



WATER QUALITY “HOT - SPOTS” IN RIVERS OF INDIA



GOVERNMENT OF INDIA
Ministry of Water Resources
CENTRAL WATER COMMISSION
New Delhi

August, 2011

FOREWORD

Water in its purest form on Earth, comes from rain and snow. This water is available first in the form of surface water through rivers and Lakes. Thus we can say the journey of water on Earth starts in the shape of surface runoff. This surface water forms the lifeline of almost all the human activities as also most of nature's activities. It is the surface water which percolates down and recharges the aquifers and becomes part of Ground Water. Therefore it can be easily said that contamination of surface water has a cascading effect and has far reaching implications throughout the reach of the river, Ground water aquifers, flora and fauna, and human activities.

Due to the fast pace of industrialization and urbanization a lot of effluent and sewage is being generated, for a major portion of which there are no effluent treatments. This has resulted in discharge of this sewage in to the rivers untreated or only partially treated. Besides this rampant use of fertilizers and pesticides, open defecation, lack of solid waste management practices also contributes to surface water pollution.

Rivers are our lifeline and we all have the responsibility of preserving it, to make our development and consequently quality of life sustainable. Pollution of rivers does not mean that they are polluted from its source to mouth, but there are stretches in some rivers which are polluted and actions are being taken by the Government to bring these stretches to acceptable conditions.

Central Water Commission has been monitoring the quality of river water at 371 stations on different rivers, all over India. It all started with the aim of monitoring the water quality parameters for agricultural purposes, but later on many more parameters were added and at present it covers more or less the entire spectrum of water quality. The present report attempts to provide the water quality scenario of our rivers viz-a-viz BIS and other Standards. The report is based on the average values observed during the last 10 years at CWC monitoring Stations. This is a first attempt at preparing this type of report and, in future, it will be further updated to include more information by inclusion of maps and graphs.

I would like to put on record my appreciation of the initiative taken by Member (River Management) and Director (WQAA) as well as the dedicated efforts put in by the officers and staff of CWC in compilation and preparation of this report.



(AK Bajaj)
Chairman, CWC

CONTENTS

1.0 INTRODUCTION	1
2.0 WATER RESOURCES IN INDIA AT A GLANCE	2
3.0 INDIAN RIVER SYSTEM	3
4.0 HYDROCHEMISTRY	6-8
4.1 Chemistry of Rainwater	
4.2 Chemistry of Surface Water	
4.3 Chemistry of Ground Water	
5.0 RIVER WATER MONITORING IN CWC	8-9
6.0 RIVER WATER POLLUTION	9-10
6.1 Source of Pollution	
6.2 River Water Quality & Environmental Factor	
7.0 RIVER WATER QUALITY HOT SPOTS OF INDIA	10-21
7.1 pH (Hydrogen Ion Concentration)	
7.2 Electrical Conductance (Salinity)	
7.3 Chloride	
7.4 Fluoride	
7.5 Nitrate	
7.6 Sulphate	
7.7 Iron	
7.8 Calcium	
7.9 Magnesium	
7.10 Total Hardness	
7.11 Dissolved Oxygen	
7.12 Bio-Chemical Oxygen Demand	
7.13 Total Coliforms and Fecal Coliforms	
7.14 Arsenic	
8.0 ANNEXURE	22-41
Table & Plate 01 – WQ Stations having pH value > 8.5 in River Water	
Table & Plate 02 – WQ Stations having EC > 3000 μ S/cm in River Water	
Table & Plate 03 – WQ Stations having Magnesium >100 mg/l in River Water	
Table & Plate 04 – WQ Stations having Total Hardness > 600 mg/l in River Water	
Table & Plate 05 – WQ Stations having Chloride > 1000 mg/l in River Water	
Table & Plate 06 – WQ Stations having Sulphate > 400 mg/l in River Water	
Table & Plate 07 – WQ Stations having Iron > 1.0 mg/l in River Water	
Table & Plate 08 – WQ Stations having Fluoride > 1.5 mg/l in River Water	
Table & Plate 09 – WQ Stations having Dissolved Oxygen < 5.0 mg/l in River Water	
Table & Plate 10–WQ Stations having Biochemical Oxygen Demand > 3mg/l in River Water	
9.0 REFERENCES	42
10.0 ABBREVIATION	43

1.0 - INTRODUCTION

Earth, the Water planet is the only one in our solar system presently characterized and shaped by abundant liquid water - a necessity for life. This vital resource makes up 60 percent of the human body. A person can live no more than 4 to 5 days without water, and we rely on it for drinking, cooking, bathing, washing clothes, growing food, recreation, industry, and mining, as well as generation of electric power. Like the air we breathe, water is essential to our daily life.

Water is a major factor in shaping our landscape. Through the processes of erosion and sediment transport, water forms many surface features such as valleys, flood plains, deltas, and beaches. Water also forms subsurface features such as caves. Natural wonders such as the Grand Canyon were, and are being, carved by water. Streams from upland areas carried much of the sand that is located on ocean beaches. Water is a renewable resource. However, it is not always available when or where it is needed, and it may not be of suitable quality for intended uses. Although we commonly take for granted that clean and abundant water is as close as the nearest faucet, water resources can be depleted or contaminated with pollutants. Having too much water (floods) or not having enough (droughts) may have serious consequences for people, wildlife, and their habitats. Providing sufficient quantities of good quality water is a major factor in creating the life style we enjoy in the India (Stephen, et al., 2002).

Why Water Is Important

Water is essential to life. It is part of the physiological process of nutrition and waste removal from cells of all living things. It is one of the controlling factors for biodiversity and the distribution of Earth's varied ecosystems, communities of animals, plants, and bacteria and their interrelated physical and chemical environments. In terrestrial ecosystems, organisms have adapted to large variations in water availability. Water use by organisms in desert ecosystems is vastly different from those in forest ecosystems. For example, some seeds lie dormant for years in arid climates waiting to be awakened by a rare precipitation event. In contrast, a large oak tree in a temperate climate returns about 4,000 gallons of water a year to the atmosphere. Through the process of transpiration, plants give off moisture largely through their leaves.

Aquatic ecosystems, such as wetlands, streams, and lakes, are especially sensitive to changes in water quality and quantity. These ecosystems receive sediment, nutrients, and toxic substances that are produced or used within their watershed - the land area that drains water to a stream, river, lake or ocean. As a result, an aquatic ecosystem is indicative of the conditions of the terrestrial habitat in its watershed.

Wetland ecosystems provide habitat to a great variety of birds, plants and animals. These transitional areas between dry and wet habitats help reduce floods and abate water pollution. They also support many recreational activities and commercial fisheries and provide a number of other important functions.

Nearly every activity that occurs on land ultimately affects groundwater or surface waters. Water plays a major role in shaping the land surface of the Earth.

Canyons, flood plains, terraces, underground and in the atmosphere. Most of the water on Earth, (approximately 97.5 percent) is salt water located mostly in the oceans, and only 2.5 percent is fresh water. The fresh water available for our water needs is less than 1 percent of Earth's supply. The problem is that fresh water is not evenly distributed on Earth. Some desert areas, like Kuwait, have very limited fresh water resources, whereas rain forest areas, such as in Papua New Guinea, can have as much as 30 feet of rainfall in a year! Approximately 88 percent of the Earth's fresh water is frozen in polar ice caps and glaciers, making it unavailable for use. Of the remaining fresh water supply, most is groundwater.

The uneven distribution of water resources has been an important control on human habitation and development throughout history. Societies have struggled to control water resources, human migrations have been made to obtain water resources, and litigation is commonly used to resolve conflicting water needs (Stephen, et al., 2002).

2.0 - Water Resources in India at a Glance

The geographical area of India is 3,287,590 sq km. The length of its Coastline is about 7500 km. The climate of India varies from tropical monsoon in south to temperate in north. Its terrain have upland plain (Deccan Plateau) in south, flat to rolling plain along the Ganges, deserts in west, Himalayas in north. India is enviably endowed in respect of water re-

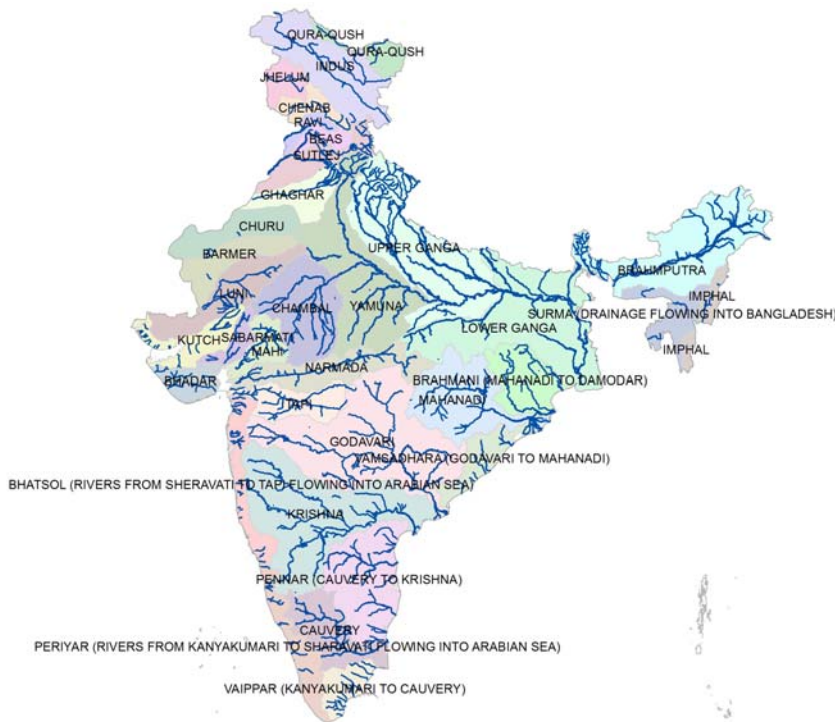
sources. The country is literally criss-crossed with rivers and blessed with high precipitation mainly due to the southwest monsoon, which accounts for 75% of the annual rainfall. There are thirteen major river basins (area more than 20,000 square kilometre) in the country, which occupy 82.4% of total drainage basins, contribute eighty five percent of total surface flow and house eighty percent of the country's population. Major river basins are Brahmaputra, Ganga (including Yamuna Sub Basin), Indus (including Satluj and Beas Sub Basin), Godavari, Krishna, Mahanadi, Narmada, Cauvery, Brahmini (including Baitarni Sub Basin), Tapi, Mahi, Pennar and Sabarmati. The classification of river basin based on catchment area is given in Table 1. There are few desert rivers, which flow for some distance and get lost in deserts. There are complete arid areas where evaporation equals rainfall and hence no surface-flow. The medium and minor river basins are mainly in coastal area. On the east coast and part of Kerala State, the width of land between mountain and sea is about 100 km, and hence the riverine length

River Basin	Catchment Area – Sq.km (%)	No. of Basin
Major	More than 20,000 (82.4)	13
Medium	Between 2000-20,000	28
Minor	Less than 2,000	52

is also about 100 km. whereas, the rivers in the west coast are much shorter as the width of the land between sea and mountains is less than 10 to 40 km. Yet, in spite of the nature's bounty, paucity of water is an issue of national concern resulting in deterioration of water quality in aquatic resources (Bhardwaj, 2005).

3.0 - INDIAN RIVER SYSTEM

The Indian River Systems can be divided into four categories – the Himalayan, the rivers traversing the Deccan Plateau, the Coastal



and those in the inland drainage basin (Figure 1). The Himalayan rivers are perennial as they are fed by melting glaciers every summer. During the monsoon, these rivers assume alarming proportions. Swollen with rainwater, they often inundate villages and towns in their path. The Gangetic basin is the largest river system in India, draining almost a quarter of the country.

The rivers of the Indian peninsular plateau are mainly fed by rain. During summer, their flow is greatly reduced, and some of the tributaries even dry up, only to be revived in the monsoon. The Godavari basin in the peninsula is the largest in the country, spanning an area of almost one-tenth of the country. The rivers Narmada (India's holiest river) and Tapi flow

almost parallel to each other but empty themselves in opposite directions. The two rivers make the valley rich in alluvial soil and teak forests cover much of the land. While coastal rivers gush down the peaks of the

Western Ghats into the Arabian Sea in torrents during the rains, their flow slow down after the monsoon. Streams like the Sambhar in western Rajasthan are mainly seasonal in character, draining into the inland basins and salt lakes. In the Rann of Kutch, the only river that flows through the salt desert is the Luni. The major river systems of India are discussed below.

3.1- Indus River System

The Indus originates in the northern slopes of the Kailash range in Tibet near Lake Manasarovar. It follows a north-westerly course through Tibet. It enters Indian territory in Jammu and Kashmir. It forms a picturesque gorge in this part. Several tributaries - the Zaskar, the Shyok, the Nubra and the Hunza join it in the Kashmir region. It flows through the regions of Ladakh, Baltistan and Gilgit and runs between the Ladakh Range and the Zaskar Range. It crosses the Himalayas through a 5181 m deep gorge near Attock, lying north of the Nanga Parbat and later takes a bend to the south west direction before entering Pakistan. It has a large number of tributaries in both India and Pakistan and has a total length of about 2897 km from the

source to the point near Karachi where it falls into the Arabian Sea. The main tributaries of the Indus in India are Jhelum, Chenab, Ravi, Beas and Sutlej.

3.2 - Brahmaputra River System

The Brahmaputra originates in the Mansarovar lake, also the source of the Indus and the Satluj. It is slightly longer than the Indus, but most of its course lies outside India. It flows eastward, parallel to the Himalayas. Reaching Namcha Barwa (7757 m), it takes a U-turn around it and enters India in Arunachal Pradesh and known as dihang. The undercutting done by this river is of the order of 5500 metres. In India, it flows through Arunachal Pradesh and Assam, and is joined by several tributaries.

3.3 - Ganga River System

The Ganga (Ganges) rises from the Gangotri Glacier in the Garhwal Himalayas at an elevation of some 4100 metres above the sea level under the name of Bhagirathi. This main stream of the river flows through the Himalayas till another two streams – the Mandakini and the Alaknanda – join it at Dev Prayag, the point of confluence. The combined stream is then known as the Ganga. The main tributaries of the Ganga are Yamuna, Ram Ganga, Gomati, Ghaghara, Son, Damodar and Sapt Kosi. The river after traversing a distance of 2525 kms from its source meets the Bay of Bengal at Ganga Sagar in West Bengal.

3.4 - Yamuna River System

The River Yamuna originates from the Yamunotri glacier, 6387m above mean sea level (msl), at the Banderpoonch peak in the Uttarakashi district of Uttarakhand. The catchment of the river extends to states of Uttar Pradesh,

Himachal Pradesh, Haryana, Rajasthan and Madhya Pradesh and the entire union territory of Delhi. The river flows 1367 km from here to its confluence with the River Ganga at Allahabad. The main tributaries joining the river include the Hindon, Chambal, Sind, Betwa and Ken. The annual flow of the river is about 10,000 cumecs. The annual usage is 4400 cumecs, irrigation accounting for 96% of this.

3.5 - Narmada River System

The Narmada or Nerbudda is a river in central India. It forms the traditional boundary between North India and South India, and is a total of 1,289 km (801 mi) long. Of the major rivers of peninsular India, only the Narmada, the Tapti and the Mahi run from east to west. It rises on the summit of Amarkantak Hill in Madhya Pradesh state, and for the first 320 kilometres (200 miles) of its course winds among the Mandla Hills, which form the head of the Satpura Range; then at Jabalpur, passing through the 'Marble Rocks', it enters the Narmada Valley between the Vindhya and Satpura ranges, and pursues a direct westerly course to the Gulf of Cambay. Its total length through the states of Madhya Pradesh, Maharashtra, and Gujarat amounts to 1312 kilometres (815 miles), and it empties into the Arabian Sea in the Bharuch district of Gujarat.

3.6 - Tapti River System

The Tapi is a river of central India. It is one of the major rivers of peninsular India with the length of around 724 km; it runs from east to west. It rises in the eastern Satpura Range of southern Madhya Pradesh state, and flows westward, draining Madhya Pradesh's historic Nimar region, Maharashtra's historic Khandesh and east Vidarbha re-

gions in the northwest corner of the Deccan Plateau and South Gujarat before emptying into the Gulf of Cambay of the Arabian Sea, in the State of Gujarat. The Western Ghats or Sahyadri range starts south of the Tapti River near the border of Gujarat and Maharashtra.

The Tapi River Basin lies mostly in northern and eastern districts Maharashtra state viz, Amravati, Akola, Buldhana, Washim, Jalgaon, Dhule, Nandurbar, Malegaon, Nashik districts but also covers Betul, Burhanpur districts of Madhya Pradesh and Surat district in Gujarat as well. The principal tributaries of Tapi River are Purna River, Girna River, Panzara River, Waghur River, Bori River and Aner River.

3.7 - Godavari River System

The river with second longest course within India, Godavari is often referred to as the Vriddh (Old) Ganga or the Dakshin (South) Ganga. The name may be apt in more ways than one, as the river follows the course of Ganga's tragedy. The river is about 1,450 km (900 miles) long. It rises at Trimbakeshwar, near Nasik and Mumbai (formerly Bombay) in Maharashtra around 380 km distance from the Arabian Sea, but flows southeast across south-central India through the states of Madhya Pradesh, Karnataka, Orissa and Andhra Pradesh, and empties into the Bay of Bengal. At Rajahmundry, 80 km from the coast, the river splits into two streams thus forming a very fertile delta. Some of its tributaries include Indravati River, Manjira, Bindusara and Sabari. Some important urban centers on its banks include Nasik, Bhadrachalam, Rajahmundry and Narsapur. The Asia's largest rail-cum-road bridge on the river Godavari

linking Kovvur and Rajahmundry is considered to be an engineering feat.

3.8 - Krishna River System

The Krishna is one of the longest rivers of India (about 1300 km in length). It originates at Mahabaleswar in Maharashtra, passes through Sangli and meets the sea in the Bay of Bengal at Hamasaladeevi in Andhra Pradesh. The Krishna River flows through the states of Maharashtra, Karnataka and Andhra Pradesh. The traditional source of the river is a spout from the mouth of a statue of a cow in the ancient temple of Mahadev in Mahabaleshwar. Its most important tributary is the Tungabhadra River, which itself is formed by the Tunga and Bhadra rivers that originate in the Western Ghats. Other tributaries include the Koyna, Bhima, Mallaprabha, Ghataprabha, Yerla, Warna, Dindi, Musi and Dudhganga rivers.

3.9 - Kaveri River System

The Kaveri (also spelled Cauvery or Kavery) is one of the great rivers of India and is considered sacred by the Hindus. This river is also called Dakshin Ganga. The headwaters are in the Western Ghats range of Karnataka state, and flows from Karnataka through Tamil Nadu. It empties into the Bay of Bengal. Its waters have supported irrigated agriculture for centuries, and the Kaveri has been the lifeblood of the ancient kingdoms and modern cities of South India. The source of the river is Talakaveri located in the Western Ghats about 5,000 feet (1,500 m) above sea level. It flows generally south and east for around 765 km, emptying into the Bay of Bengal through two principal mouths. Its basin is estimated to be 27,700 square miles (71,700 km²), and it has

many tributaries including Shimsha, Hemavathi, Arkavathy, Kapila, Honnuhole, Lakshmana Tirtha, Kabini, Lokapavani, Bhavani, Noyyal and Famous Amaravati.

3.10 - Mahanadi River System

The Mahanadi River system is the third largest in the peninsula of India and the largest river of Orissa state. The basin ($80^{\circ}30'$ – $86^{\circ}50'$ E and $19^{\circ}20'$ – $23^{\circ}35'$ N) extends over an area approximately $141,600 \text{ km}^2$, has a total length of 851 km and an annual runoff of $50 \times 10^9 \text{ m}^3$ with a peak discharge of $44740 \text{ m}^3 \text{ s}^{-1}$.

The basin is characterized by a tropical climate with average annual rainfall of 142 cm (NWDA, 1981) with 90% occurring during the SW-monsoon. The river begins in the Baster hills of Madhya Pradesh flows over different geological formations of Eastern Ghats and adjacent areas and joins the Bay of Bengal after divided into different branches in the deltaic area. The main branches of River Mahanadi meet Bay of Bengal at Paradip and Nugarh (Devi estuary). The tidal estuarine part of the river covers a length of 40 km and has a basin area of 9 km^2 . Based on physical characteristics, the estuary has been characterized as a partially mixed coastal plain estuary.

4.0 HYDROCHEMISTRY

Hydrochemistry is an interdisciplinary science that deals with the chemistry of water in the natural environment. Professional fields such as chemical hydrology, aqueous chemistry, hydrochemistry, water chemistry and hydro-geochemistry are all more or less synonyms. The classical use of chemical characteristics in chemical hydrology is to provide in-

formation about the regional distribution of water qualities.

At the same time, hydrochemistry has a potential use for tracing the origin and history of water. The hydrochemistry can also be of immense help in yielding information about the environment through which water has circulated. Hydrochemistry can be helpful in knowing about residence times, flow paths and aquifer characteristics as the chemical reactions are time and space dependent. It is essential to study the entire system like atmospheric water (rainwater), surface water and ground water simultaneously in evaluating their hydrochemistry and pollution effect.

4.1 CHEMISTRY OF RAINWATER

The atmosphere is composed of water vapors, dust particles and various gaseous components such as N_2 , O_2 , CO_2 , CH_4 , CO , SO_x , NO_x etc. Pollutants in the atmosphere can be transported long distances by the wind. These pollutants are mostly washed down by precipitation and partly as dry fall out. Composition of rainwater is determined by the source of water vapors and by the ion, which are taken up during transport through the atmosphere. In general, chemical composition of rainwater shows that rainwater is only slightly mineralized with specific electrical conductance (EC) generally below $50 \mu\text{S}/\text{cm}$, chloride below $5 \text{ mg}/\text{l}$ and HCO_3 below $10 \text{ mg}/\text{l}$. Among the cations, concentration of Ca, Mg, Na & K vary considerably but the total cations content is generally below $15 \text{ mg}/\text{l}$ except in samples contaminated with dust. The concentration of sulfates and nitrates in rainwater may be high in areas near industrial hubs.

4.2 CHEMISTRY OF SURFACE WATER

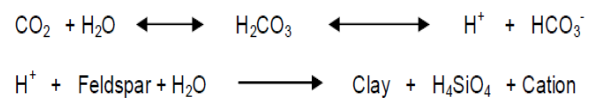
Surface water is found extremely variable in its chemical composition due to variations in relative contributions of ground water and surface water sources. The mineral content in river water usually bears an inverse relationship to discharge. The mineral content of river water tends to increase from source to mouth, although the increase may not be continuous or uniform. Other factors like discharge of city wastewater, industrial waste and mixing of waters can also affect the nature and concentration of minerals in surface water. Among anions, bicarbonates are the most important and constitute over 50% of the total anions in terms of milli equivalent per liter (meq/l). In case of cations, alkaline earths or normally calcium predominates but with increasing salinity the hydrochemical facies tends to change to mixed cations or even to Na-HCO₃ type.

4.3 CHEMISTRY OF GROUND WATER

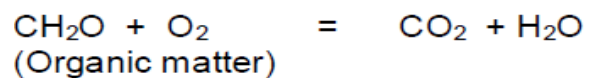
The downward percolating water is not inactive, and it is enriched in CO₂. It can also act as a strong weathering agent apart from general solution effect. Consequently, the chemical composition of ground water will vary depending upon several factors like frequency of rain, which will leach out the salts, time of stay of rain water in the root-zone and intermediate zone, presence of organic matter etc. It may also be pointed out that the water front does not move in a uniform manner as the soil strata are generally quite heterogeneous. The movement of percolating water through larger pores is much more rapid than through the finer pores. The overall effect of all these factors is that the

composition of ground water varies from time to time and from place to place.

Before reaching the saturated zone, percolating water is charged with oxygen and carbon dioxide and is most aggressive in the initial stages. This water gradually loses its aggressiveness, as free CO₂ associated with the percolating water gets gradually exhausted through interaction of water with minerals.



The oxygen present in this water is used for the oxidation of organic matter that subsequently generates CO₂ to form H₂CO₃. This process goes on until oxygen is fully consumed.



Apart from these reactions, there are several other reactions including microbiological mediated reactions, which tend to alter the chemical composition of the percolating water. For example, the bicarbonate present in most waters is derived mostly from CO₂ that has been extracted from the air and liberated in the soil through biochemical activity. Some rocks serve as sources of chloride and sulphate through direct solution. The circulation of sulphur, however, may be greatly influenced by biologically mediated oxidation and reduction reactions. Chloride circulation may be a significant factor influencing the anion content in natural water.

5.0 RIVER WATER MONITORING IN CWC

Central Water Commission is monitoring water quality at 371 key locations covering all the major river basins of India. CWC is maintaining a three tier laboratory system for analysis of the parameters. The level-I laboratories are located at 258 field water quality monitoring stations on various rivers of India where physical parameters such as temperature, colour, odour, specific conductivity, total dissolved solids, pH and dissolved oxygen of river water are observed. There are 23 level – II laboratories located at selected division offices to analyze 25 nos. physico-chemical characteristics and bacteriological parameters of river water. 4 level-III / II+ laboratories are functioning at Varanasi, Delhi, Hyderabad and Coimbatore where 41 parameters including heavy metals / toxic parameters and pesticides are analysed. The following procedure is followed in CWC for classification of stations, sampling frequency, identification of parameters and their analysis, which is based on Water Quality Assessment Authority's Gazette Notification dated June 18, 2005.

(A) Classification:

Stations are classified as Base, Trend and Flux Stations. CWC has 164 Base stations, 179 Trend stations and 28 Flux stations.

(B) Frequency of Monitoring :

- **Base Station:** One sample is collected every two months and totals six samples in a year.
- **Trend Stations:** Sample is collected once in every month.
- **Flux Stations:** Samples are collected thrice in a month, however toxic and trace metal are analyzed once in a month.

(C) Parameters :

Level -I Laboratory:

1. Temperature
2. Colour
3. Odour
4. Electrical Conductivity/ Total Dissolved Solids
5. pH
6. Dissolved Oxygen

Level -II Laboratory:

1. Temperature
2. Electrical Conductivity
3. pH
4. Dissolved Oxygen
5. Biochemical Oxygen Demand (BOD)
6. Chemical Oxygen Demand (COD)
7. Sodium
8. Calcium
9. Magnesium
10. Potassium
11. Iron
12. Boron
13. Carbonate
14. Bicarbonate
15. Fluoride
16. Chloride
17. Sulphate
18. Nitrate
19. Nitrite
20. Silicate
21. Phosphate
22. Total Plate count
23. Total Coliform
24. F. coliform
25. E. Coliform

Level -II+ / III Laboratory:

In addition to the parameters as indicated for level-II laboratory, the following additional parameters are analyzed.

26. Total Kjeldhal Nitrogen
27. Cyanide
28. Ammonia Nitrogen
- 29-34. Pesticides (6 nos.)
35. Total Organic Carbon
- 36-41. Toxic Elements
Arsenic, Cadmium, Mercury, Chromium, Lead, Zinc

6.0 - River Water Pollution

A river is defined as a large natural stream of water emptying into an ocean, lake, or other body of water and usually fed along its course by converging tributaries. Rivers and streams drain water that falls in upland areas. Moving water dilutes and decomposes pollutants more rapidly than standing water, but many rivers and streams are significantly polluted all around the world.

A primary reason for this is that all three major sources of pollution (industry, agriculture and domestic) are concentrated along the rivers. Industries and cities have historically been located along rivers because the rivers provide transportation and have traditionally been a convenient place to discharge waste. Agricultural activities have tended to be concentrated near rivers, because river floodplains are exceptionally fertile due to the many nutrients that are deposited in the soil when the river overflows.

6.1- Source of pollution

Farmers put fertilizers and pesticides on their crops so that they grow better. But these fertilizers and pesticides can be washed through the soil by rain, to end up in rivers. If large amounts of fertilizers or farm waste drain into a river the concentration of nitrate and phosphate in the water increases considerably. Algae use these substances to grow and multiply rapidly turning the water green. This massive growth of algae, called eutrophication, leads to pollution. When the algae die they are broken down by the action of the bacteria which quickly multiply, using up all the oxygen in the water which leads to the death of many animals.

Chemical waste products from industrial processes are sometimes accidentally discharged into rivers. Examples of such pollutants include cyanide, zinc, lead, copper, cadmium and mercury. These substances may enter the water in such high concentrations that fish and other animals are killed immediately. Sometimes the pollutants enter a food chain and accumulate until they reach toxic levels, eventually killing birds, fish and mammals.

Factories use water from rivers to power machinery or to cool down machinery. Dirty water containing chemicals is put back in the river. Water used for cooling is warmer than the river itself. Raising the temperature of the water lowers the level of dissolved oxygen and upsets the balance of life in the water. People are sometimes careless and throw rubbish directly into rivers.

6.2- River water quality & Environmental factors

River water quality is highly variable by nature due to environmental conditions such as basin lithology, vegetation and climate. In small watersheds spatial variations extend over orders of magnitude for most major elements and nutrients, while this variability is an order of magnitude lower for major basins. Standard river water for use as reference is therefore not applicable. As a consequence natural waters can possibly be unfit for various human uses, even including drinking.

There are three major natural sources of dissolved and soluble matter carried by rivers: the atmospheric inputs of material, the degradation of terrestrial organic matter and the weathering of surface rocks. These substances

generally transit through soil and porous rocks and finally reach the rivers. On their way, they are affected by numerous processes such as recycling in terrestrial biota, recycling and storage in soils, exchange between dissolved and particulate matter, loss of volatile substances to the atmosphere, production and degradation of aquatic plants within rivers and lakes etc. As a result of these multiple sources and pathways, the concentrations of elements and compounds found in rivers depend on physical factors (climate, relief), chemical factors (solubility of minerals) and biological factors (uptake by vegetation, degradation by bacteria). The most important environmental factors controlling river chemistry are:

- ✚ Occurrence of highly soluble (halite, gypsum) or easily weathered (calcite, dolomite, pyrite, olivine) minerals
- ✚ Distance to the marine environment which controls the exponential decrease of ocean aerosols input to land (Na^+ , Cl^- , SO_4^{2-} , and Mg^{2+}).
- ✚ Aridity (precipitation/runoff ratio) which determines the concentration of dissolved substances resulting from the two previous processes.
- ✚ Terrestrial primary productivity which governs the release of nutrients (C, N, Si, K).
- ✚ Ambient temperature which controls, together with biological soil activity, the weathering reaction kinetics.
- ✚ Uplift rates (tectonism, relief) Stream quality of unpolluted waters (basins without any direct pollution sources such as dwellings, roads, farming, mining etc.

7.0 – River Water Quality Hot Spots in India

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, outdoor 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 Standard Institute (ISI) vide its document IS: 10500:1991, Edition 2.2 (2003-09) has recommended the quality standards for drinking water 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 desirable, permissible and unfit for human consumption. River water quality is very important for aspect in India. The physico-chemical parameters like pH, electrical conductance (TDS), Chloride, Fluoride, Iron, Nitrate, Sulphate, Total hardness, Calcium and Magnesium are main constituents defining the quality of river water in surface water. Therefore, presence of these parameters in river water beyond the permissible limit in the absence of alternate source has been considered as river water quality hotspots.

River water quality hot spot tables of the rivers have been prepared depicting twelve main parameters based on their distribution shown on the separate table 1-10.

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 dissolved oxygen and biochemical oxygen demand, the 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.

The data for water quality is generated for almost all major, medium and minor rivers in India through a network of 371-water quality monitoring stations of CWC.

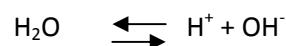
Source: ADSPRBS/3/1978-79.

- A. Drinking water source without conventional treatment but after disinfections,
- B. Out door bathing Organized,
- C. Drinking water source with conventional treatment followed by disinfections,
- D. Propagation of wildlife, fisheries,
- E. rrigation, industrial cooling, controlled waste disposal

S.No.	Characteristics	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 Coliforms organism** MPN/100 ml, Max.	50	500	5,000	-	-
4.	pH Value	6.5-8.5	6.5-8.5	6-9	6.5-8.5	6.5-8.5
5.	Free ammonia (as N), mg/l Max	-	-	-	1.2	-
6.	Electrical Conductivity Micromhos.cm, Max	-	-	-	-	2,250
7.	7. Sodium adsorption Ratio, Max.	-	-	-	-	26
8.	Boron, mg/l, Max.	-	-	-	-	2

7.1 - pH

pH is the measurement of the *hydrogen ion concentration*, $[H^+]$. Water and water-based solutions, consist of charged particles called ions and uncharged particles called molecules. Some ions have a positive electrical charge and others have a negative charge. In every case, the number and magnitude of the charges balance so that there is no excess charge. In pure water, some of the water molecules, which consist of two hydrogen atoms and one oxygen atom (H_2O), dissociate into ions:



The H^+ hydrogen ions normally vary in concentration from 1.0 to 0.000000000000001 moles per liter. Such numbers are cumbersome to work with. Therefore, chemists sought an easier way to express hydrogen ion concentration. Several methods were tried, but the method universally adopted is the pH scale. To translate a hydrogen ion concentration to a pH value, the concentration (moles/liter) is expressed in scientific notation as a power of ten. For example:

$$0.000001 \text{ moles/liter} = 10^{-6} \text{ moles/liter}$$

Consequently, the power of ten exponent numbers (without negative sign) becomes the pH value. For this example, the H^+ (hydrogen ion) concentration is equal to 6 pH. Note that changing the hydrogen ion concentration by a factor of ten changes the pH value by one pH unit. pH is defined as the negative logarithm of the hydrogen ion concentration. This definition of pH was introduced in 1909 by the Danish biochemist, Soren Peter Lauritz Sorensen. It is expressed mathematically as:

$$pH = -\log [H^+]$$

where: $[H^+]$ is hydrogen ion concentration in mol/L

The pH scale provides a convenient way to express hydrogen ion concentrations of any magnitude. Usually, the pH scale spans 0 to 14, although it is possible to have a pH value of less than zero (negative) or greater than 14. Typical pH values of some common solutions are listed in the table below.

The pH value is express the ratio of $[H^+]$ to $[OH^-]$ (hydroxide ion concentration). Hence, if the $[H^+]$ is greater than $[OH^-]$, the solution is acidic. Conversely, if the $[OH^-]$ is greater than the $[H^+]$, the solution is basic. At 7 pH, the ratio of $[H^+]$ to $[OH^-]$ is equal and, therefore, the solution is neutral. As shown in the equation below, pH is a logarithmic function. A change of one pH unit represents a 10-fold change in concentration of hydrogen ion. In a neutral solution, the $[H^+] = 1 \times 10^{-7}$ mol/L. This represents a pH of 7.

BIS (Bureau of Indian Standard) have recommended a desirable limit of 6.5 – 8.5l of pH in drinking water.

High values of pH greater than 8.5 are observed during the Monsoon season (July – September) water quality stations at Seondha and Gummanur. During the non-monsoon season (October – June) high values of pH greater than 8.5 at twelve water quality stations are found in the states of Uttar Pradesh, Madhya Pradesh, Rajasthan, Jharkhand, Maharashtra, Tamilnadu, Orissa and Andhra Pradesh.

Health Concerns

Because pH is related to a variety of other parameters, it is not possible to determine whether pH has a direct relationship with

human health. Insofar as pH affects the unit processes in water treatment that contribute to the removal of viruses, bacteria and other harmful organisms, it could be argued that pH has an indirect effect on health. The destruction of viruses by the high pH levels encountered in water softening by the lime/soda ash process could also be considered beneficial. On the other hand, the increased yield of trihalomethanes at high pH values may be detrimental. In one of the few epidemiological studies carried out on drinking water supplies in which pH was one of the parameters considered, Taylor and co-workers were unable to obtain any significant correlation between the incidence of infectious hepatitis and finished water pH. Sixteen U.S. cities that used surface water as a source of drinking water were considered in the study.

7.2 - ELECTRICAL CONDUCTANCE (EC)

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. It is related to nature of the dissolved substance, their actual and relative concentrations, and the temperature at which the measurement is made. The conductivity or conductance of a solution is the reciprocal of its resistance and is given of units of μmhos , mhos , or Seimens (all a reciprocal ohms). Resistivity as the inverse of conductivity is defined as the measure of the ability of a solution to resist an electric current flow.

The conductivity measurement is directly affected by the number of dissolved ions in the solution and will increase as the quantity and mobility of ions increases. The higher the conductivity reading, the better ability the solution has to conduct electricity. Conversely, the lower the conductivity reading, the poorer ability the solution has to conduct electricity.

Salinity is the saltiness or dissolved salt contents of a water body. Salt content is an important factor in water use. Salinity can be technically defined as the total mass in grams of all the dissolved substances per Kilogram of water. Different substances dissolve in water giving it taste and odor. In fact, humans and other animals have developed senses which are, to a degree, able to evaluate the potability of water, avoiding water that is too salty or putrid.

BIS has recommended a drinking water standard for total dissolved solids a limit of 500mg/l (corresponding to about EC of 750 $\mu\text{S}/\text{cm}$ at 25⁰C) that can be extended to a TDS of 2000mg/l (corresponding to about 3000 $\mu\text{S}/\text{cm}$ at 25⁰C) in case of no alternate source. Water having TDS more than 2000 mg/litre are not suitable for drinking uses.

High values of electrical conductance in excess of 3000 $\mu\text{S}/\text{cm}$ are observed at three water quality stations spread in the states of T.N. M.P. and Gujarat.

7.3 – CHLORIDE (Cl⁻)

Chlorides are widely distributed in nature, usually in the form of sodium, potassium, and calcium salts (NaCl, KCl, and CaCl₂), although many minerals contain small amounts of chloride as an impurity. The presence of chloride

ions in drinking water sources can be attributed to the dissolution of salt deposits, salting of highways to control ice and snow, (rarely in India), effluents from chemical industries, oil well operations, sewage, irrigation drainage, refuse leachates, volcanic emanations, sea spray and seawater intrusion in coastal areas. Each of these sources may result in local contamination of surface water and groundwater. The chloride ion is highly mobile and is eventually transported into closed basins or to the oceans.

Chloride in the form of Cl⁻ ion is one of the major inorganic anions in water and wastewater. In potable water, the salty taste produced by chloride concentration is variable and depends on the chemical composition of the water. Some waters containing 250 mg/l chloride have a detectable salty taste if the cation involved is Na⁺. On the other hand, the typical salty taste may be absent in waters containing as much as 1000 mg/l Cl⁻ when the predominant cations are calcium and magnesium.

BIS (Bureau of Indian Standard) have recommended a desirable limit of 250 mg/l of chloride in drinking water; this concentration limit can be extended to 1000mg/l of chloride in case no alternative source of water with desirable concentration is available.

One water quality station in the state of T.N. has chloride concentration in excess of 1000 mg/l .

Health Concerns

Chloride is the most abundant anion in the human body and is essential to normal electrolyte balance of body fluids. For adults, a daily dietary intake of about 9 mg of chloride per kilogram of body weight is considered es-

sential for good health. Chlorides in water are more of a taste than a health concern, although high concentrations may be harmful to people with heart or kidney problems.

7.4 – FLUORIDE (F)

Fluorine is a fairly common element but it does not occur in the elemental state in nature because of its high reactivity. Fluorine is the most electronegative and reactive of all elements that occur naturally within many type of rock. It exists in the form of fluorides in a number of minerals of which fluorspar, cryolite, fluorite and fluorapatite are the most common. Fluorite (CaF_2) is a common fluoride mineral.

Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or weathering and deposition of atmospheric particles. Most of the fluorides are sparingly soluble and are present in ground water in small amounts. The occurrence of fluoride in natural water is affected by the type of rocks, climatic conditions, nature of hydrogeological strata and time of contact between rock and the circulating ground water. Presence of other ions, particularly bicarbonate and calcium ions also affects the concentration of fluoride in ground water. It is well known that small amounts of fluoride (less than 1.0 mg/l) have proven to be beneficial in reducing tooth decay. Community water supplies commonly are treated with NaF or fluorosilicates to maintain fluoride levels ranging from 0.8 to 1.2 ppm to reduce the incidence of dental carries.

However, high concentrations such as 1.5 mg/l of F and above have resulted in staining of tooth enamel while at still higher levels of

fluoride ranging between 5.0 and 10 mg/l, further pathological changes such as stiffness of the back and difficulty in performing natural movements may take place.

BIS has recommended an upper desirable limit of 1.0 mg/l of F as desirable concentration of fluoride in drinking water, which can be extended to 1.5 mg/l of F in case no alternative source of water is available. River/ground Water having fluoride concentration of more than 1.5 mg/l are not suitable for drinking purposes.

Fluoride concentration more the 1.5 mg/l is observed at fifteen water quality stations in the states of Delhi, T.N., Karnataka, Bihar, Jharkhand, Haryana, U.P., Kerala, Chhattisgarh and A.P.

Health Concerns

Small amounts of fluoride appear to be an essential nutrient. People in the United States ingest about 2 mg/day in water and food. A concentration of about 1 mg/L in drinking water effectively reduces dental caries without harmful effects on health. Dental fluorosis can result from exposure to concentrations above 2 mg/L in children up to about 8 years of age. In its mild form, fluorosis is characterized by white opaque mottled areas on tooth surfaces. Severe fluorosis causes brown to black stains and pitting. Although the matter is controversial, EPA has determined that dental fluorosis is a cosmetic and not a toxic or an adverse health effect. Water hardness limits fluoride toxicity to humans and fish. The severity of fluorosis decreases in harder drinking water. Crippling skeletal fluorosis in adults requires the consumption of about 20 mg or more of fluoride per day over a 20 year pe-

riod. No cases of crippling skeletal fluorosis have been observed in the United States from the long term consumption of 2 L/day of water containing 4 mg/L of fluoride. EPA has concluded that 0.12 mg/kg/day of fluoride is protective of crippling skeletal fluorosis. Fluoride therapy, where 20 mg/day is ingested for medical purposes, is sometimes used to strengthen bone, particularly spinal bones (Hussain et al., 2002; 2004).

7.5 - NITRATE (NO_3^-)

Nitrate and nitrite anions are highly soluble in water. Due to their high solubility and weak retention by soil, nitrate and nitrite are very mobile, moving through soil at approximately the same rate as water. Thus, nitrate has a high potential to migrate to groundwater. Because they are not volatile, nitrate and nitrite are likely to remain in water until consumed by plants or other organisms. Nitrate is the oxidized form and nitrite is the reduced form. Aerated surface waters will contain mainly nitrate and groundwaters, with lower levels of dissolved oxygen, will contain mostly nitrite. They readily convert between the oxidized and reduced forms depending on the redox potential. Nitrite in groundwater is converted to nitrate when brought to the surface or exposed to air in wells. Nitrate in surface water is converted to nitrite when it percolates through soil to oxygen-depleted groundwater. The main inorganic sources of contamination of drinking water by nitrate are potassium nitrate and ammonium nitrate. Both salts are used mainly as fertilizers. Ammonium nitrate is also used in explosives and blasting agents. Because nitrogenous materials in natural waters tend to be converted to nitrate, all envi-

ronmental nitrogen compounds, particularly organic nitrogen and ammonia, should be considered as potential nitrate sources. Primary sources of organic nitrates include human sewage and livestock manure, especially from feedlots.

BIS has recommended standard for drinking water the maximum desirable limit of Nitrate concentration in 10.16 mg/l as nitrate N (45 mg/l as Nitrate NO_3).

All the water quality stations of CWC have nitrate concentration within the permissible limit.

Health Concerns

Nitrate is a normal dietary component. A typical adult ingests around 75 mg/day, mostly from the natural nitrate content of vegetables, particularly beets, celery, lettuce, and spinach. Short-term exposure to levels of nitrate in drinking water higher than the MCL can cause serious illness or death, particularly in infants. Nitrate is converted to nitrite in the body, and nitrite oxidizes Fe^{2+} in blood hemoglobin to Fe^{3+} , rendering the blood unable to transport oxygen, a condition called methemoglobinemia. Infants are much more sensitive than adults to this problem because of their small total blood supply. Symptoms include shortness of breath and blueness of the skin. This can be an acute condition in which health deteriorates rapidly over a period of days.

7.6 SULFATE (SO_4^{-2})

The sulfate anion (SO_4^{-2}) is the stable, oxidized form of sulfur. Sulfate minerals are widely distributed in nature, and most sulfate compounds are readily soluble in water. All sulfate salts are very soluble except for calcium and

silver sulfates, which are moderately soluble, and barium, mercury, lead, and strontium sulfates, which are insoluble.

It is estimated that about one-half of the river sulfate load arises from mineral weathering and volcanism, the other half from biochemical and anthropogenic sources. Industrial discharges are another significant source of sulfates. Mine and tailings drainage, smelter emissions, agricultural runoff from fertilized lands, pulp and paper mills, textile mills, tanneries, sulfuric acid production, and metal-working industries are all sources of sulfate-polluted water. Aluminum sulfate (alum) is used as a sedimentation agent for treating drinking water. Copper sulfate is used for controlling algae in raw and public water supplies. Air emissions from industrial fuel combustion and the roasting of sulfur-containing ores carry large amounts of sulfur dioxide and sulfur trioxide into the atmosphere, adding sulfates to surface waters through precipitation. Sulfate concentrations normally vary between 10 and 80 mg/L in most surface waters, although they may reach several thousand milligrams per liter near industrial discharges. High sulfate concentrations are also present in areas of acid mine drainage and in well waters and surface waters in arid regions where sulfate minerals are present.

BIS has recommended an upper desirable limit of 200 mg/l of SO_4^{-2} as desirable concentration of fluoride in drinking water, which can be extended to 400 mg/l of SO_4^{-2} in case no alternative source of water is available. Water having fluoride concentration of more than 400 mg/l are not suitable for drinking purposes.

Sulphate concentration more than 400 mg/l is observed during Monsoon season at one water quality stations in the state of M.P.

Health Concerns

The sulfate anion is generally considered non-toxic to animal, aquatic, and plant life. It is an important source of sulfur, an essential nutrient for plants and animals. Sulfates are used as additives in the food industry, and the average daily intake of sulfate from drinking water, air, and food is approximately 500 mg. As examples, some measured sulfate concentrations in beverages are 100–500 mg/L in drinking water, 500 mg/L in coconut milk, 260 mg/L in beer (bitter), 250 mg/L in tomato juice, and 300 mg/L in red wine (FNB 2004). Available data suggest that people acclimate rapidly to the presence of sulfates in their drinking water. No upper limit likely to cause detrimental human health effects has been determined for sulfate in drinking water. However, concentrations of 500–750 mg/L may cause a temporary mild laxative effect, although doses of several thousand milligrams per liter generally do not cause any long-term ill effects. Because of the laxative effects resulting from ingestion of drinking water containing high sulfate levels, EPA recommends that health authorities be notified of sources of drinking water that contain sulfate concentrations in excess of 500 mg/L. The presence of sulfate can adversely affect the taste of drinking water. The lowest taste threshold concentration for sulfate is approximately 250 mg/L as the sodium salt but higher as calcium or magnesium salts (up to 1000 mg/L).

7.7 - IRON (Fe)

Iron is a common constituent in soil and ground water. It is present in water either as soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air, the water turns cloudy due to oxidation of ferrous iron into reddish brown ferric oxide.

The concentration of iron in natural water is controlled by both physico chemical and microbiological factors. It is contributed to ground water mainly from weathering of feruginous minerals of igneous rocks such as hematite, magnetite and sulphide ores of sedimentary and metamorphic rocks.

Natural waters contain variable, but minor amounts of iron, despite its universal distribution and abundance. Iron is generally present in surface waters in small quantity as Fe (III) when the pH is above 7, as most of these salts are insoluble and settle out or are adsorbed onto sediment. Therefore, the concentration of iron in well-aerated waters is seldom high. Under reducing conditions, which may exist in some groundwaters, lakes or reservoirs, and in the absence of sulphide and carbonate, high concentrations of soluble Fe (II) may be found. Fe II is readily oxidized to Fe III in alkaline condition by oxygen. The presence of iron in natural waters can be attributed to the weathering of rocks and minerals, acidic mine water drainage, landfill leachates, sewage effluents and iron-related industries. Taste thresholds of iron in water, 0.1 mg/L for Fe²⁺ and 0.2 mg/L for Fe³⁺, result in a bitter or astringent taste. Water used in industrial processes must contain less than 0.2 mg/l of total iron.

The permissible Iron concentration in surface water is less than 1.0 mg/litre as per the BIS Standard for drinking water. The occurrences of iron in surface water beyond permissible limit (>1.0 mg /litre) have been shown on the table as point sources.

It is observed that high concentration of iron greater than 1.0 mg/l at twenty two water quality stations has been found in the state of the M.P., J & K, Karnataka, Kerala, chhattisgarh and Bihar.

Health Concerns

Iron is an essential nutrient in animal and plant metabolism. It is not normally considered a toxic substance. It is not regulated in drinking water except as a secondary standard for aesthetic reasons. Adults require between 10 and 20 mg of iron per day. Excessive iron ingestion may result in hemochromatosis, a condition of tissue damage from iron accumulation. This condition rarely occurs from dietary intake alone, but has resulted from prolonged consumption of acidic foods cooked in iron utensils and from the ingestion of large quantities of iron tablets. Iron can be toxic to freshwater aquatic life above 1 mg/L and may interfere with fish uptake of oxygen through their gills above 0.3 mg/L.

7.8 - CALCIUM (Ca²⁺)

Calcium cations (Ca²⁺) and calcium salts are among the most commonly encountered substances in water, arising mostly from dissolution of minerals. Calcium often is the most abundant cation in river water. Among the most common calcium minerals are the two crystalline forms of calcium carbonate-calcite and aragonite (CaCO₃, limestone is primarily calcite), calcium sulfate (the dehydrated form,

CaSO_4 , is anhydrite; the hydrated form, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, is gypsum), calcium magnesium carbonate ($\text{CaMg}(\text{CO}_3)_2$, dolomite), and, less often, calcium fluoride (CaF_2 , fluorite). Water hardness is caused by the presence of dissolved calcium, magnesium, and sometimes iron (Fe^{2+}), all of which form insoluble precipitates with soap and are prone to precipitating in water pipes and fixtures as carbonates. Limestone (CaCO_3), lime (CaO), and hydrated lime ($\text{Ca}(\text{OH})_2$) are heavily used in the treatment of wastewater and water supplies to raise the pH and precipitate metal pollutants. Very low concentrations of calcium can enhance the deleterious effects of sodium in irrigation water by increasing the value of the sodium absorption ratio (SAR).

BIS has recommended an upper desirable limit of 75 mg/l Ca^{+2} as CaCO_3 desirable concentration of fluoride in drinking water, which can be extended to 200 mg/l Ca^{+2} as CaCO_3 in case no alternative source of water is available. Water having fluoride concentration of more than 400 mg/l are not suitable for drinking purposes.

All the water quality stations of CWC have calcium concentration within the permissible limit.

Health Concerns

Calcium is an essential nutrient for plants and animals, essential for bone, nervous system, and cell development. Recommended daily intakes for adults are between 800 and 1200 mg/day. Most of this is obtained in food; drinking water typically accounts for 50–300 mg/day, depending on the water hardness and assuming ingestion of 2 L/day. Calcium in food and water is essentially nontoxic. A

number of studies suggest that water hardness protects against cardiovascular disease. One possible adverse effect from ingestion of high concentrations of calcium for long periods of time may be a greater risk of kidney stones. The presence of calcium in water decreases the toxicity of many metals to aquatic life. Stream standards for these metals are expressed as a function of hardness and pH. Thus, the presence of calcium in water is beneficial and no limits on calcium have been established for protection of human or aquatic health.

7.9 - MAGNESIUM (Mg^{+2})

Magnesium is used in the textile, tanning, and paper industries. Lightweight alloys of magnesium are used extensively in molds, die castings, extrusions, rolled sheets and plate forgings, mechanical handling equipment, portable tools, luggage, and general household goods. The carbonates, chlorides, hydroxides, oxides, and sulfates of magnesium are used in the production of magnesium metal, refractories, fertilizers, ceramics, explosives, and medicinals. Magnesium is abundant in the earth's crust and is a common constituent of natural water. Along with calcium, it is one of the main contributors to water hardness. The aqueous chemistry of magnesium is similar to that of calcium in the formation of carbonates and oxides. Magnesium compounds are, in general, more soluble than their calcium counterparts. As a result, large amounts of magnesium are rarely precipitated. Magnesium carbonates and hydroxides precipitate at high pH (>10). Magnesium concentrations can

be extremely high in certain closed saline lakes. Natural sources contribute more magnesium to the environment than do all anthropogenic sources. Magnesium is commonly found in magnesite, dolomite, olivine, serpentine, talc, and asbestos minerals. The principal sources of magnesium in natural water are ferromagnesium minerals in igneous rocks and magnesium carbonates in sedimentary rocks. Water in watersheds with magnesium-containing rocks may contain magnesium in the concentration range of 1–100 mg/L. The sulfates and chlorides of magnesium are very soluble, and water in contact with such deposits may contain several hundred milligrams of magnesium per liter.

BIS has recommended an upper desirable limit of 30 mg/l Mg^{+2} as $CaCO_3$ desirable concentration of fluoride in drinking water, which can be extended to 100 mg/l Mg^{+2} as $CaCO_3$ in case no alternative source of water is available. Water having fluoride concentration of more than 100 mg/l are not suitable for drinking purposes.

Relatively high value of magnesium in excess of 100 mg/l is observed at one water quality station in the state of Tamilnadu.

Health Concerns

Magnesium is an essential nutrient for plants and animals, essential for bone and cell development. It accumulates in calcareous tissues, and is found in edible vegetables (700–5600 mg/kg), marine algae (6400–20,000 mg/kg), marine fish (1200 mg/kg), and mammalian muscle (900 mg/kg) and bone (700–1800 mg/kg). Magnesium is one of the principal cations of soft tissue. It is an essential

part of the chlorophyll molecule. Recommended daily intake for adults is 400–450 mg/day, of which drinking water can supply from 12 to 250 mg/day, depending on the magnesium concentration and assuming ingestion of 2 L/day. Magnesium salts are used medicinally as cathartics and anticonvulsants. In general, the presence of magnesium in water is beneficial and no limits on magnesium have been established for protection of human or aquatic health.

7.10 - HARDNESS

The hardness of water depends mainly on the presence of dissolved calcium and magnesium salts. Public acceptability of the degree of hardness of water may vary considerably from one community to another, depending on local conditions. The taste threshold for the calcium ion is in the range 100-300 mg/l depending on the associated anion, and the taste threshold for magnesium is probably less than that for calcium. In some instances, a water hardness in excess of 500 mg/l is tolerated by consumers. Other divalent ions such as zinc etc also contribute to hardness.

Depending on the interaction of other factors, such as pH and alkalinity, water with hardness above approximately 200 mg/l may cause scale deposition in the distribution system and will result in excessive soap consumption and subsequent “scum” formation. On heating, hard waters form deposits of calcium carbonate scale. Soft water, with a hardness of less than 100 mg/l, may, on the other hand, have a low buffer capacity and so be more corrosive for water pipes.

High value of total hardness > 300 mg/l is observed at two water quality station in the state of Madhya Pradesh and Tamilnadu.

BIOLOGICAL PARAMETERS

7.11 - DISSOLVED OXYGEN (DO)

DO is required to maintain the health of aquatic ecosystems. Oxygen is produced by photosynthesis, but is also used by plants, animals, and microorganisms that live in water. DO is crucial for the survival of fish and most other aquatic life forms. It oxidizes many sources of objectionable tastes and odors. Oxygen becomes dissolved in surface waters by diffusion from the atmosphere and from aquatic-plant photosynthesis.

On average, most oxygen dissolves into water from the atmosphere; only a little net DO is produced by aquatic-plant photosynthesis. Although water plants produce oxygen during the day, they consume oxygen at night as an energy source. When they die and decay, dead plant matter serves as an energy source for microbes, which consume additional oxygen. The net change in DO is small during the life cycle of aquatic plants.

Oxygen makes up 21% of all gases in air. Only a fraction of a percentage of atmospheric oxygen, however, dissolves in water. Oxygen dissolves in water through diffusion from the atmosphere and is facilitated by wind-mixing. This transfers oxygen to the water, especially in shallow aquatic systems that are not strongly stratified. Colder water can hold more DO than warm water as the solubility of oxygen is greater in colder water than in warm water. At the same time, cold temperatures reduce respiration rates in microorganisms that use DO. Phytoplankton and submersed aquatic macrophytes in the photic zone of lakes infuse oxygen into the water during the day during photosynthesis. Absence of photosynthesis, and respiration by

these organisms and others, reduces oxygen concentration in the water at night.

BIS has recommended 5.0 mg/l concentration of dissolved oxygen for out door bathing. Water having below 5.0 mg/l DO concentration is not suitable for out-door bathing in river. Dissolved Oxygen below 5.0 mg/l is observed at 17 water quality stations in the state of Delhi, Karnataka, U.P., Rajasthan, Chhattisgarh, Jharkhand, Haryana, Maharashtra and Gujarat,

7.12- BIOCHEMICAL OXYGEN DEMAND

Biochemical oxygen demand (BOD) is usually defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions. The term "decomposable" may be interpreted as meaning that the organic matter can serve as food for the bacteria, and energy is derived from its oxidation. BOD is an indicator of the potential for a water body to become depleted in oxygen and possibly become anaerobic because of biodegradation.

The BOD test is widely used to determine the pollutional strength of domestic and industrial wastes in terms of the oxygen that they will require if discharged into natural watercourses in which aerobic conditions exist. The test is one of the most important in stream-pollution-control activities. This test is of prime importance in regulatory work and in studies designed to evaluate the purification capacity of receiving bodies of water. The BOD test is essentially a bioassay procedure involving the measurement of oxygen consumed by living organisms (mainly bacteria) while utilizing the organic matter present in a waste, under conditions as similar as possible to those that occur in nature. Oxygen con-

sumed by living organisms (mainly bacteria) while utilizing the organic matter present in a waste, under conditions as similar as possible to those that occur in nature.

BIS has recommended 3.0 mg/l concentration of biochemical oxygen demand for out-door bathing. Water having above 3.0 mg/l BOD concentration is not suitable for out-door bathing in river. Relatively high values of Biochemical Oxygen Demand more than 3.0 mg/l are observed at 37 water quality stations in the states of U.P., Rajasthan, Delhi, M.P., T.N., Karnataka, Chhattisgarh, Haryana, Maharashtra, Orissa, Jharkhand, Bihar, Kerala and Gujarat.

7.13 – TOTAL COLIFORMS & FECAL COLIFORMS

Coliform organisms are used as indicators of water pollution. The coliform organism is a very common rod-shaped bacterium. Because pathogenic bacteria in wastes and polluted waters are usually much lower in numbers and much harder to isolate and identify than coliforms, which are usually in high numbers in polluted water, total coliforms is used as a general indicator of potential contamination with pathogenic organisms. However, many coliform bacteria live in the soil, and these organisms may be the source of those that appear in water, especially surface water. Fecal coliforms, on the other hand, are more specific because they refer to the coliforms that live in the intestinal track of humans and many other animals.

Pathogens are relatively scarce in water, making them difficult and time-consuming to monitor directly. Instead, fecal coliform levels are monitored, because of the correlation between fecal coliform counts and the proba-

bility of contracting a disease from the water. As per CPCB guidelines for bathing (outdoor), the Total Coliforms Organism MPN/100ml shall be 500 or less. The main source of Total Coliforms in Indian rivers is sewage discharge, open defecation, cattle wallowing, disposal of animal carcass and unburnt bodies. Most of the Indian River stretches (middle and lower) are high in total coliforms. It has been reported that stretches which are high in BOD have high total coliform and fecal coliform.

TRACE & TOXIC METAL

7.14 - ARSENIC (As)

A silvery-white, very brittle, semi-metallic element, arsenic is notorious for its toxicity to humans. The most toxic are the trivalent compounds. The lethal dose is 130 mg. Accumulation in the body is expected to raise progressively at low intake level. Arsenic is used in bronzing, pyro technique, dye manufacturing, insecticides, poison, and medicine. As medication in low doses, arsenic is excellent to enhance growth. Groundwater may contain a higher concentration of arsenic that originated from geological materials. Sources of arsenic pollution are from industrial wastes, arsenic containing pesticides, and smelting operation. These industrial processes (as well as coal burning) are responsible for the presence of arsenic in the atmosphere. The USEPA has classified arsenic as "carcinogenic in humans by inhalation and ingestion. According to BIS the Maximum permissible limit of As for drinking waters as 0.05 mg/L. All the water quality stations of CWC have arsenic concentration within the permissible limit prescribed by BIS.

ANNEXURE

TABLE :- 01

Stations having pH value above 8.5 in River Water

S. No.	Water Quality Site	River	Division	State	District	M	NM
1	Seondha	Sindh	LYD, Agra	M.P.	Datia	8.55	8.54
2	Kora	Rind	LYD, Agra	U.P.	Fatehpur	-	8.51
3	Garrauli	Dhasan	LYD, Agra	M.P.	Chhattarpur	-	8.53
4	AB Road Xing	Parwati	CD, Jaipur	M.P.	Guna	-	8.63
5	Aklera	Parwan	CD, Jaipur	Rajasthan	Jhalarwar	-	8.51
6	Barod	Kalisind	CD, Jaipur	Rajasthan	Kota	-	8.66
7	Khatoli	Parwati	CD, Jaipur	Rajasthan	Kota	-	8.51
8	Tekra	Pranhita	WGD, Nagpur	Maharashtra	Gadchiroli	-	8.54
9	Gummanur	Ponniyar	SRD, Coimbatore	Tamilnadu	Dharmapuri	9.91	8.78
10	Maighat	Gomti	MGD-III, Varanasi	U.P.	Jaunpur	-	8.60
11	Bawapuram	Tungabhadra	LKD, Hyderabad	A.P.	Kurnool	-	8.60
12	Tilga	Sankh	ERD, Bhubaneswar	Jharkhand	Simdega	-	8.65

Note: M= Monsoon; NM= Non-Monsoon

PLATE – 01

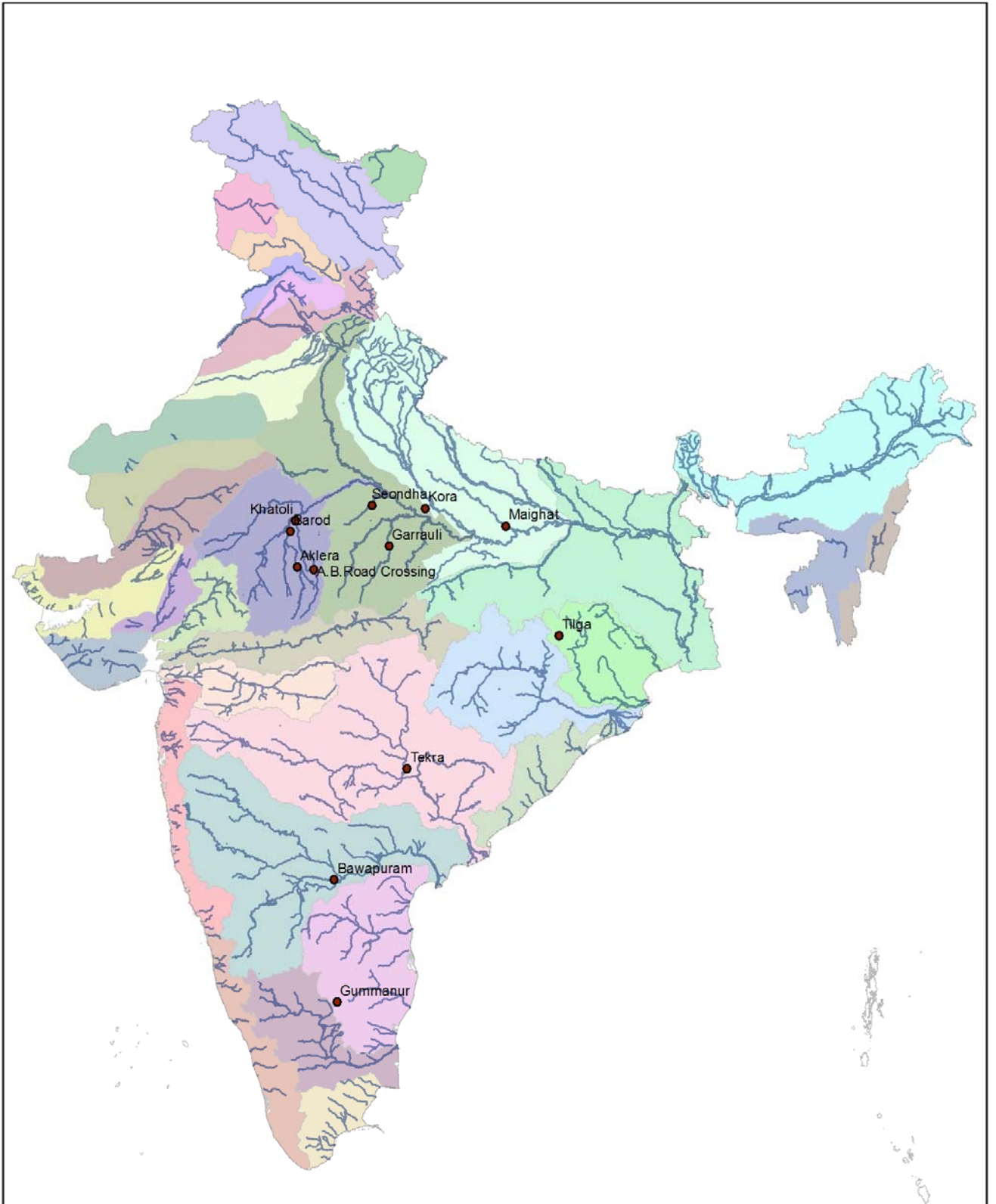


Figure 1: Stations having pH value above 8.5 in River Water

TABLE :- 2

Stations having Electrical Conductance (EC) > 3000 μ S/cm in River

S.No.	Water Quality Site	River	Division	State	District	M	NM
1	Elunuthimangalam	Noyyal	SRD, Coimbatore	Tamilnadu	Erode	5910	4602
2	Tal	Chambal	CD, Jaipur	M.P.	Ratlam	4062	-
3	Vautha	Sabarmati	MD, Ahemadabad	Gujarat	Kheda	-	3409

Note: M= Monsoon; NM= Non-Monsoon

Plate – 02

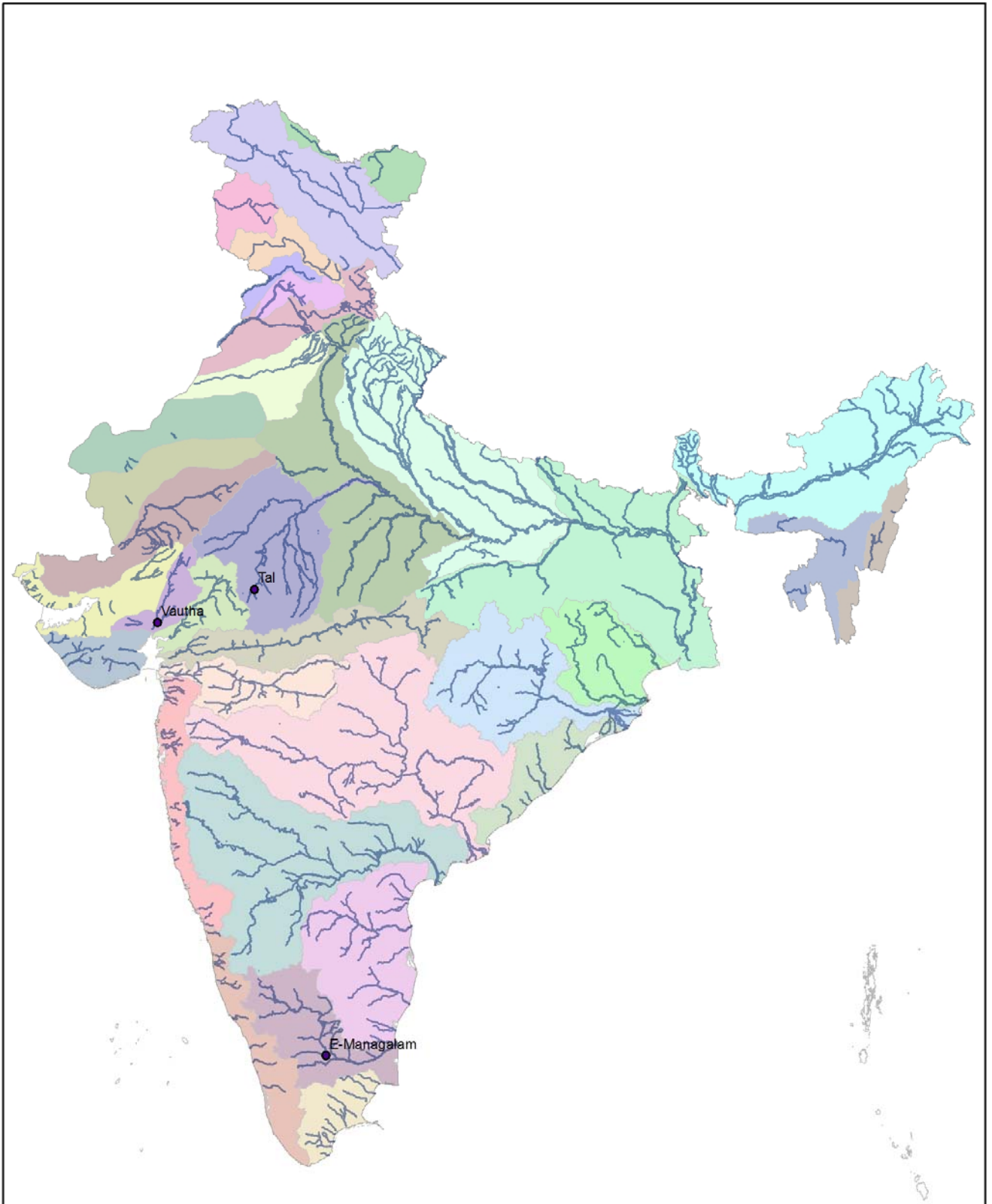


Figure2: Stations having Electrical Conductance (EC) > 3000 μ S/cm in River

TABLE :- 03

Water Quality Stations having Magnesium concentration above 100 mg/l in River

S.No.	Water Quality Site	River	Division	State	District	M	NM
1	Elunuthimangalam	Noyyal	SRD, Coimbatore	Tamilnadu	Erode	104.70	-

Note: M= Monsoon; NM= Non-Monsoon

Plate – 03

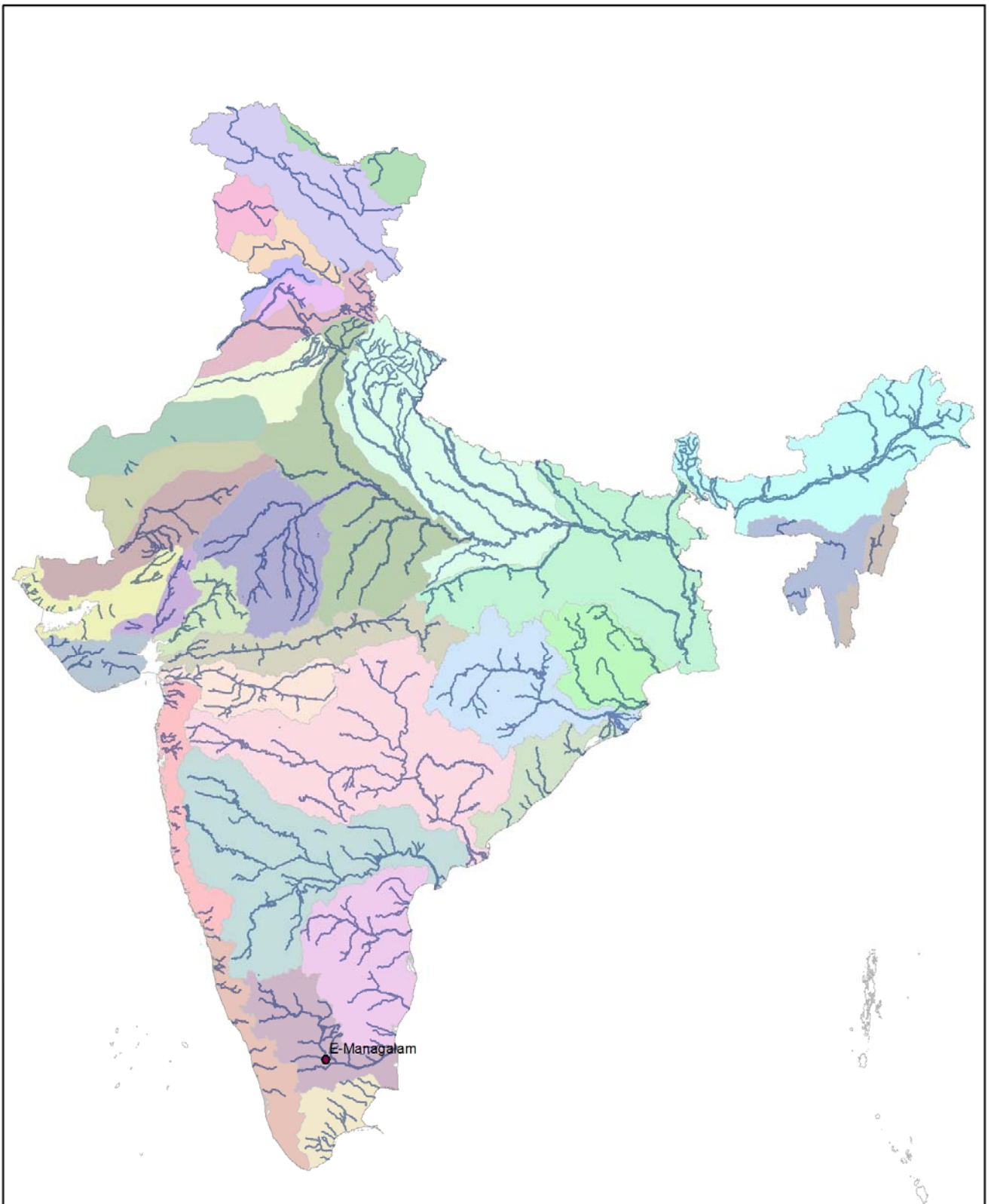


Figure3: Water Quality Stations having Magnesium concentration above 100 mg/l in River

TABLE :-: 04**Stations having Total Hardness (TH) concentration above 600 mg/l in River Water**

S.No.	Water Quality Site	River	Division	State	District	M	NM
1	Tal	Chambal	CD, Jaipur	M.P.	Ratlam	624	-
2	Elunuthimangalam	Noyyal	SRD, Coimbatore	Tamilnadu	Erode	684	656

Note: M= Monsoon; NM= Non-Monsoon

Plate – 04

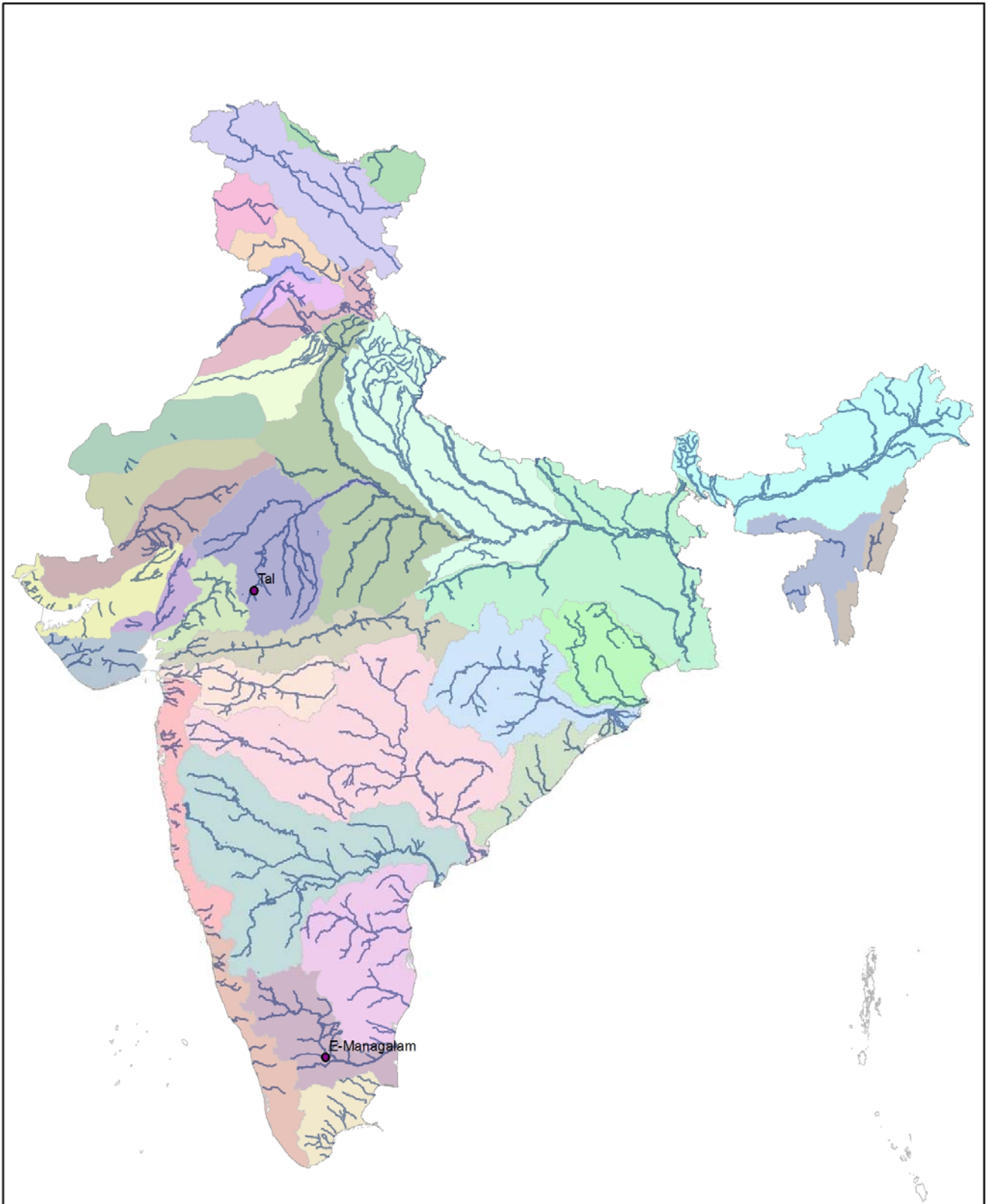


Figure4: Stations having Total Hardness (TH) concentration above 600 mg/l in River Water

TABLE :- 05

Water Quality Stations having Chloride concentration above 1000 mg/l in River

S.No.	Water Quality Site	River	Division	State	District	M	NM
1	Elunuthimangalam	Noyyal	SRD, Coimbatore	Tamilnadu	Erode	1656	1175

Note: M= Monsoon; NM= Non-Monsoon

Plate – 05

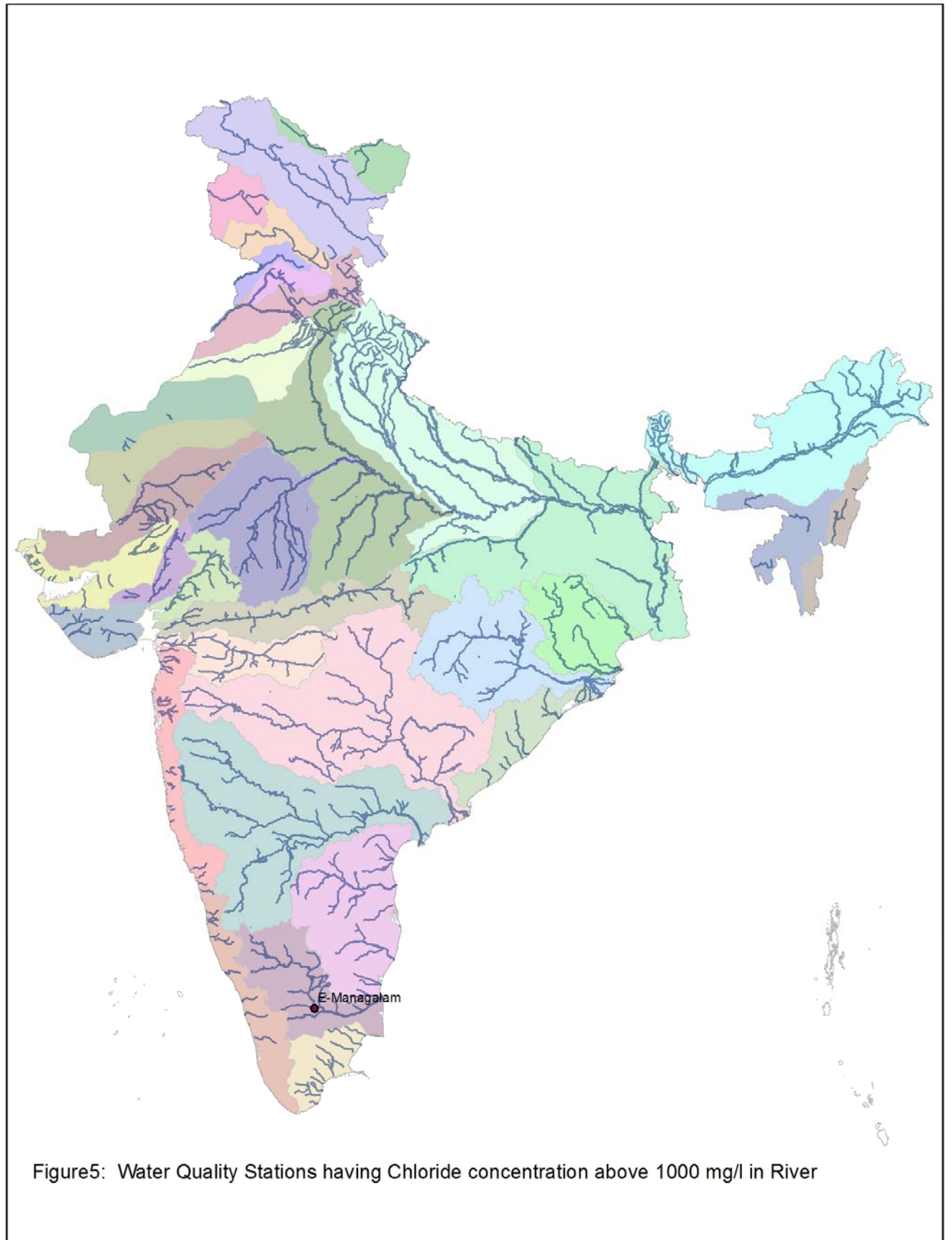


Figure5: Water Quality Stations having Chloride concentration above 1000 mg/l in River

TABLE :- 06

Water Quality Stations having Sulphate concentration above 400 mg/l in River

S.No.	Water Quality Site	River	Division	State	District	M	NM
1	Tal	Chambal	CD, Jaipur	M.P.	Ratlam	672	-

Note: M= Monsoon; NM= Non-Monsoon

Plate - 06

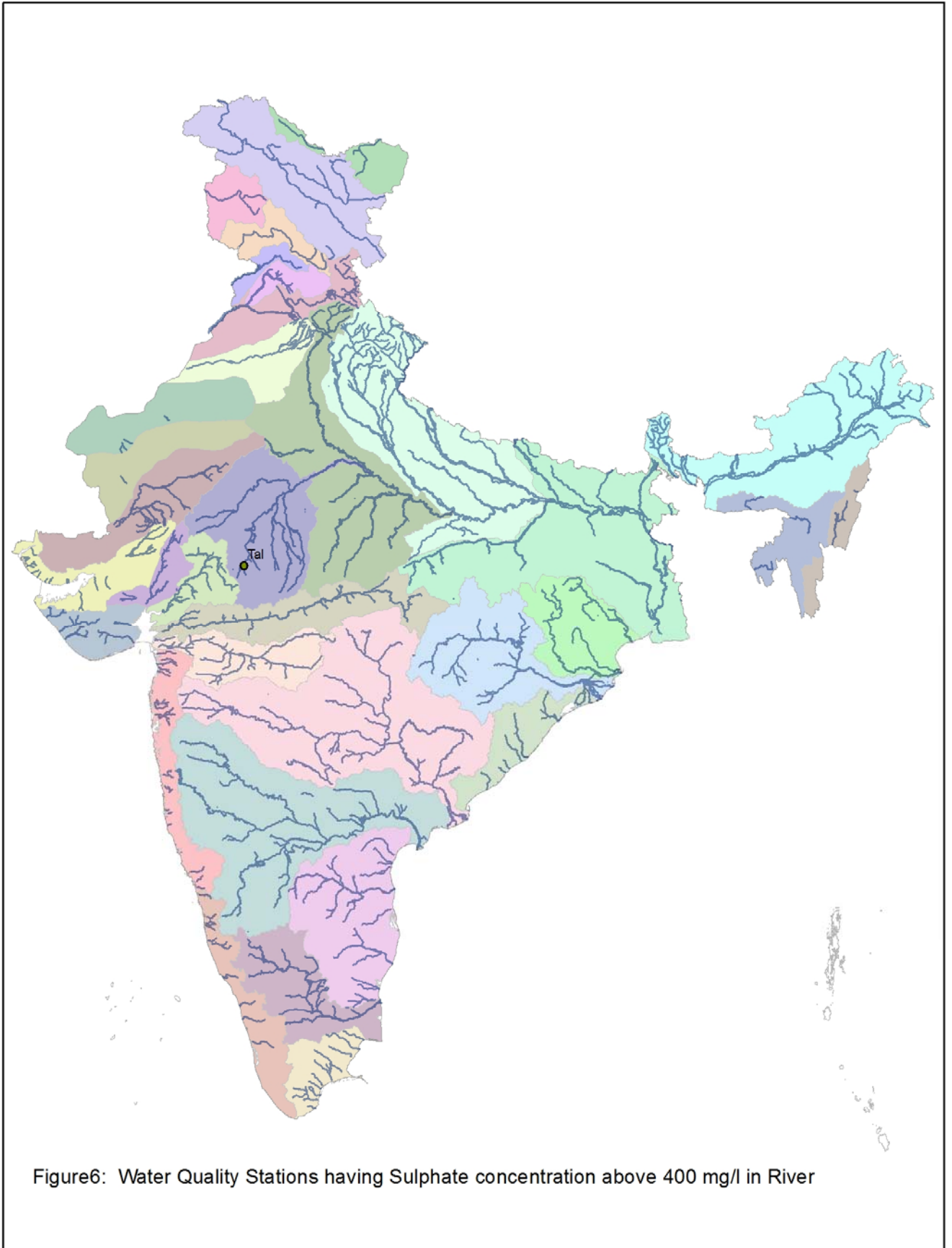


TABLE :- 07

Stations having Iron (Fe) concentration above 1.0 mg/l in River

S. No.	Water Quality Site	River	Division	State	District	M	NM
1	Kumhhari	Wainganga	WGD, Nagpur	M.P.	Balaghat	16.40	64.39
2	Udaipur	Chandrabhaga	CD, Jammu	H.P.	Lahaul Spiti	1.15	-
3	Villupuram	Ponnaiyar	HD, Chennai	Tamilnadu	Villupuram	1.15	-
4	Kidangoor	Meenachil	SWR, Cochin	Kerala	Kottayam	-	1.30
5	Erinjipuzha	Payaswani	SWR, Cochin	Kerala	Kasargod	-	1.30
6	Hogenakkal	Chinnar	CD, Bangalore	Tamilnadu	Dharmapuri	1.68	1.86
7	T. Bekuppe	Arkavathi	CD, Bangalore	Karnataka	Ramanagaram	1.02	-
8	Akkihebbal	Hemavathi	CD, Bangalore	Karnataka	Mandya	-	1.16
9	Sakaleshpur	Hemavathi	CD, Bangalore	Karnataka	Hassan	1.68	2.12
10	Gaya	Phalgu	MGD-V, Patna	Bihar	Gaya	2.55	-
11	Koelwar	Sone	MGD-V, Patna	Bihar	Arrah	3.58	2.10
12	Japla	Sone	MGD-V, Patna	Jharkhand	Palamu	4.77	2.27
13	Mohammad Ganj	North Koel	MGD-V, Patna	Jharkhand	Palamu	2.22	1.50
14	Azamabad	Ganga	MGD-V, Patna	Bihar	Bhagalpur	5.78	6.33
15	Hathidah	Ganga	MGD-V, Patna	Bihar	Patna	2.45	2.93
16	Gandhighat	Ganga	MGD-V, Patna	Bihar	Patna	4.59	3.78
17	Buxar	Ganga	MGD-V, Patna	Bihar	Bhojpur	3.05	4.03
18	Lakhisarai	Kiul	MGD-V, Patna	Bihar	Lakhisarai	4.62	1.50
19	Sripalpur	Punpun	MGD-V, Patna	Bihar	Patna	2.45	1.43
20	Lalganj	Gandak	MGD-V, Patna	Bihar	Vaishali	2.30	-
21	Darrighat	Arpa	MD, Burla	Chhattisgarh	Bilaspur	1.90	2.20
22	MBPL	Hasdeo	MD. Burla	Chhattisgarh	Bilaspur	1.80	1.50

Note: M= Monsoon; NM= Non-Monsoon

Plate – 07

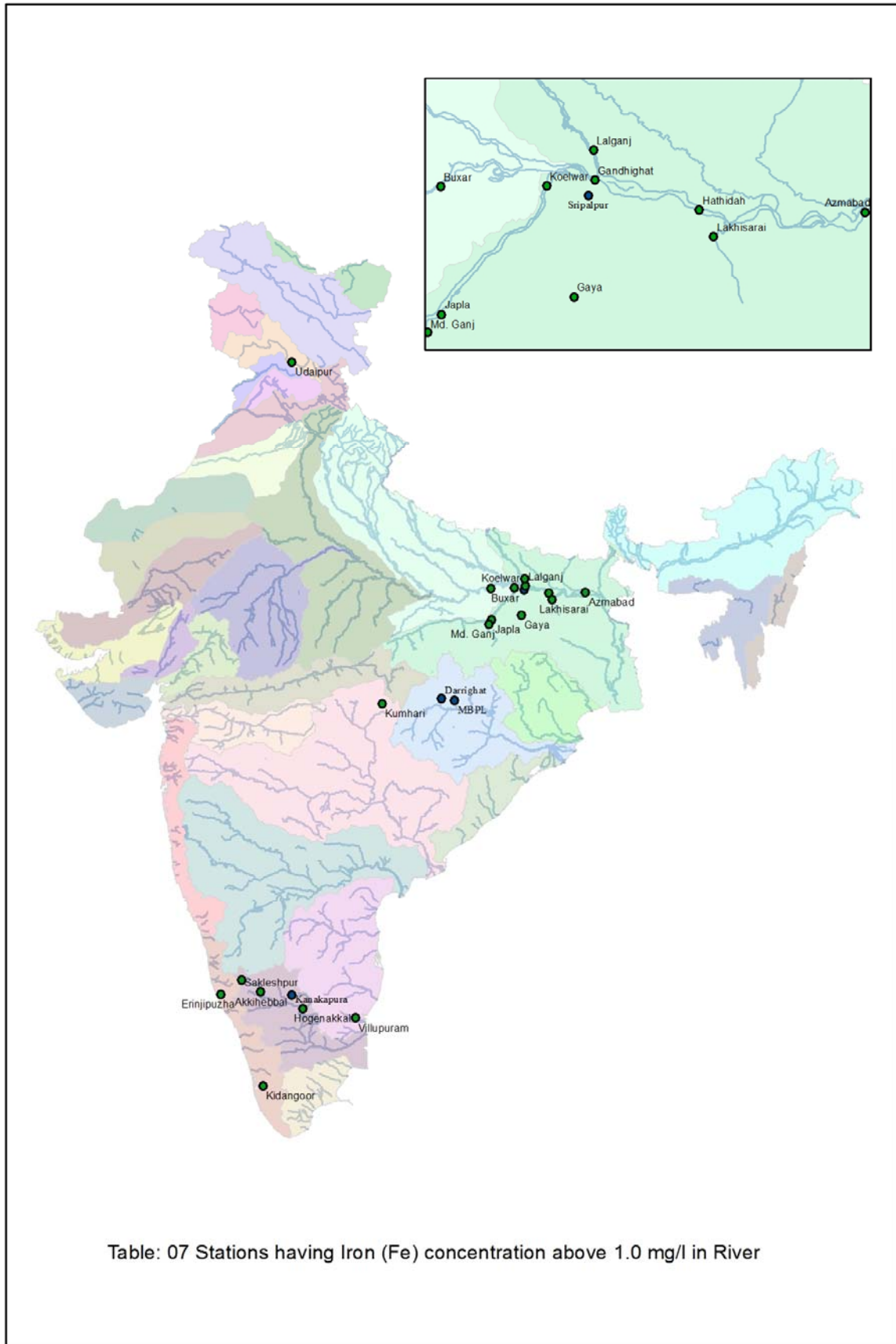


Table: 07 Stations having Iron (Fe) concentration above 1.0 mg/l in River

TABLE :- 08**Stations having Fluoride concentration above 1.5 mg/l in River**

S. No.	Water Quality Site	River	Division	State	District	M	NM
1	Delhi	Yamuna	UYD, Delhi	Delhi	Delhi	1.52	-
2	Mohana	Yamuna	UYD, Delhi	Haryana	Faridabad	1.92	-
3	Mathura	Yamuna	UYD, Delhi	U.P.	Mathura	1.72	-
4	Kuniyil	Chaliyar	SWR, Cochin	Kerala	Mallapuram	2.00	-
5	Hogenakkal	Chinnar	CD, Bangalore	Tamilnadu	Dharmapuri	-	1.70
6	Thimmanahalli	Yagachi	CD, Bangalore	Karnataka	Hassan	4.08	5.07
7	Thoppur	Thoppaiyar	SRD, Coimbatore	Tamilnadu	Salem	1.76	-
8	Azamabad	Ganga	MGD-V, Patna	Bihar	Bhagalpur	1.57	1.60
9	Gandhighat	Ganga	MGD-V, Patna	Bihar	Patna	-	14.71
10	Sripalpur	Punpun	MGD-V, Patna	Bihar	Patna	-	1.57
11	Damercharla	Musi	LKD, Hyderabad	A.P.	Nalgonda	1.83	-
12	Bawapuram	Tungabhadra	LKD, Hyderabad	A.P.	Kurnool	-	1.60
13	Darrighat	Arpa	M.D., Burla	Chhattisgarh	Bilaspur	1.80	1.56
14	MBPL	Hasdeo	M.D., Burla	Chhattisgarh	Bilaspur	2.72	2.22
15	Baridhinala	Subarnarekha	ERD, Bhubaneswar	Jharkhand	Paschimsingbhum	2.26	-

Note: M= Monsoon; NM= Non-Monsoon

Plate – 08

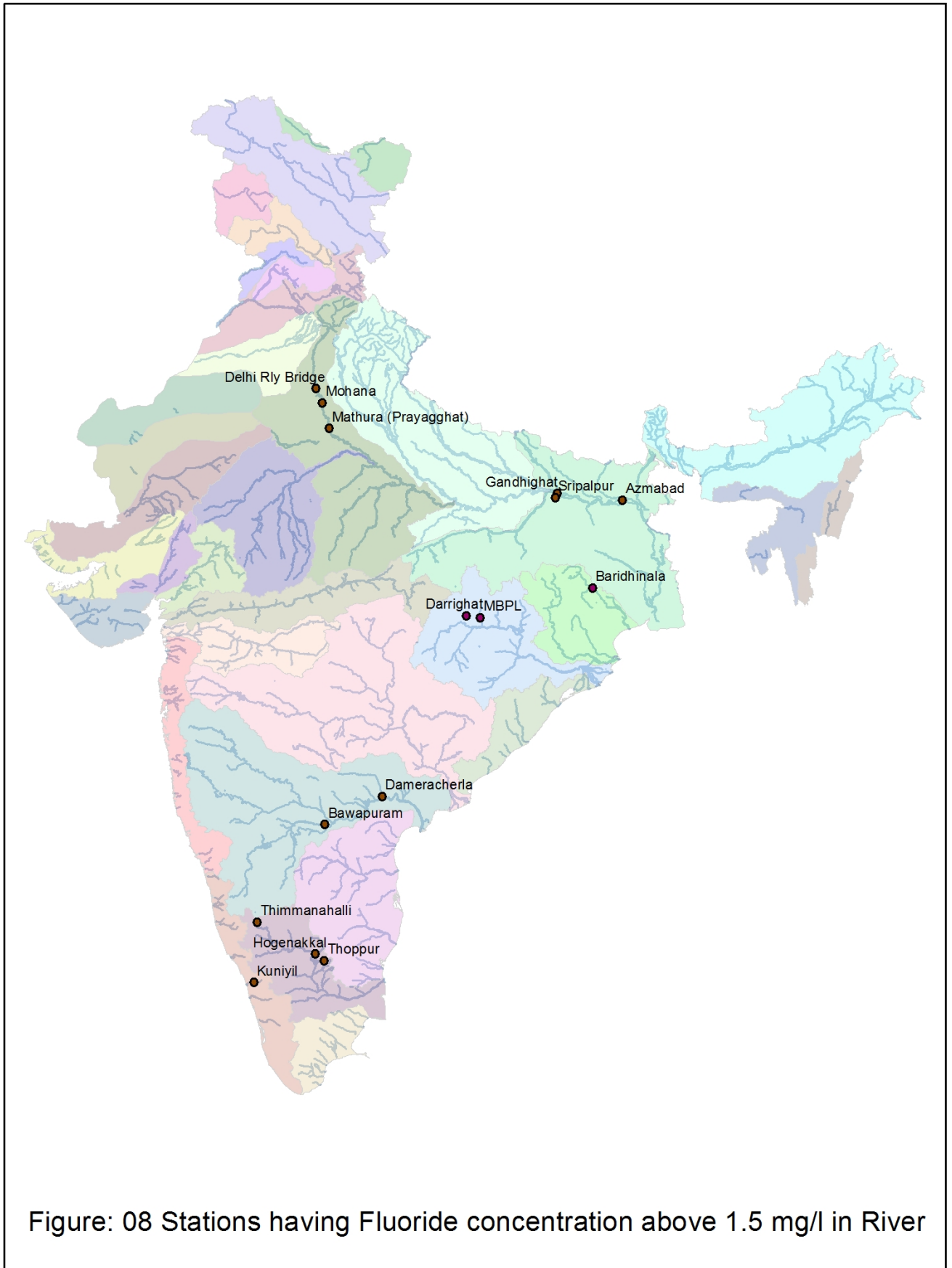


Figure: 08 Stations having Fluoride concentration above 1.5 mg/l in River

TABLE :- 09

Stations having Dissolved Oxygen concentration below 5.0 mg/l in River Water

S. No.	Water Quality Site	River	Division	State	District	M	NM
1	Delhi	Yamuna	UYD, Delhi	Delhi	Delhi	3.31	1.07
2	Galeta	Hindon	UYD, Delhi	U.P.	Jhajjar	-	3.81
3	Mathura	Yamuna	UYD, Delhi	U.P.	Mathura	4.90	4.27
4	Bishnur	Wardha	WGD, Nagpur	Maharashtra	Wardha	4.76	4.88
5	T. Bekuppe	Arkavathi	CD, Bangalore	Karnataka	Ramanagaram	4.65	4.65
6	Yennehole	Yennehole	CD, Bangalore	Karnataka	Udupi	4.90	-
7	Bantwal	Nethravathi	CD, Bangalore	Karnataka	Dakshina Kannada	-	3.90
8	Bareilly	Ramganga	MGD-II, Lucknow	U.P.	Bareilly	-	4.70
9	Takli	Bhima	UKD, Hyderabad	Maharashtra	Sholapur	4.88	3.02
10	Derol Bridge	Sabarmati	MD, Ahmadabad	Gujarat	Sabarkantha	3.70	-
11	Lowara	Shetrunji	MD, Ahmadabad	Gujarat	Bhavnagar	-	3.78
12	Abu Road	Banas	MD, Ahmadabad	Rajasthan	Sirohi	2.68	-
13	Chitrasani	Balaram	MD, Ahmadabad	Gujarat	Banaskantha	3.10	-
14	Darrighat	Arpa	Mahanadi Div. Burla	Chhattisgarh	Bilaspur	0.8	0.9
15	Ghatora	Seonath	Mahanadi Div. Burla	Chhattisgarh	Bilaspur	-	4.7
16	MBPL	Hasdeo	Mahanadi Div. Burla	Chhattisgarh	Bilaspur	0.3	0.5
17	Baridhinala	Subarna- rekha	ERD, Bhubaneswar	Jharkhand	Paschimsingbhum	0.8	0.9

Note: M= Monsoon; NM= Non-Monsoon

Plate – 09

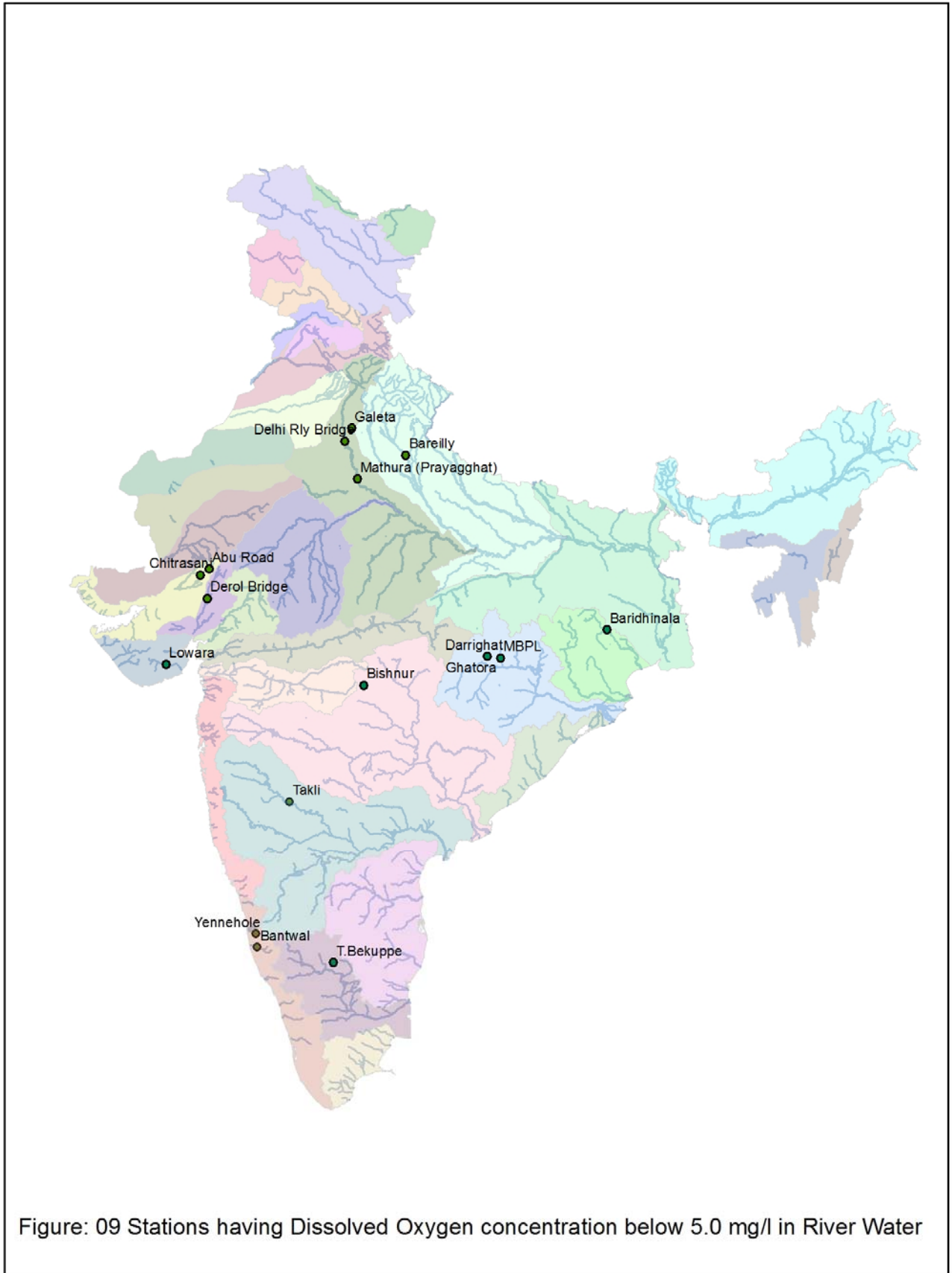


TABLE :- 10

Stations having Biochemical Oxygen Demand Concentration above 3.0 mg/l in River Water

S. No.	Water Quality Site	River	Division	State	District	M	NM
1	Agra	Yamuna	LYD, Agra	U.P.	Agra	17.59	21.07
2	Etawah	Yamuna	LYD, Agra	U.P.	Etawah	7.96	15.51
3	Seondha	Sindh	LYD, Agra	M.P.	Datia	4.54	3.33
4	Sahijana	Betwa	LYD, Agra	U.P.	Hamirpur	3.67	3.68
5	Auraiya	Yamuna	LYD, Agra	U.P.	Auraiya	3.04	4.63
6	Garauli	Dhasan	LYD, Agra	M.P.	Chhatarpur	3.31	3.11
7	Hamirpur	Yamuna	LYD, Agra	U.P.	Hamirpur	3.10	4.02
8	Khatoli	Parwati	CD, Jaipur	Rajasthan	Kota	3.36	-
9	Mawi	Yamuna	UYD, Delhi	U.P.	Muzaffarnagar	12.06	10.77
10	Delhi	Yamuna	UYD, Delhi	Delhi	Delhi	28.24	39.83
11	Galeta	Hindon	UYD, Delhi	U.P.	Jhajjar	21.91	32.18
12	Mohana	Yamuna	UYD, Delhi	Haryana	Faridabad	24.27	30.55
13	Mathura	Yamuna	UYD, Delhi	U.P.	Mathura	17.56	28.53
14	Bamni	Wardha	WGD, Nagpur	Maharashtra	Chandrapur	6.74	10.05
15	Bishnur	wardha	WGD, Nagpur	Maharashtra	Wardha	5.74	8.63
16	Pudur	Bharathapuzha	SWR, Cochin	Kerala	Palakkad	7.30	6.00
17	Kanakpura	Arkavathi	CD, Bangalore	Karnataka	Bangalore	4.28	3.50
18	T. Bekuppe	Arkavathi	CD, Bangalore	Karnataka	Ramanagaram	-	3.65
19	Thimmanahalli	Yagachi	CD, Bangalore	Karnataka	Hassan	10.08	8.62
20	Elunuthimangalam	Noyyal	SRD, Coimbatore	Tamilnadu	Erode	-	3.10
21	Gummanur	Ponnoiyar	SRD, Coimbatore	Tamilnadu	Dharmapuri	3.03	3.10
22	Kanpur	Ganga	MGD-II, Lucknow	U.P.	Kanpur	3.10	3.40
23	Shahzadpur	Ganga	MGD-III, Varanasi	U.P.	Kaushambi	-	3.10
24	Allahabad	Ganga	MGD-III, Varanasi	U.P.	Allahabad	3.50	3.80
25	Pingalwada	Dhadher	TD, Surat	Gujarat	Vadodara	12.37	14.76
26	Vautha	Sabarmati	MD, Ahmadabad	Gujarat	Kheda	17.21	29.59
27	Darrighat	Arpa	MD. Burla	Chhattisgarh	Bilaspur	241.6	282.4
28	Ghatora	Seonath	MD. Burla	Chhattisgarh	Bilaspur	3.8	19.4
29	MBPL	Hasdeo	MD. Burla	Chhattisgarh	Bilaspur	276.3	259.8
30	Adityapur	Kharkai	ERD, Bhubaneswar	Bihar	Purba Singhbhum	-	8.0
31	Baridhinala	Subarnarekha	ERD, Bhubaneswar	Jharkhand	Paschim-singbhum	76.6	88.8
32	Jamshedpur	Subarnarekha	ERD, Bhubaneswar	Jharkhand	Purba Singhbhum	-	9.3
33	Kulpatanga	Kharkai	ERD, Bhubaneswar	Jharkhand	Dumka	6.3	8.0
34	Gomlai	Brahmani	ERD, Bhubaneswar	Orissa	Sundergarh	-	3.2
35	Kamalanga	Brahmani	ERD, Bhubaneswar	Orissa	Angul	6.8	7.3
36	RSP Nalla	Brahmani	ERD, Bhubaneswar	Orissa	Sundergarh	5.6	5.8

Note: M= Monsoon; NM= Non-Monsoon

Plate – 10

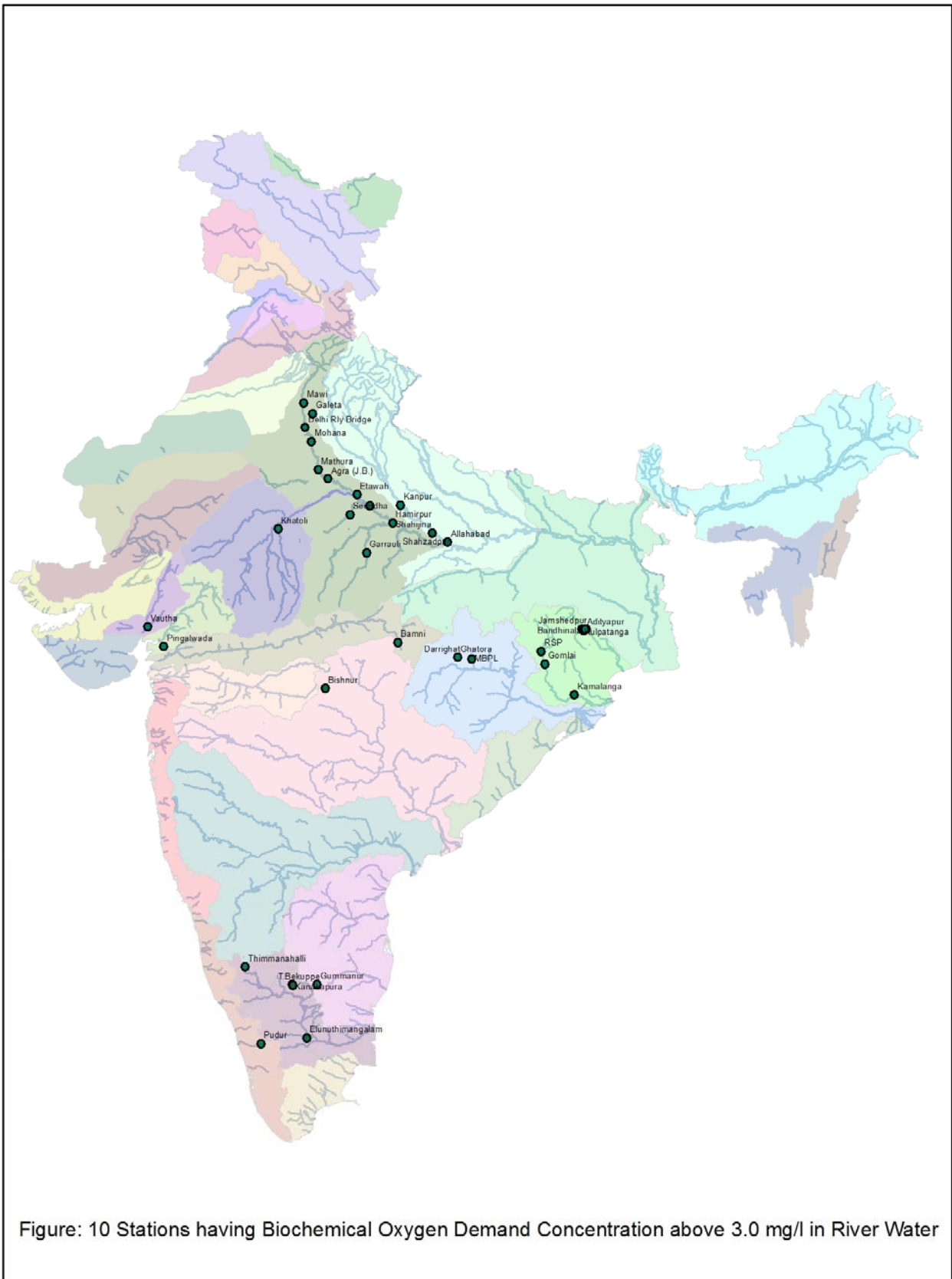


Figure: 10 Stations having Biochemical Oxygen Demand Concentration above 3.0 mg/l in River Water

REFERENCES

- Stephen J. Vandas, Thomas C. Winter, William A. Battaglin 2002** . Water and the Environment. Page 7-12 *American Geological Institute, 4220 King Street Alexandria, VA 22302*
- Bhardwaj, R.M. 2005.** Water Quality Monitoring in India achievements and Constraints. *IWG-Env, International Work Session on Water Statistics, Vienna, June 20-22 2005*
- Taylor, F.B., Eagen, J.H., Smith, H.F.D., Jr., and Coene, R.F. 1966.** The case for water-borne infectious hepatitis. *Am. J. Public Health, 56: 2093.*
- S.K. Shukla, 2009.** Indian River systems and pollution, *Encyclopedia of Earth, November 12, 2009*
- Hussain, I., Hussain, J., Sharma, K.C. and Ojha, K.G. 2002.** Fluoride in Drinking Water and Health Hazardous: Some Observations on Fluoride Distribution Rajasthan. *Environmental Scenario of 21st Centaury, 355–374.* APH Pub. Co., New Delhi.
- Hussain, J., Sharma, K. C., & Hussain, I. 2004.** Fluoride in drinking water and its ill affect on Human Health: A review. *Journal of Tissue Research, 4(2), 263–273.*

ABBREVIATION

Andhra Pradesh	= AP
Arsenic	= As
Biochemical Oxygen Demand	= BOD
Bureau of Indian Standards	= BIS
Calcium	= Ca ⁺²
Cauvery Division	= CD
Central Pollution Control Board	= CPCB
Central Water Commission	= CWC
Chambal Division	= CD
Chenab Division	= CD
Chloride	= Cl ⁻
Dissolved Oxygen	= DO
Eastern River Division	= ERD
Electrical Conductance	= EC
Fluoride	= F ⁻
Godavari Division	= GD
Himachal Pradesh	= HP
Himalayan Ganga Division	= HGD
Hydrology Division	= HD
Iron	= Fe
Lower Krishna Division	= LKD
Lower Yamuna Division	= LYD
Madhya Pradesh	= MP
Magnesium	= Mg ⁺²
Mahanadi Division	= MD
Mahanadi Division	= MD
Mahi Division	= MD
Middle Brahmaputra Division	= MBD
Middle Ganga Division	= MGD
Narmada Division	= ND
Nitrate	= NO ₃ ⁻
Sodium Absorption Ratio	= SAR
South Western Division	= SWR
Southern River Division	= SRD
Sulphate	= SO ₄ ⁻²
Tapi Division	= TD
Total Dissolved Solids	= TDS
Total Hardness	= TH
Upper Yamuna Division	= UYD
Uttar Pradesh	= UP
Wainganga Division	= WGD
Water Quality Assessment Authority	= WQAA
Rourkela Steel Plant	= RSP
Madhya Bharat Paper Ltd	= MBPL

PREPARED UNDER THE GUIDANCE OF

Shri A. K. Bajaj, Chairman, CWC
Shri R. C. Jha, Member (River Management)
Shri Rajesh Kumar, (Chief Engineer), P & D
Dr. P.K. Mehrotra, Director (Water Quality), M/o WR
Shri Anupam Prasad (Director), River Data Directorate

PRINCIPAL CONTRIBUTORS

Dr. Jakir Hussain, Assistant Research Officer (Incharge), NRWQL, Delhi
Shri Naveen Kumar, AD, Data Center RDC, Delhi
Shri S.K. Kulshrestha, Senior Research Assistant
Shri Aditya Sarin, Senior Research Assistant

DATA CONTRIBUTION

Superintending Engineer (HOC), Noida; Deputy Director, River Data Directorate, New Delhi; Deputy Director, RDC Delhi
Executive Engineers, Chambal Division, Jaipur; Upper Yamuna Division, Delhi; Lower Yamuna Division, Agra; Middle Ganga Division, I & II, Lucknow; Middle Ganga Division, III, Varanasi; Middle Ganga Division, IV & V, Patna; Himalayan Ganga Division, Dehradun; Chenab Division, Jammu; Tapi Division, Surat; Mahi Division, Gandhinagar; Narmada Division, Bhopal; Cauvery Division, Bangalore; Godawari Division, Hyderabad; Upper Krishna Division, Pune; Southern River Division, Coimbatore; Hydrology Division, Chennai; South Western River Division, Kochi; Middle Brahmaputra Division, Guwahati; Meghna Investigation Division, Shillong; Mahanadi Division, Burlan; Eastern River Division, Bhubaneswar



CENTRAL WATER COMMISSION

Ministry of Water Resources

Sewa Bhawan,

R.K. Puram, New Delhi - 110 066 India