8.7	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	235 to 829	**E : 2250**
3	**DO**	mg/L, Min	4.1 to 11.4	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.2 to 35.0	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	20 to 5000	**A : 50 C : 5000**
6	**Total dissolved solids**	mg/L, Max	141 to 497	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	171 to 329	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	19.0 to 320.6	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	2.2 to 54.1	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 1.932	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	17.2 to 161.2	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.27 to 0.61	**A & C : 1.5**
13	**Sulphate**	as SO_4, mg/L, Max	19.6 to 132.7	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	0.0 to 28.8	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	20 to 1300	-
16	**Boron**	as B, mg/L, Max	0.02 to 2.28	**E : 2.0**
17	**Sodium percent,**	Max	12.68 to 50.24	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.33 to 2.36	**E : 26**

❖ The water of Sakmur water quality monitoring station is not suitable for Class A with reference to DO, Fe, NO_3 and also not suitable for Class C in reference to pH, BOD, CH, TH and TC.

❖ The water of Sakmur Water Quality monitoring station is suitable for Class E with reference to all above parameters except pH & B.

3.2.15 Tekra :

Table 42: Water Quality Monitoring Stations : Tekra				
River : Pranhita			**Year :** 2018-19	
S. No.	**Constituents**	**Unit**	**Result Range during year**	**Remark's (BIS 2296: 1982)**
1	**pH**	-	7.7 to 8.4	**A & C : 6.5 - 8.5 E : 6.0 - 8.5**
2	**EC at 25°C**	µS/cm, Max	224 to 454	**E : 2250**
3	**DO**	mg/L, Min	6.1 to 8.8	**A : 6 C : 5**
4	**BOD**	mg/L, Max	1.0 to 3.4	**A : 2 C : 3**
5	**Total Coliform Organisms**	MPN/100 ml, Max	40 to 1700	**A : 50 C : 5000**

6	**Total dissolved solids**	mg/L, Max	134 to 273	**A : 500, C : 1500, E : 2100**
7	**Total Hardness**	as $CaCO_3$, mg/L, Max	122 to 234	**A : 300**
8	**Calcium hardness**	as $CaCO_3$, mg/L, Max	15.7 to 212.5	**A : 200**
9	**Magnesium**	as $CaCO_3$, mg/L, Max	2.0 to 29.1	**A : 100**
10	**Iron**	as Fe, mg/L, Max	0.000 to 2.038	**A : 0.3 C : 50**
11	**Chloride**	as Cl, mg/L, Max	9.4 to 29.0	**A : 250 C & E : 600**
12	**Fluoride**	as F,mg/L, Max	0.26 to 0.55	**A & C : 1.5**
13	**Sulphate**	as SO_4, mg/L, Max	15.9 to 36.2	**A & C : 400, E:1000**
14	**Nitrate**	as NO_3, mg/L, Max	0.0 to 17.4	**A : 20 C : 50**
15	**Faecal Coliform Organisms**	MPN/100 ml, Max	20 to 700	-
16	**Boron**	as B, mg/L, Max	0.02 to 0.94	**E : 2.0**
17	**Sodium percent,**	Max	12.60 to 42.28	**E : 60**
18	**Sodium Absorption Ratio**	Max	0.47 to 1.71	**E : 26**

- The water of Tekra water quality monitoring station is not suitable for Class A with reference to CH, Fe, TC and also not suitable for Class C in reference to BOD.

- The water of Tekra water quality monitoring station is suitable for Class E with reference to all above parameters.

4.0 CONCLUSION:

The data has been analyzed for 24 important water quality parameters such as EC, pH, DO, BOD, Na, K, Ca, CH, TH, Mg, Fe, HCO_3, Cl, F, SO_4,NO_3,NO_2, NH3-N, B, SAR, Na %, PO_4, COD and TC & FC. The value of all above water quality parameters compared with designated use class of Inland surface water specifications (BIS 2296-1982) and observation given in the form of summary of results (Table 28). The prescribed limit for Na, K, Ca, HCO_3, PO_4 and F.Coli are not mentioned in the BIS 2296-1982. It is observed from the results of the important water quality parameters such as EC, DO, BOD, CH, TH, Fe, SO_4,NO_3, NH3-N, B, and TC shows water are not suitable for different classes. However the other parameters such as pH, Mg, Cl, F,SAR, and Na % are suitable for all classes.

All the water quality monitoring stations results are concluded in Table 44 for suitability of water for Class A & C and irrigation water for Class E. The various water quality parameters such pH, DO, BOD, CH, TH, Fe, SO_4, NO_3 and TC generally shows high value in respect of Class A & C. It also observed that the water quality parameters such as pH, B and EC show high value in respect of Class E.

The high values of various water quality parameters clearly show the water of river basin is polluted at various locations. The major sources of pollution in Wainganga river basin are agriculture and domestic wastes directly finding way to rivers. In some cases small industries are also discharging its untreated waste water into the river. Industries and cities have located along the Wainganga river basin have traditionally been a convenient place to discharge industrial and sewage waste. Other Non-point sources of pollution are Natural contaminants (dry leaves, dead insects and animals, bird droppings), Agricultural contaminants (agricultural runoff containing fertilizers, pesticides), Industrial contaminants (Industrial runoff containing toxic and non toxic wastes), Microbial contaminants (Faecal& Total Coliform), Ritual contaminants (worship items and Human Ash) and Human added contaminants (organic matter through domestic discharges).

TABLE 43: SUMMARY OF PARAMETERS-WISE SUITABILITY OF WATER QUALITY FOR DESIGNATED USE		
WQ Parameters	**Value**	**Remarks**
EC	Maximum	All values are within prescribed limit for Class A, D & E except Bamni sites are above Class A below Class D & E
	Minimum	All values are within prescribed limit for Class A, D & E
	Average	All values are within prescribed limit for Class A, D & E
P^H	Maximum	All values are within prescribed range for Class A,B,C,D & E
	Minimum	All values are within prescribed range for Class A,B,C,D & E
	Average	All values are within prescribed range for Class A,B,C,D & E
DO	Maximum	All values are within above the limit for Class A,B,C & D
	Minimum	All values with in above the limit for for Class A, B, C & D. However, the value of Kumhari, Ramakona, PG Bridge are below class A and Values of Bhatpalli, Nandgaon, Sakmur are below Class B. The value of Bamni, Hivra, Asthi, Pauni and Satrapur are below Class C & D.
	Average	All values with in above the limit for Class A, B, C & D. However, Bamni are below Class A and Satrapur site are below Class A & B.
BOD	Maximum	All values are above prescribed limit for Class A,B & C
	Minimum	All values are within prescribed limit for Class A, B & C
	Average	All values are above prescribed limit for Class A,B & C however the value of Keolari site are above class A and Bamni, Satrapur, Nandgaon, Hivra, Pauni,Rajegaon are above Class B and C.
CH	Maximum	All values are above prescribed limit for Class A however the value of Bamni, Tekra,PG Bridge, Nandgaon, Asthi, Pauni, Satrapur, Kumhari, Sakmur are above Class A.
	Minimum	All values are within prescribed limit for Class A
	Average	All values are within prescribed limit for Class A
TH	Maximum	All values are within prescribed limit Class A except Bamni site, Hivra, Asthi, Kumhari and Sakmur are above Class A
	Minimum	All values are within prescribed limit for Class A
	Average	All values are within prescribed limit for Class A except Bamni site.
Mg	Maximum	All values are within prescribed limit for Class A
	Minimum	All values are within prescribed limit for Class A
	Average	All values are within prescribed limit for Class A
Fe	Maximum	All values are also above the prescribed limit for class A except Keolari, Nandgaon are within limit, however the maximum values of all sites below prescribed limit for Class C
	Minimum	All values are within prescribed limit for Class A and C
	Average	All values are above prescribed limit for class A except Keolari, Rajegaon, Ramakona, Nandgaon, Wairagarh sites are under the prescribed limit and all value are all sites below prescribed limit for class C

WQ Parameters	Value	Remarks
Cl	Maximum	All values are within prescribed limit for Class A
	Minimum	All values are within prescribed limit for Class A
	Average	All values are within prescribed limit for Class A
F	Maximum	All values are within prescribed limit for Class A
	Minimum	All values are within prescribed limit for Class A
	Average	All values are within prescribed limit for Class A
SO_4	Maximum	All values are within prescribed limit for Class A,C& E except Bamni site above class A & C below Class E.
	Minimum	All values are within prescribed limit for Class A,C& E
	Average	All values are within prescribed limit for Class A,C& E
NO_3	Maximum	All values are within prescribed limit for Class A & C except Keolari is above Class A & C.
	Minimum	All values are within prescribed limit for Class A & C
	Average	All values are within prescribed limit for Class A & C
NH_3N	Maximum	All values are above prescribed limit for Class D except Hivra and Ramakona
	Minimum	All values are within prescribed limit for Class D
	Average	All values are within prescribed limit for Class D except Tekra, Bamni and Hivra
B	Maximum	All values are within prescribed limit for class E except Bhatpalli, Bamni, Rajegaon, Kumhari and Sakmur.
	Minimum	All values are within prescribed limit for Class E
	Average	All values are within prescribed limit for Class E
SAR	Maximum	All values are within prescribed limit for Class E
	Minimum	All values are within prescribed limit for Class E
	Average	All values are within prescribed limit for Class E
Na %	Maximum	All values are within prescribed limit for Class E
	Minimum	All values are within prescribed limit for Class E
	Average	All values are within prescribed limit for Class E
TC	Maximum	The all values are above class C except Tekra, Ramakona and Keolari.
	Minimum	The all values are above class A except Tekra and Sakmur. However, all values are within Class B.
	Average	All values are above class A and below class B except Bamni, Nandgaon, Pauni, Satrapur and Wairagarh.

TABLE 44 : SUMMARY OF STATION-WISE WATER QUALITY FOR DRINKING AND IRRIGATION		
Water Quality Monitoring Stations	**Water Suitability for Class A and Class C:**	**Water Suitability for Class E**
Keolari	Water is suitable for all observed parameters except CH, TC for Class – A and pH, BOD & NO3 for Class – C	Water is suitable for all observed parameters except pH for Class – E
Kumhari	Water is suitable for all observed parameters except DO, CH, TH , Fe, NO_3 for Class – A and BOD & TC for Class – C	Water is suitable for all observed parameters except B for Class – E
Rajegaon	Water is suitable for observed parameters except DO, Fe for Class – A and BOD & TC for Class – C	Water is suitable for all observed parameters except B for Class – E
Ramakona	Water is suitable for all observed parameters except DO, Fe, BOD,TC for Class – A and water is suitable for all observed parameters for Class – C	Water is suitable for all observed parameters for Class – E
Satrapur	Water is suitable for all observed parameters except CH for Class – A and pH, DO, BOD & TC for Class – C	Water is suitable for all observed parameters except pH for Class – E
Pauni	Water is suitable for all observed parameters except CH, Fe for Class – A and DO, BOD & TC for Class – C.	Water is suitable for all observed parameters for Class – E
Hivra	Water is suitable for all observed parameters except TH, Fe for Class – A and pH, DO, BOD & TC for Class – C.	Water is suitable for all observed parameters except pH for Class – E
Nandgaon	Water is suitable for all observed parameters except to DO CH,TH for Class – A and BOD & TC for Class – C.	Water is suitable for all observed parameters except pH for Class – E
P.G.Bridge	Water is suitable for all observed parameters except to DO, TH, TC, Fe for Class – A and BOD & TC for Class – C.	Water is suitable for all observed parameters for Class – E
Bamni	Water is suitable for all observed parameters except to CH, TH, Fe, Cl for Class – A and DO, BOD, SO_4 & TC for Class – C.	Water is suitable for all observed parameters except EC & B for Class – E.
Ashti	Water is suitable for all observed parameters except to CH, TH, Fe for Class – A and pH, DO, BOD & TC for Class – C.	Water is suitable for all observed parameters except pH for Class – E
Wairagarh	Water is suitable for all observed parameters except to Fe, NO_3 for Class – A and BOD & TC for Class – C.	Water is suitable for all observed parameters for Class – E
Bhatpalli	Water is suitable for all observed parameters except to DO, BOD, Fe, NO_3 for Class – A and TC for Class – C.	Water is suitable for all observed parameters except B for Class – E

Water Quality Monitoring Stations	Water Suitability for Class A and Class C:	Water Suitability for Class E
Sakmur	Water is suitable for all observed parameters except to CH, Fe, TC for Class – A and pH, BOD, CH, TH & TC for Class – C.	Water is suitable for all observed parameters except pH & B for Class – E.
Tekra	Water is suitable for all observed parameters except to DO, Fe, NO_3 for Class – A and BOD for Class – C.	Water is suitable for all observed parameters for Class – E

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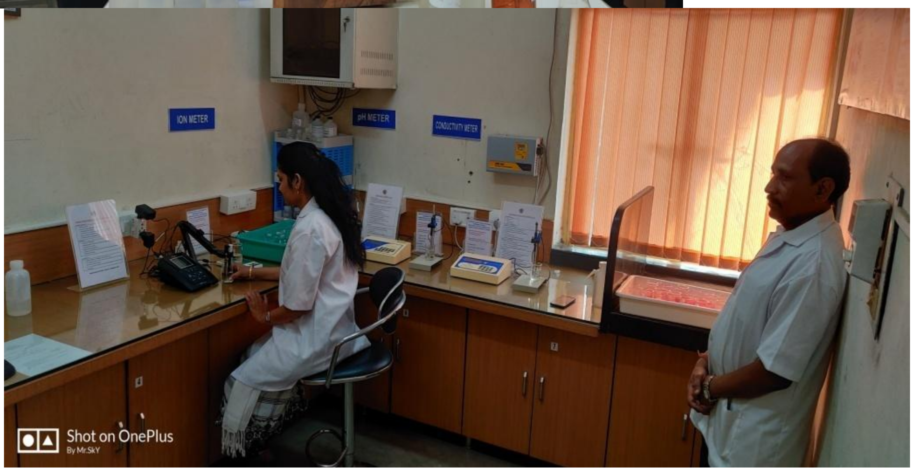

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Comparative Study between Ground (Well) Water Quality and River (Ganga) Water Quality in different season at Buxar (GDSQ) site

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)

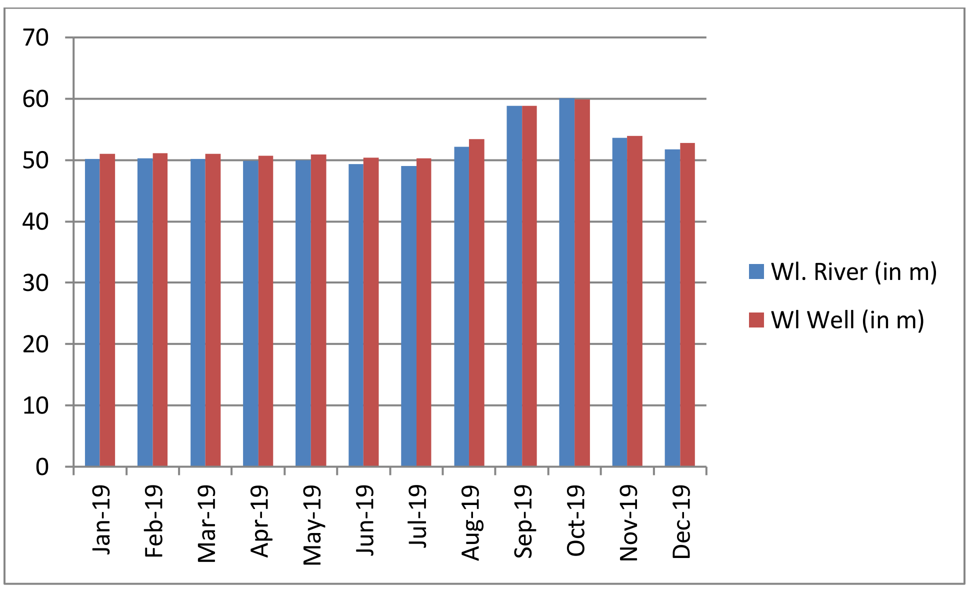
The data generated after the analysis of River Water:

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

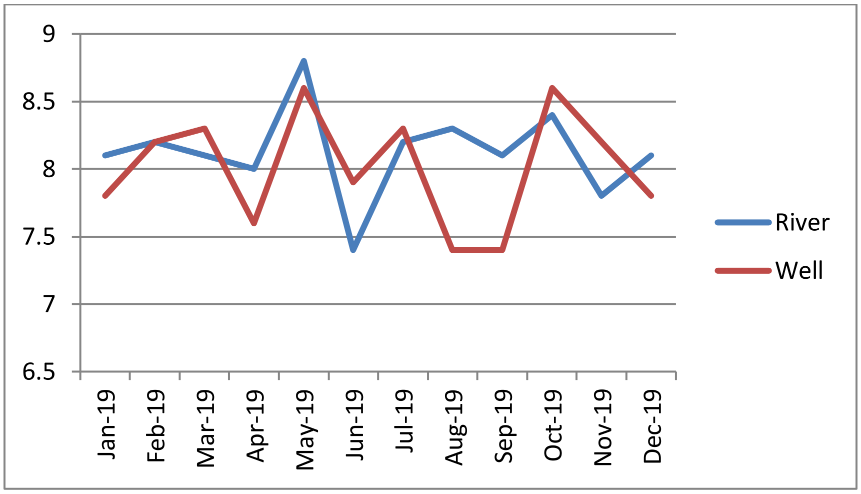


Water level (w.r.t. mean Sea level) of both Well and River from Jan-19 to Dec-19

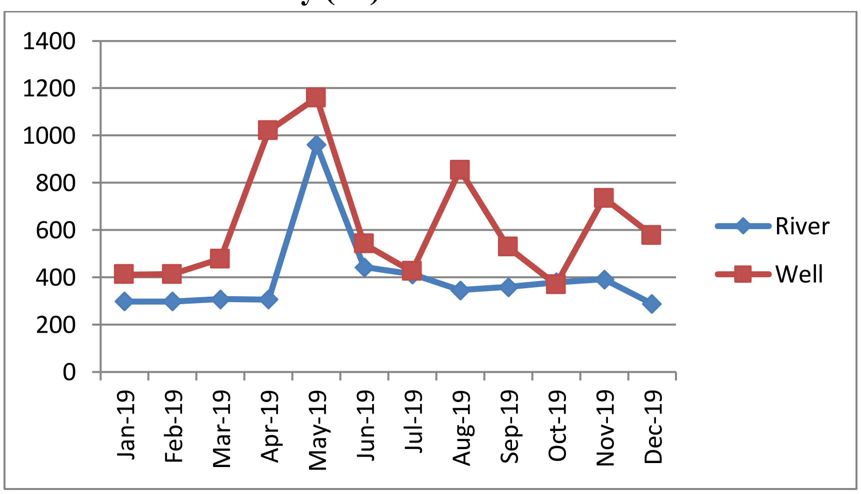
It is clear from the above bar graph that water level of well is higher than that of river throughout the year 2019 by almost 01mtr.

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.

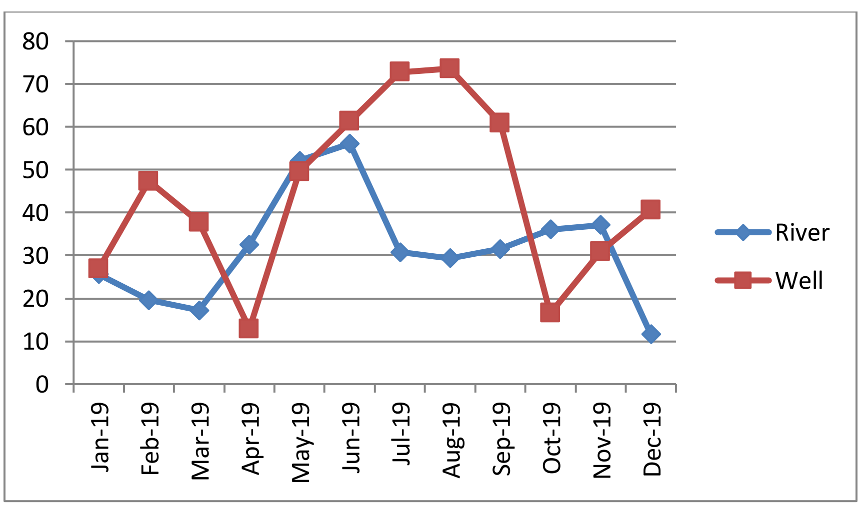
1. pH:



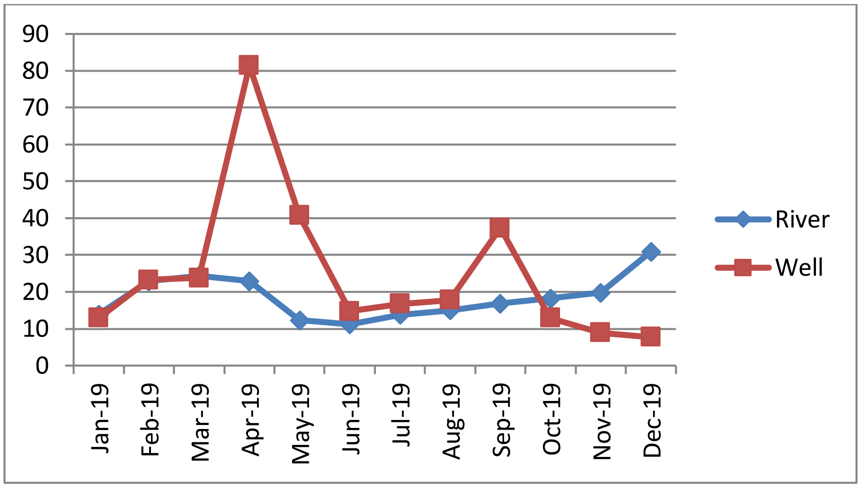
2. Electricle Conductivity (Ec):



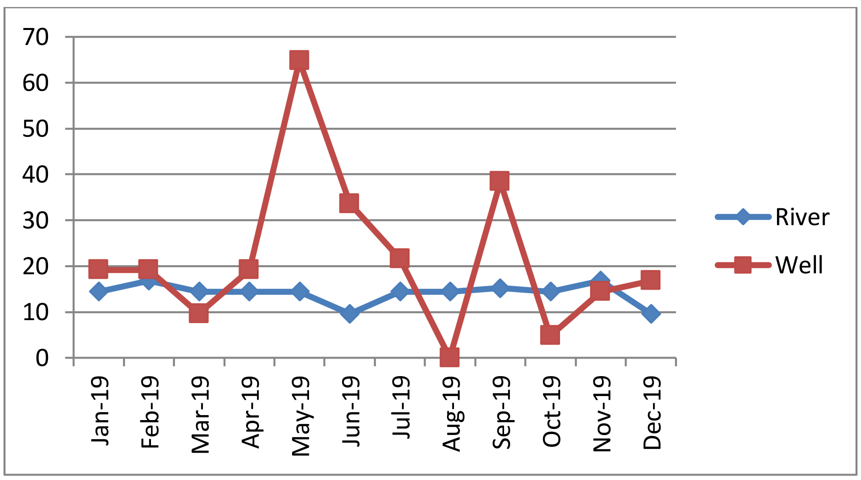
3. Sodium:



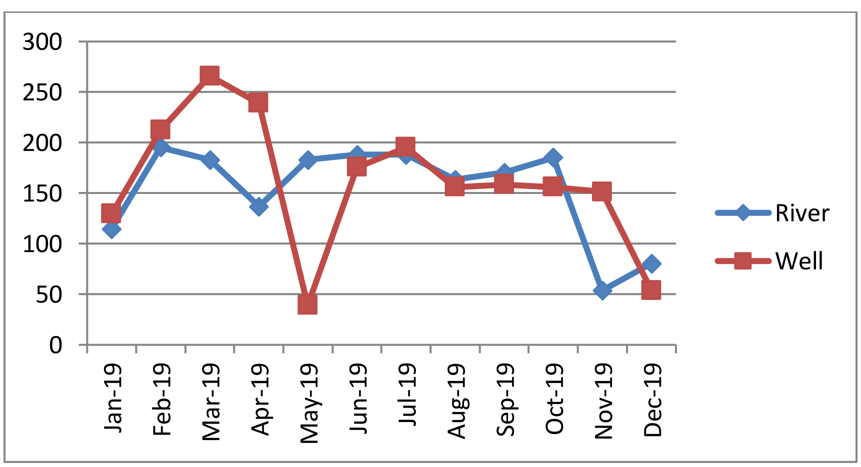
4. Potassium:



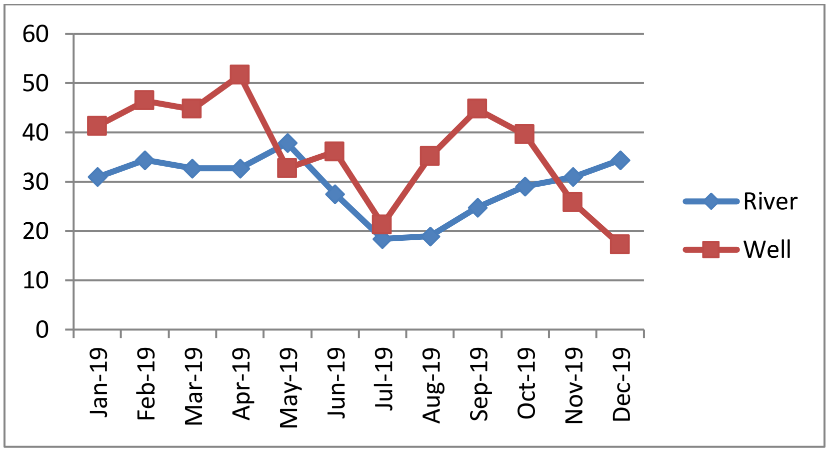
5. Carbonate:



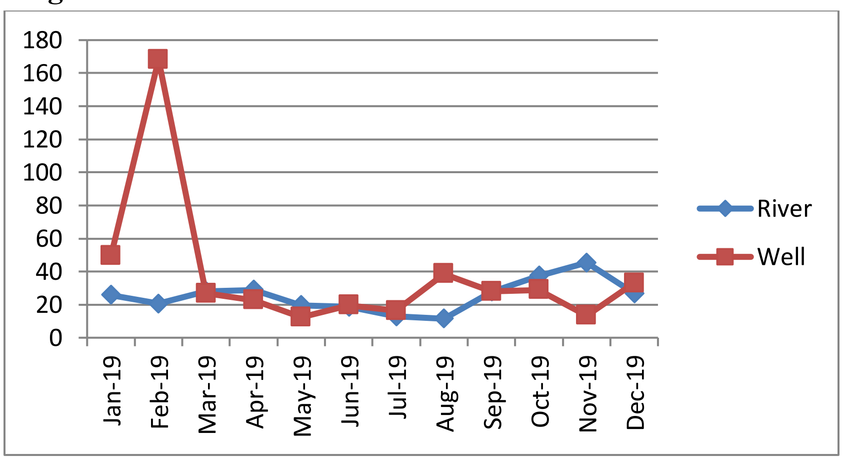
6. Bibarbonate:



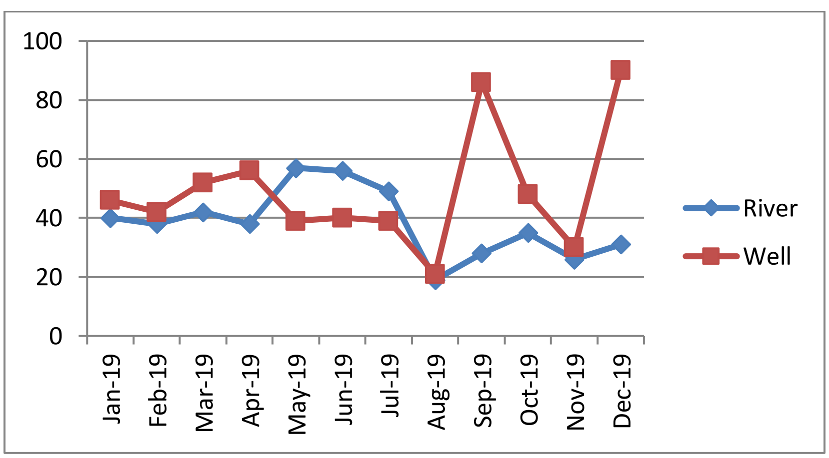
7. Calcium:



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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Seasonal Variation in Water Quality of Tapi River

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Abstract

Rivers are considered as vital and vulnerable freshwater ecosystems that are important for the sustenance of all life. They represent the major source of water used for human consumption, 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 Tapi river basin at two permanent water quality monitoring stations (Burhanpur and Sarangkheda) maintained by Central Water Commission (CWC). In this study, surface water quality data collected from these two monitoring stations were analyzed for six major physicochemical parameters namely Electrical Conductivity (EC), pH, Fluoride (F^-), Nitrate-Nitrogen (NO_3^- – N), Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO) for three different seasons (Flood, Winter and Summer) for the period 2009-2018.

Introduction

Rivers are important multi-usage components, such as sources of drinking water, irrigation, fishery and energy 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 favourable 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.

Study Area

The Tapi River

The Tapi is the second largest westward draining interstate river. It originates near Multai in Betul district at an elevation of 752 m above *msl*. The total length of this west flowing river from its origin to its out- fall into Gulf of Cambay is 724 km. It's drainage area is around 65,145 sq.km, out of which nearly 80% lies in Maharashtra, 15% in Madhya Pradesh and rest 5% in Gujarat .The Tapi basin is the northern most basin of Deccan Plateau and is situated between latitudes 20°N to 22°N approximately. The Satpura range forms its northern boundary and the Ajanta and Satmala hills forms its southern extremity. Mahadeo hills form its eastern boundary and its outlet into the Arabian Sea is in the west. Bounded by three sides by the hill ranges, the river Tapi, along with its tributaries flows more or less over the plains of Vidarbha, Khandesh and Gujarat.

The Tapi receives several tributaries on both the banks. There are 14 major tributaries having length more than 50 km. Out of which 4 tributaries viz. Vaki, Gomi, Arunavati and Aner join on the right bank. Other 10 tributaries viz. Nesu, Amaravati, Buray, Panjhra, Bori, Girna, Vaghur, Purna, Mona and Sipna drain on left bank of the main channel. The drainage system on the left bank of Tapi is, therefore, more extensive as compared to the right bank area.

The Purna and Girna, two important left bank tributaries, together account for nearly 45% of the total catchment area of the Tapi. The Purna is the principal tributary of the Tapi and originates in Betul district near Gawilgarh hills of Satpura range at an elevation of 900 m. It traverses 274 km having catchment area of about 18929 sq km. The Girna, another major tributary, rises in the hill ranges of Western Ghats at an elevation of 900 m. It traverses a distance of about 260 km having a catchment area about 10061 sq km.

The average rainfall in the Tapi basin is 830 mm. Owing to topographical characteristics, the climate is variable. The Purna sub catchment in the upper half of the Tapi Basin is one of the hottest regions in India.

At present, there are 40 major and medium Irrigation schemes completed and 15 ongoing schemes in the form of reservoirs weirs in the Tapi catchment. The main projects on main river are Kakrapar weir, Ukai Dam and Hathnur Dam. The upper Tapi Stage- II project is under progress at Nawtha.

Sampling Location

The water samples were collected from the two different locations in the Tapi River, namely Burhanpur and Sarangkheda. The Central Water Commission (CWC) has permanent water quality monitoring station in these two locations.

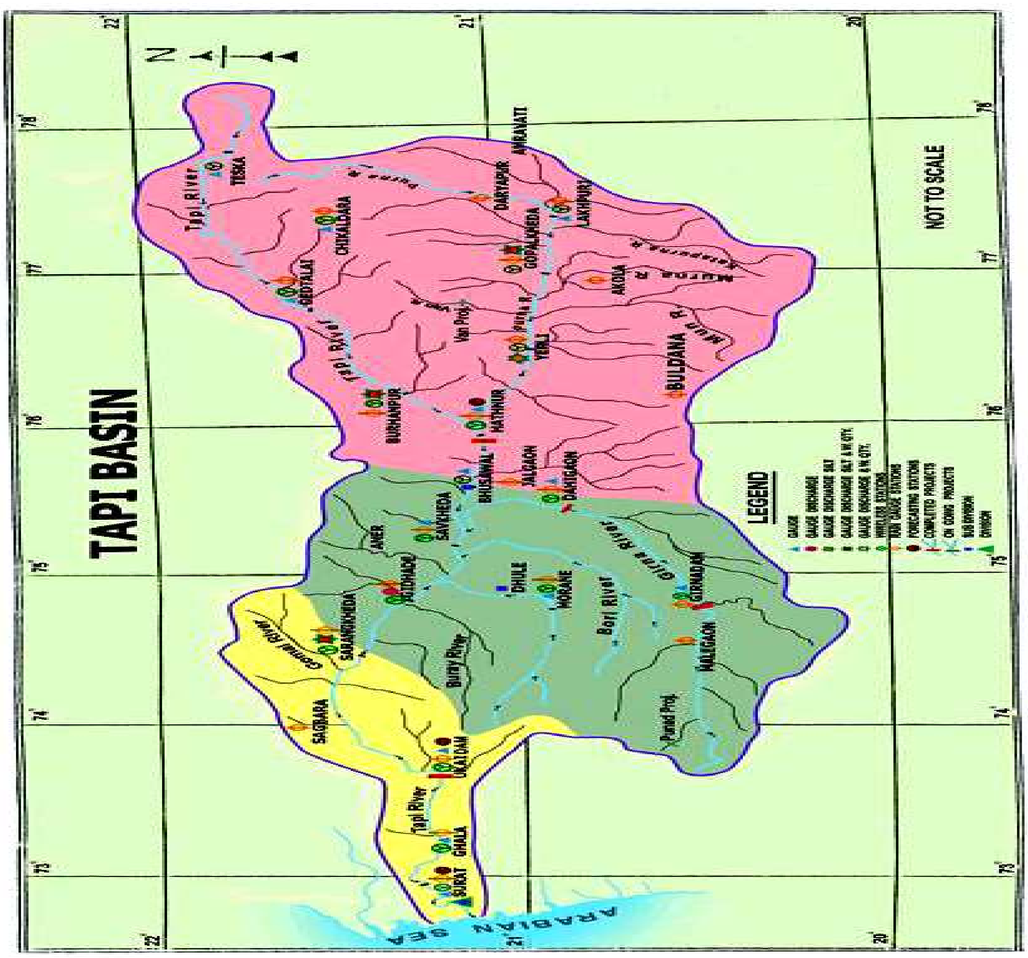
Burhanpur Site

The Burhanpur site (21º17'12" N and 76º30'18" E) is located at Khandwa district in Madhya Pradesh. The length of the river at this site is 241 km from the origin of Tapi River. The drainage area of this site is around 8487 Sq. Km. This is a GDSQ (Gauge, Discharge, Silt and Water Quality) site.

Sarangkheda Site

The Sarankheda site (21º25'55" N and 74º31'37" E) is located at Nandurbar district in Maharashtra. The length of the river at this site is 488 km from the origin of Tapi River. The drainage area of this site is around 58400 Sq. Km. This is a GDSQ (Gauge, Discharge, Silt and Water Quality) site.

Tapi River Basin Map



Materials and Method
Sampling and Analysis

Water samples were collected once every 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 Tapi Division Water Quality Laboratory with proper preservation for further analysis of physiochemical parameters. 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, six major physio-chemical parameters were taken into consideration i.e. Electrical Conductivity (EC), pH, Fluoride (F^-), Nitrate-Nitrogen (NO_3^- – N), Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO). 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 Tapi at site Burhanpur - maximum and minimum values for the parameters were computed and compared for different seasons for the period 2009-2018. For site Sarangkheda, maximum and minimum values could not be computed due to non-availability of sufficient data as the river remains dry or in pooling condition during the summer season. So, average values of the parameters were taken and compared for different seasons for the period 2013-2018.

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

Sl. No.	Year	Flood	Winter	Summer
1	2009	635	461	683
2	2010	1584	499	-
3	2011	401	564	-
4	2012	300	592	545
5	2013	1370	561	650
6	2014	1230	584	481
7	2015	477	618	430
8	2016	419	516	1180
9	2017	730	980	1990
10	2018	450	570	1009

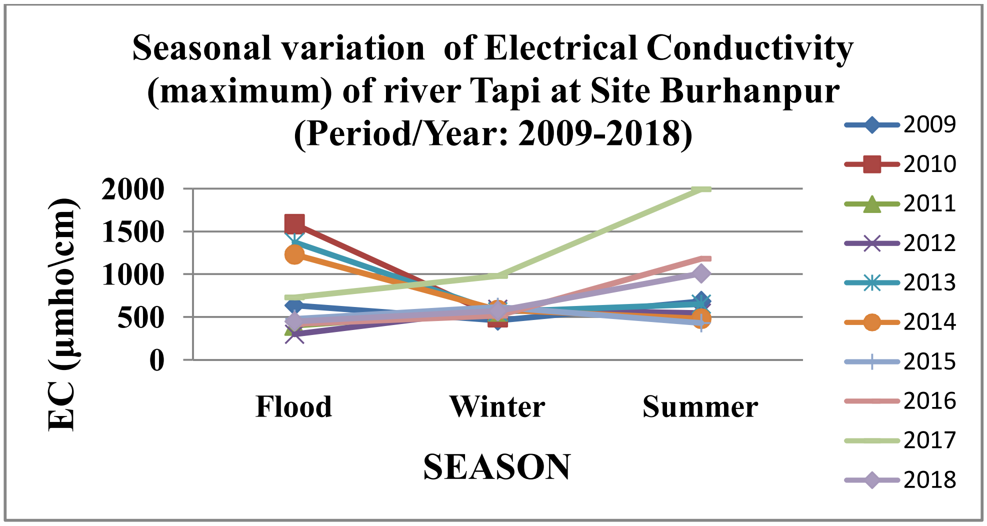


Figure 1. Seasonal variation of Electrical Conductivity (maximum)

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

Sl. No.	Year	Flood	Winter	Summer
1	2009	218	297	397
2	2010	221	359	-
3	2011	216	461	-
4	2012	250	400	520
5	2013	179	416	580
6	2014	384	390	410
7	2015	300	310	340
8	2016	280	430	400
9	2017	240	315	-
10	2018	343	469	681

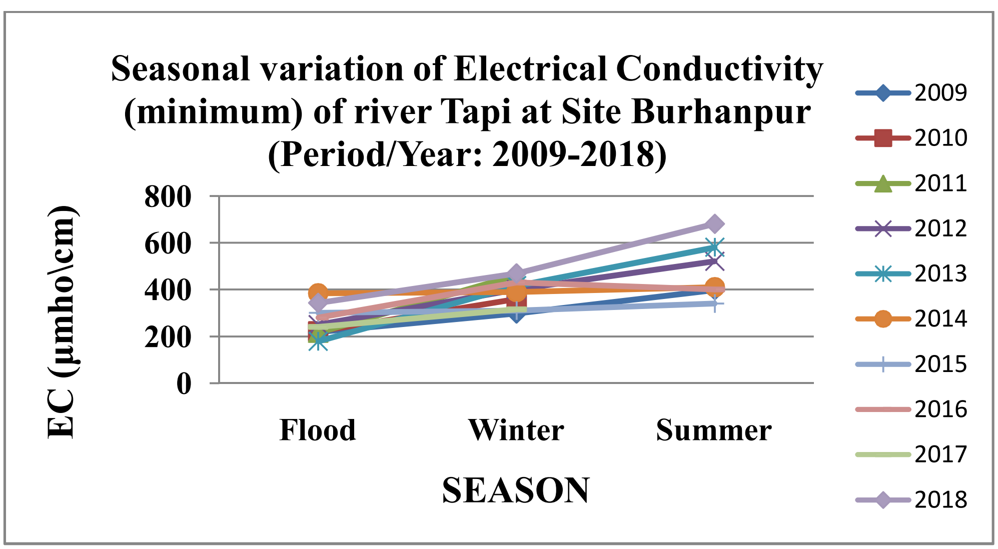


Figure 2. Seasonal variation of Electrical Conductivity (minimum)

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

Sl. No.	Year	Flood	Winter	Summer
1	2009	7.9	8.2	8.8
2	2010	8.5	8.4	-
3	2011	8.0	7.6	-
4	2012	8.0	8.2	8.2
5	2013	8.2	8.2	8.3
6	2014	8.4	8.3	8.4
7	2015	8.3	8.2	8.3
8	2016	8.2	8.3	8.2
9	2017	8.2	8.2	8.7
10	2018	8.2	8.6	8.6

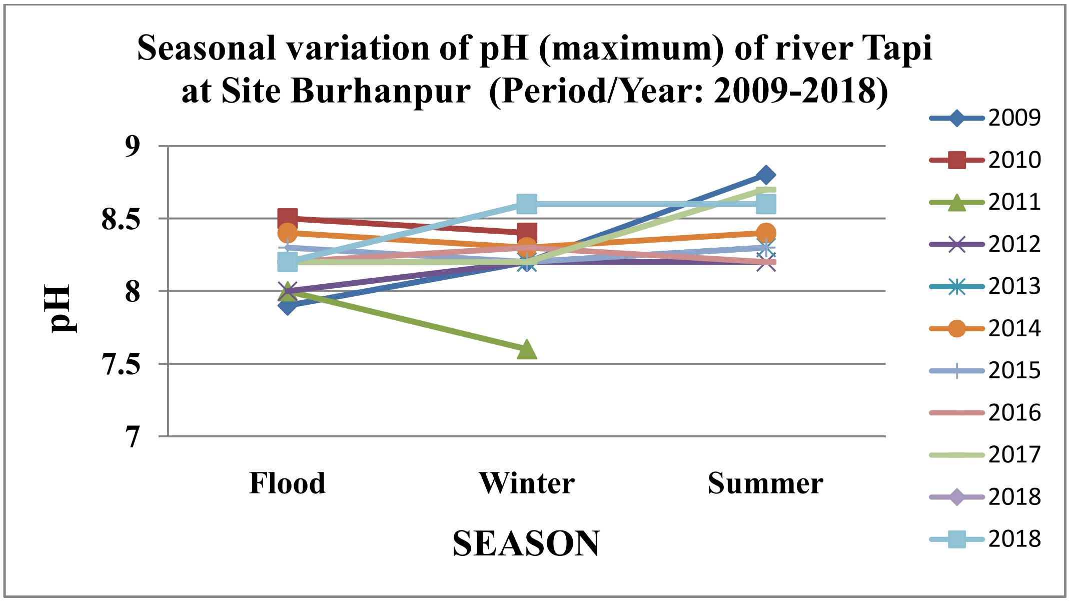


Figure 3. Seasonal variation of pH (maximum)

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

Sl. No.	Year	Flood	Winter	Summer
1	2009	7.4	6.3	7.7
2	2010	8.2	8.2	-
3	2011	7.0	6.6	-
4	2012	6.8	6.9	8.0
5	2013	8.2	7.5	8.3
6	2014	8.2	8.2	7.5
7	2015	8.0	7.8	8.2
8	2016	7.2	7.8	8.0
9	2017	8.0	6.8	-
10	2018	8.0	8.1	8.5

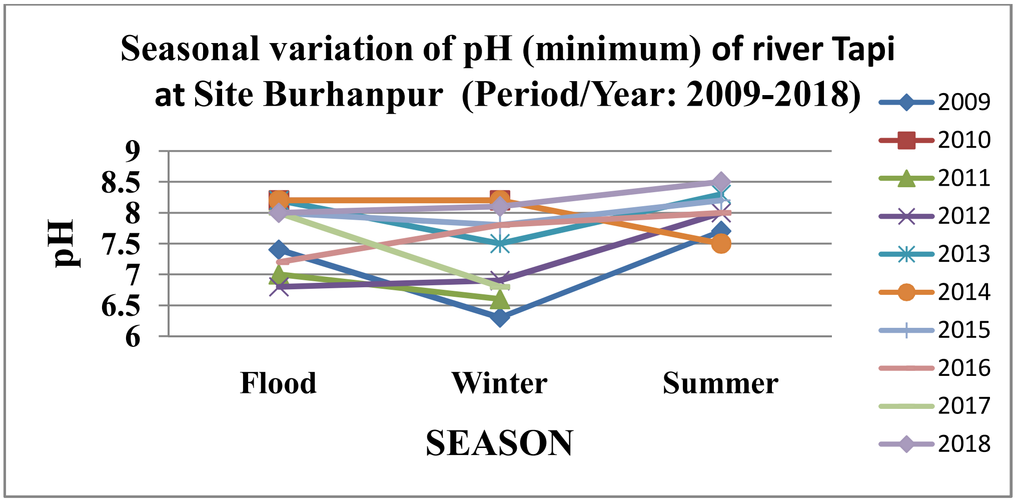


Figure 4. Seasonal variation of pH (minimum)

Table 5. Maximum values of Fluoride in mg/L at Burhanpur site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2009	0.36	0.30	0.36
2	2010	0.36	0.34	-
3	2011	0.22	0.26	-
4	2012	0.30	0.30	0.18
5	2013	0.18	0.16	0.22
6	2014	0.35	0.18	0.13
7	2015	0.14	0.14	0.14
8	2016	0.13	0.14	0.13
9	2017	0.13	0.19	0.66
10	2018	0.24	0.22	0.18

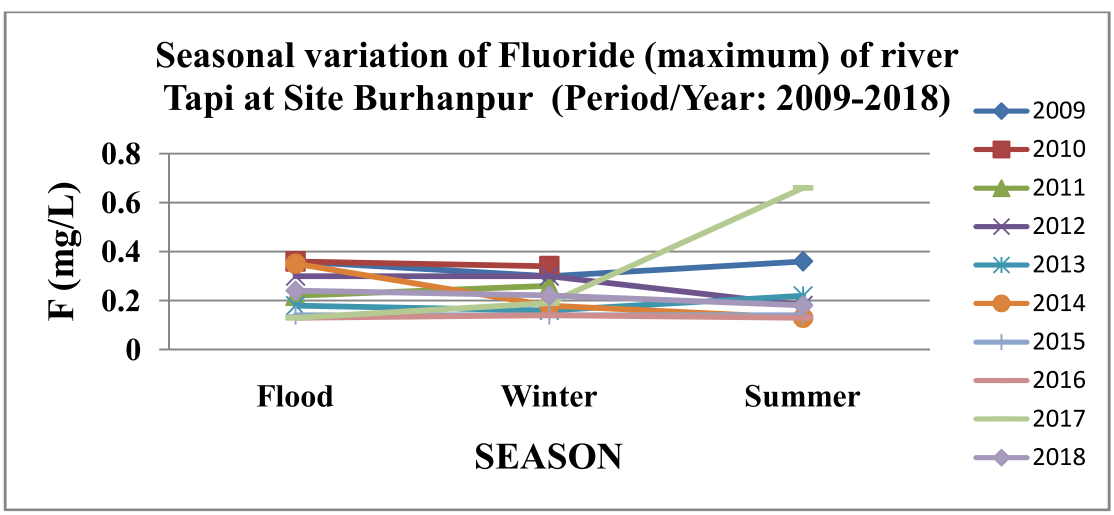


Figure 5. Seasonal variation of Fluoride (maximum)

Table 6. Minimum values of Fluoride in mg/L at Burhanpur site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2009	0.08	0.24	0.32
2	2010	0.12	0.10	-
3	2011	0.12	0.18	-
4	2012	0.16	0.16	0.16
5	2013	0.15	0.14	0.12
6	2014	0.10	0.11	0.13
7	2015	0.10	0.13	0.11
8	2016	0.08	0.13	0.10
9	2017	0.09	0.12	-
10	2018	0.15	0.16	0.14

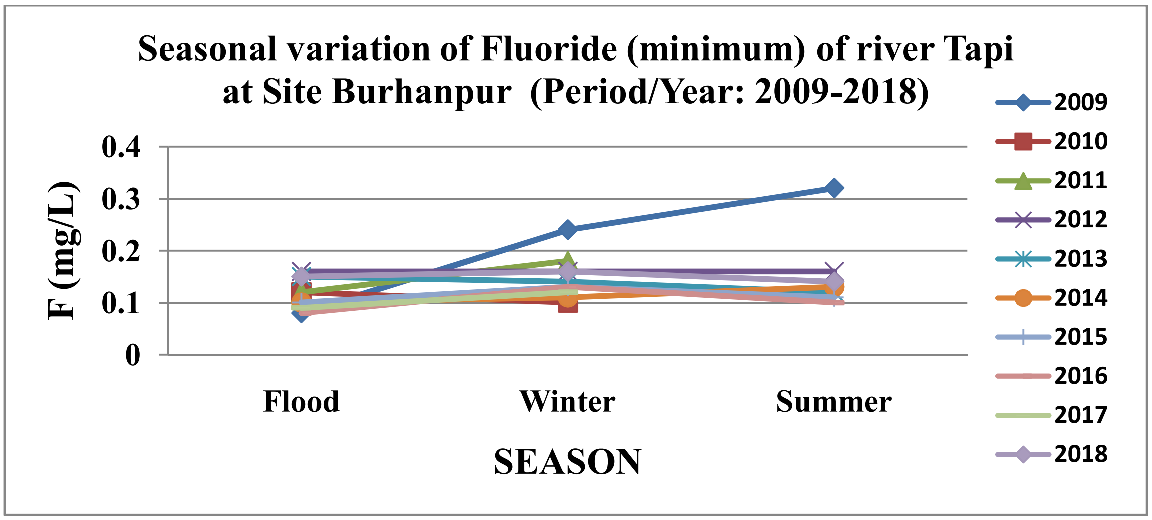


Figure 6. Seasonal variation of Fluoride (minimum)

Table 7. Maximum values of Nitrate in mg/L at Burhanpur site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2009	0.40	0.40	0.40
2	2010	0.38	0.36	-
3	2011	0.25	0.18	-
4	2012	0.20	0.20	0.17
5	2013	0.14	0.14	0.10
6	2014	0.13	0.16	0.13
7	2015	0.13	0.13	0.13
8	2016	0.13	0.14	0.14
9	2017	0.12	0.14	0.67
10	2018	1.26	1.30	2.84

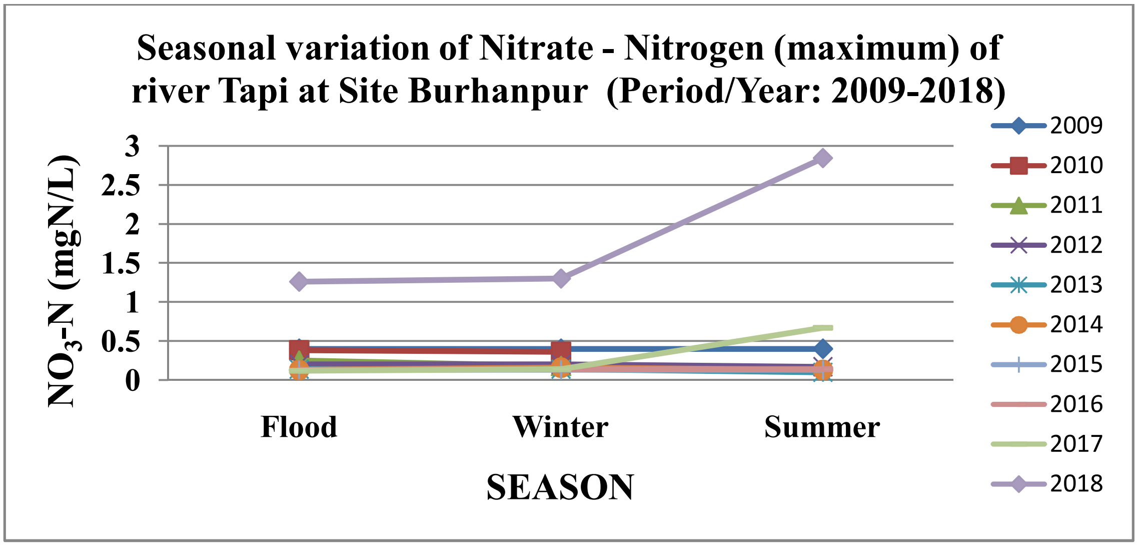


Figure 7. Seasonal variation of Nitrate - Nitrogen (maximum)

Table 8. Minimum values of Nitrate in mg/L at Burhanpur site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2009	0.08	0.10	0.30
2	2010	0.16	0.12	-
3	2011	0.16	0.12	-
4	2012	0.10	0.14	0.14
5	2013	0.10	0.12	0.10
6	2014	0.10	0.12	0.12
7	2015	0.10	0.13	0.10
8	2016	0.10	0.12	0.10
9	2017	0.10	0.11	-
10	2018	0.39	1.16	1.39

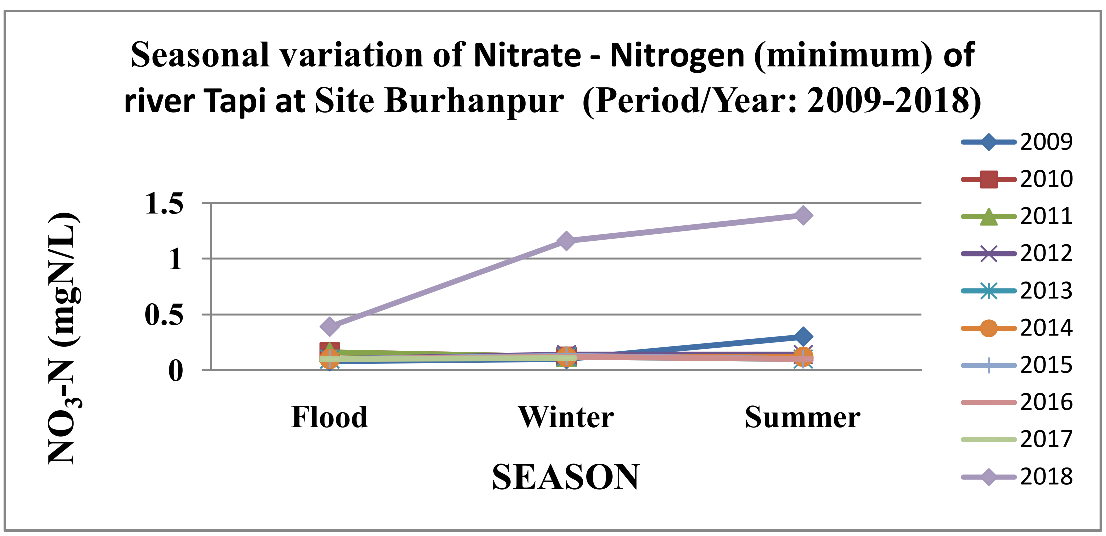


Figure 8. Seasonal variation of Nitrate - Nitrogen (minimum)

Table 9. Maximum values of BOD in mg/L at Burhanpur site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2009	2.8	0.6	3.7
2	2010	1.5	0.8	-
3	2011	3.0	4.3	-
4	2012	2.0	1.6	1.6
5	2013	1.6	2.8	4.3
6	2014	2.7	4.5	4.8
7	2015	1.6	2.6	3.0
8	2016	2.0	2.7	4.3
9	2017	17.0	3.9	3.1
10	2018	2.0	2.1	4.6

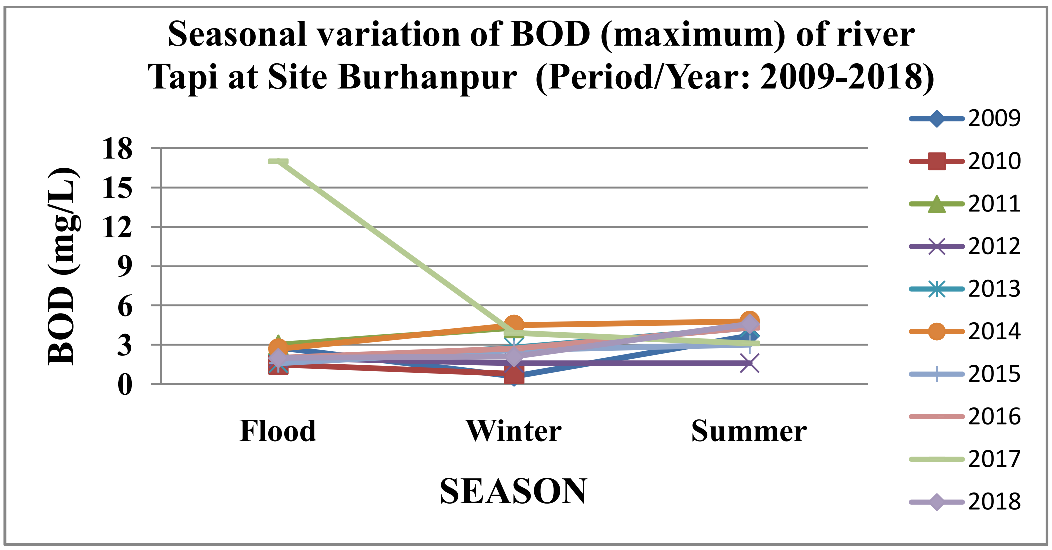


Figure 9. Seasonal variation of BOD (maximum)

Table 10. Minimum values of BOD in mg/L at Burhanpur site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2009	0.2	0.2	1.6
2	2010	0.4	0.3	-
3	2011	0.6	1.2	-
4	2012	0.5	0.8	1.4
5	2013	0.5	1.0	1.6
6	2014	0.5	2.1	0.6
7	2015	0.4	0.5	1.4
8	2016	0.8	1.0	1.2
9	2017	0.6	0.6	-
10	2018	0.8	1.5	3.4

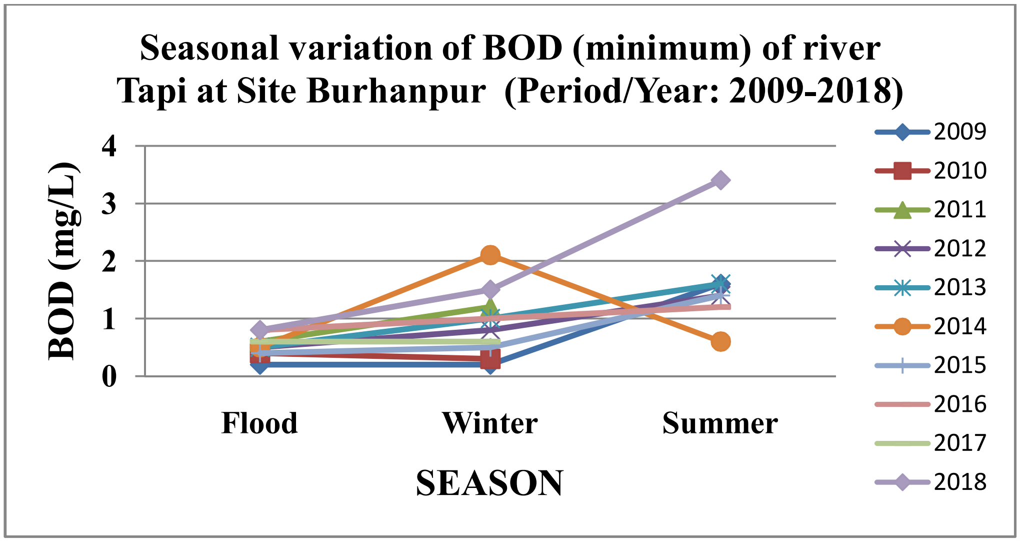


Figure 10. Seasonal variation of BOD (minimum)

Table 11. Maximum values of DO in mg/L at Burhanpur site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2009	-	7.3	10.2
2	2010	-	-	-
3	2011	-	-	-
4	2012	-	-	-
5	2013	7.2	6.8	-
6	2014	7.4	6.3	6.1
7	2015	6.3	9.8	8.3
8	2016	10.2	8.2	7.5
9	2017	6.3	6.3	-
10	2018	6.7	8.6	6.4

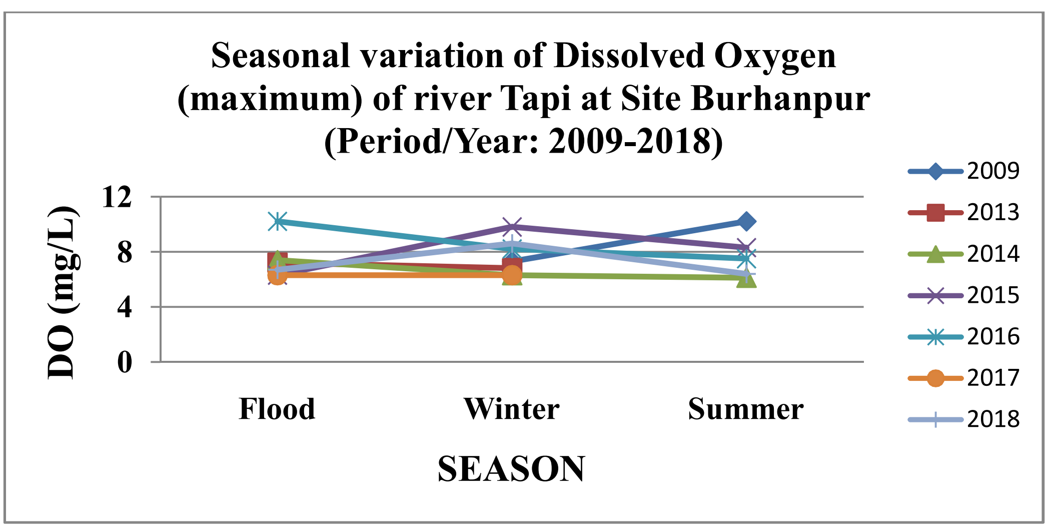


Figure 11. Seasonal variation of Dissolved Oxygen (maximum)

Table 12. Minimum values of DO in mg/L at Burhanpur site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2009	-	7.0	2.3
2	2010	-	-	-
3	2011	-	-	-
4	2012	-	-	-
5	2013	7.2	6.5	-
6	2014	4.5	5.5	2.6
7	2015	6.3	9.8	4.6
8	2016	1.3	6.9	4.3
9	2017	4.8	5.3	5.1
10	2018	5.0	6.3	5.1

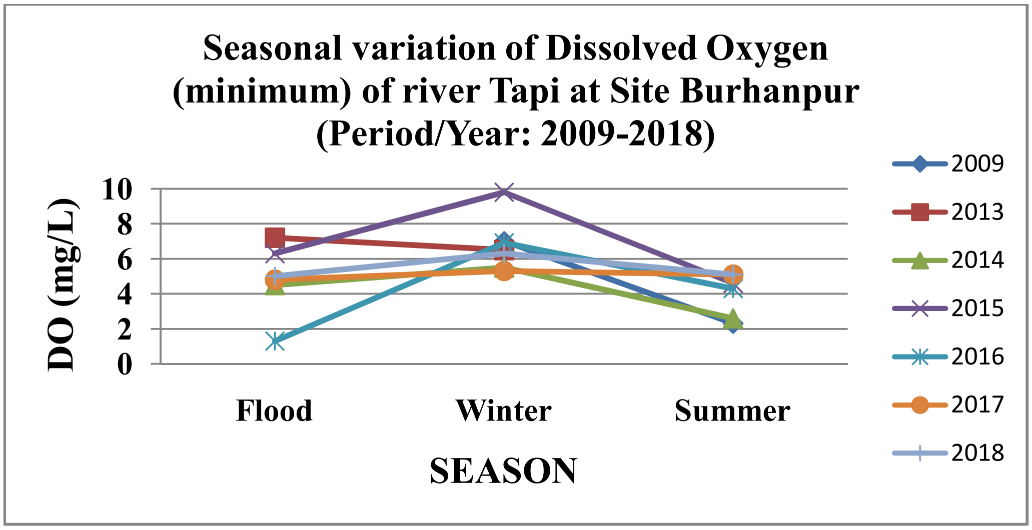


Figure 12. Seasonal variation of Dissolved Oxygen (minimum)

Table 13. Average values of Electrical Conductivity in µmho/cm at Sarangkheda site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2013	413	460	630
2	2014	425	410	444
3	2015	417	368	280
4	2016	300	356	462
5	2017	250	306	498
6	2018	422	495	525

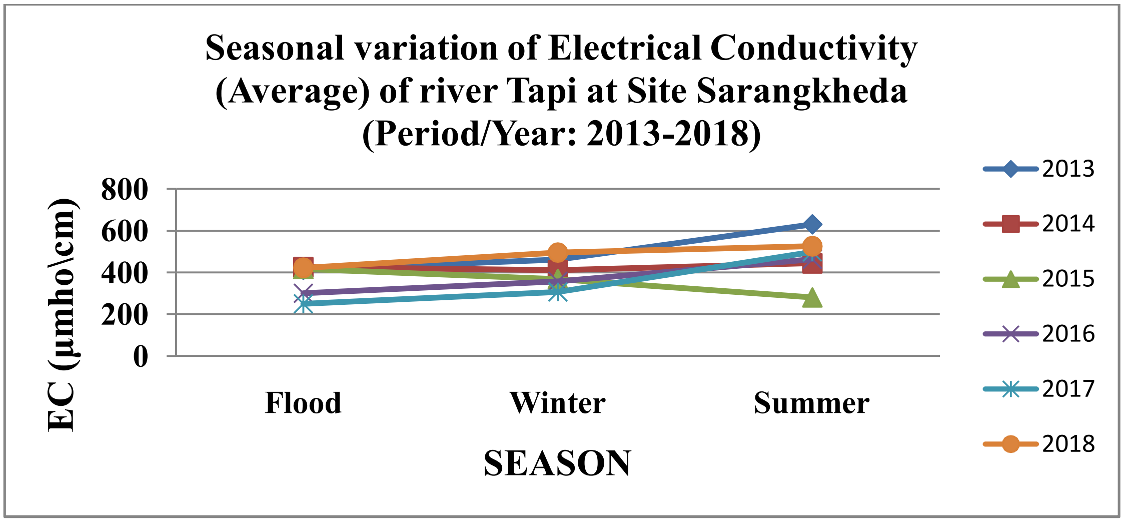


Figure 13. Seasonal variation of Electrical Conductivity (average)

Table 14. Average values of pH at Sarangkheda site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2013	8.0	8.3	8.1
2	2014	8.6	8.1	8.2
3	2015	8.1	7.8	8.3
4	2016	7.7	8.3	8.2
5	2017	8.0	8.1	8.3
6	2018	8.1	8.3	8.4

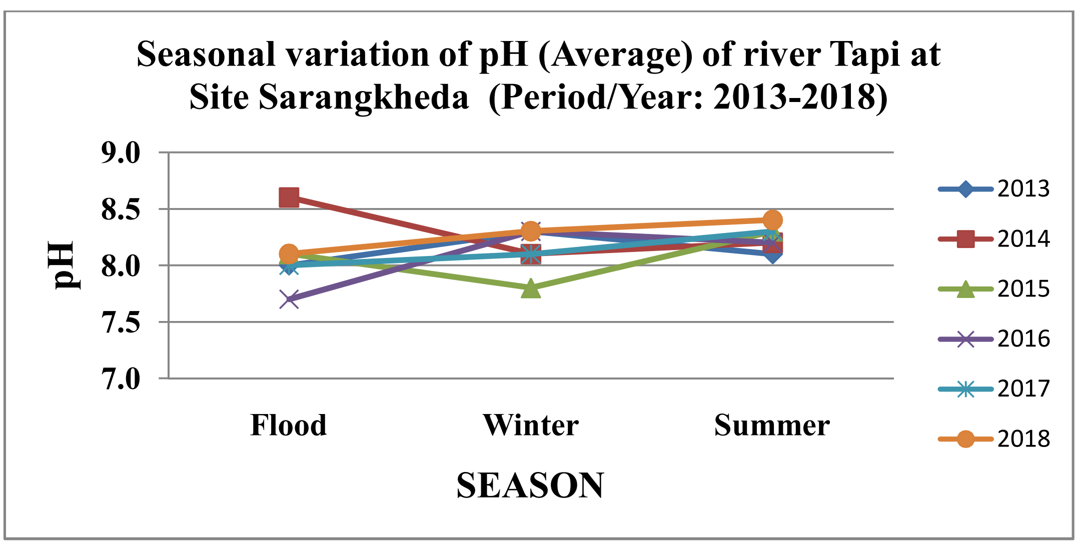


Figure 14. Seasonal variation of pH (average)

Table 15. Average values of Fluoride in mg/L at Sarangkheda site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2013	0.12	0.15	0.18
2	2014	0.10	0.16	0.13
3	2015	0.15	0.14	0.14
4	2016	0.11	0.12	0.13
5	2017	0.09	0.15	0.37
6	2018	0.28	0.24	0.52

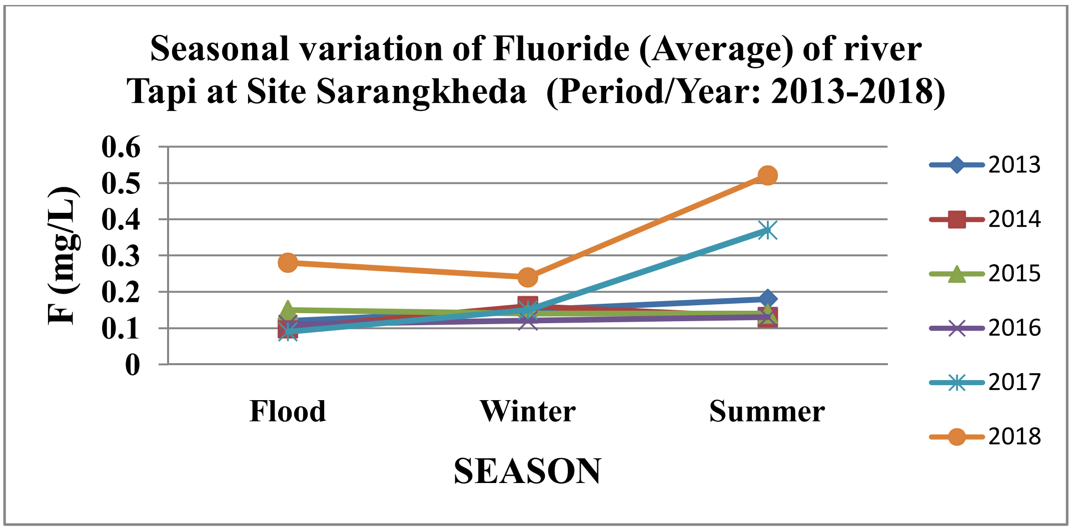


Figure 15. Seasonal variation of Fluoride (average)

Table 16. Average values of Nitrate in mg/L at Sarangkheda site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2013	0.11	0.10	0.12
2	2014	0.11	0.11	0.11
3	2015	0.13	0.13	0.13
4	2016	0.11	0.12	0.12
5	2017	0.13	0.14	0.38
6	2018	0.76	0.73	0.30

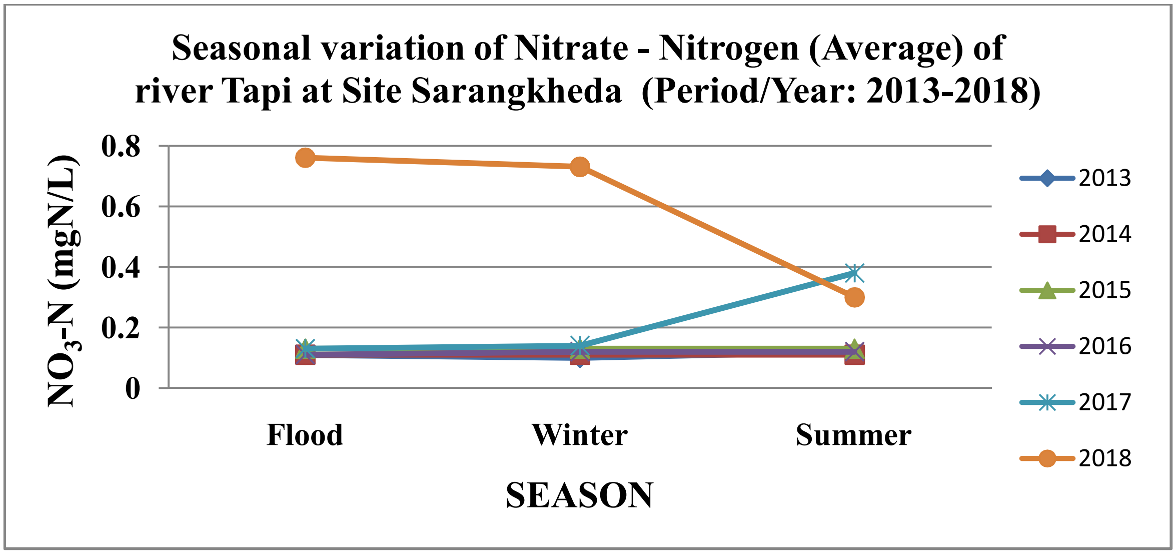


Figure 16. Seasonal variation of Nitrate - Nitrogen (average)

Table 17. Average values of BOD in mg/L at Sarangkheda site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2013	1.0	2.5	2.4
2	2014	2.2	2.4	4.0
3	2015	2.3	2.8	1.0
4	2016	1.2	2.1	4.3
5	2017	2.3	1.3	2.9
6	2018	2.4	2.4	2.8

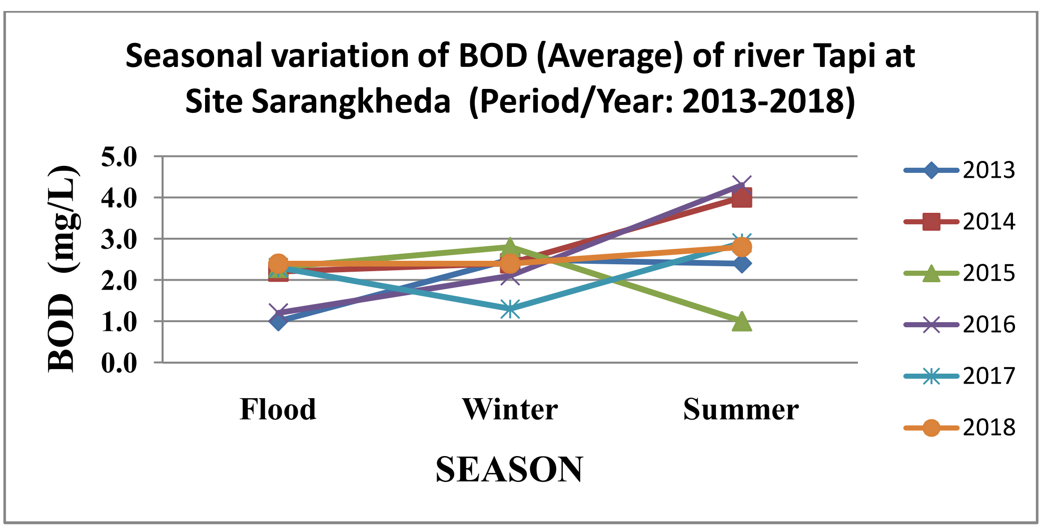


Figure 17. Seasonal variation of BOD (average)

Table 18. Average values of DO in mg/L at Sarangkheda site during different seasons

Sl. No.	Year	Flood	Winter	Summer
1	2013	9.0	9.8	10.2
2	2014	7.2	9.0	8.3
3	2015	7.2	6.5	6.7
4	2016	10.3	8.1	7.7
5	2017	6.2	7.5	6.1
6	2018	6.5	8.1	8.4

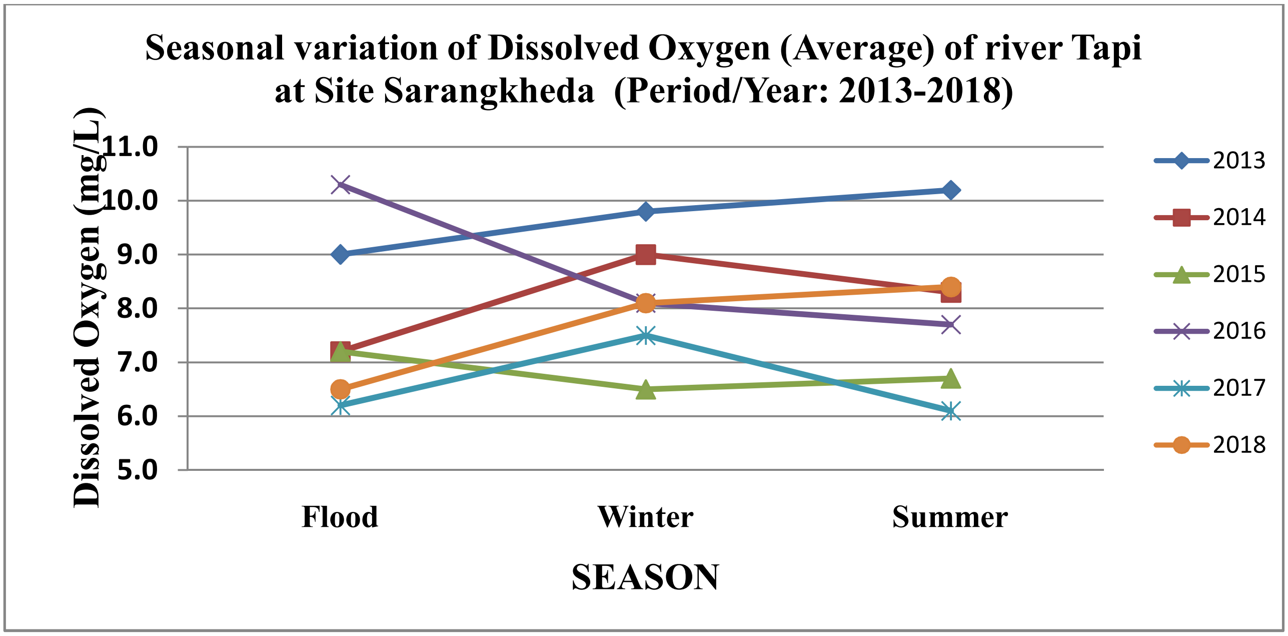


Figure 18. Seasonal variation of Dissolved Oxygen (average)

Results and Discussion

Electrical Conductivity (EC)

Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds. 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 river Tapi at both the sites Burhanpur and Sarangkheda shows seasonal variation being maximum during summer and minimum during monsoon. High values of EC during summer could be attributed to lower flow volume, high temperature and evaporation. Evaporation can cause salinity concentrations to rise. As the water level lowers, the ions present become concentrated, contributing to higher conductivity levels. On the other side of the scale, rain can increase water volume and level, thus lowering conductivity.

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 biota, impede recreational uses of water and alter the toxicity of other pollutants in one form or the other.

During the study, pH of river Tapi at both the sites Burhanpur and Sarangkheda 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 summer. 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 within the limits of BIS / WHO standard value.

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 Tapi River varied from 0.08 mg/L to 0.66 mg/L. Seasonally, Fluoride concentration in Tapi River for both the sampling stations was found to be maximum in summer and minimum during monsoon. Fluoride concentration was found within the permissible limit of BIS. The Bureau of Indian Standards has recommended the limit of 1.5mg/L.

Nitrate – Nitrogen (NO_3^- – N)

Nitrate–Nitrogen in surface water is an important parameter for water quality assessment to find out the pollution status and anthropogenic load in the river water due to both point and non–point sources. It is a highly oxidized form of nitrogenous compounds and is usually present in surface water as it is the end product of aerobic decomposition of organic nitrogenous matter present in animal waste and its concentration depends on the nitrification and denitrification activities of microorganisms. Unpolluted natural waters usually contain only minute amounts of nitrate. The excessive use of fertilizers in agriculture, urban activities and atmospheric deposition are generally assumed to be the major sources of elevated nitrate concentration in fresh water. High concentration of nitrate can result in many environmental and ecological problems, such as blooms of toxic algae, eutrophication of lakes and reservoirs and extinction of species in the river ecosystem. In addition, long-term exposure to high nitrate drinking water may increase human health risks, which may lead to chronic poisoning, linked to methemoglobinemia.

Nitrate (NO_3^--N) concentration in Tapi River varied from 0.08 mg/L to 2.84 mg/L. There was an increase in nitrate concentration during summer for Site Burhanpur. Higher nitrate values during summer may be due to increase in the degradation of organic matter by microbial activities. For Site Sarangkheda, an increase in nitrate concentration during monsoon was observed. This increase could be due to entry of water from agricultural fields, decayed vegetable, animal matter, domestic effluents, sewage or sludge disposal, industrial discharges, atmospheric washout and precipitation that enrich river water with nitrogen compounds.

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 surface and ground 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 municipal sewage or the raw sewage which requires more oxygen for decomposition by bacteria thus, increasing the BOD.

BOD values of river Tapi at site Burhanpur, were found to be highest during Summer followed by winter and flood. The high values of BOD during summer could be attributed to the acceleration in the metabolic activities of various aerobic micro-organisms in the decomposition of organic matter at high temperature, decrease in water flow and direct discharge of untreated domestic and industrial waste into the river. The low values of BOD in monsoon could be due to dilution in concentration of dissolved organic matter due to fresh rain water. Values of BOD for Site Sarangkheda also exhibited similar seasonal variation.

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 river Tapi at Burhanpur, were highest in winter and lowest in summer and intermediate values were recorded in monsoon. 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.

For site Sarangkheda, higher values of DO were observed during winter season as compared to summer and monsoon.

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 River Tapi 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 either with the reduction of water level during the summer season or 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 summer season, which may be attributed to decrease in flow volume and high 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.

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