Status of Trace and Toxic Metals in Indian Rivers

Arsenic
Cadmium
Copper
Chromium
Iron
Lead
Nickel
Zinc

River Data Compilation -2 Directorate Planning and Development Organisation
New Delhi 110066
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April, 2018
FOREWORD

Water quality monitoring issues in Indian rivers have emerged as a critical challenge in the country; Contaminants, whether industrial effluents or domestic waste, are finding their way to the rivers, adversely affecting their health. Lack of monitoring and enforcement also makes it difficult for countries and regions to understand and deal with this challenge. Metal contamination in the environment is one of the persistent global environmental problems. This contamination is caused by continuous growth in mining, fertilizer, tannery, paper, batteries and electroplating industries which subsequently has shown noxious effects on human health around the globe. Unlike organic contaminants, heavy metals are non-biodegradable and also carcinogenic. Heavy metals such as Zinc, Copper, Nickel, Mercury, Cadmium, Lead, Chromium and Arsenic tend to accumulate in organisms, which may lead to a reduction in species diversity.

Central Water Commission under Ministry of Water Resources, RD & GR has been playing a major role in the monitoring water quality of river water since year 1963 and at present, is observing water quality at 429 key locations covering all major river basins of India. The present report attempts to provide the water quality scenario of Indian rivers in respect of trace & toxic metals. Based on the analysis results of various metal elements, first edition of the Status of Trace and Toxic Metals in Indian Rivers was published by River Data Directorate, CWC, in May 2014. The revised and comprehensive edition of this report is in your hand which includes the data of eight elements viz; Arsenic, Cadmium, Chromium, Copper, Iron, Lead, Nickel and Zinc for the period from May 2014 to August 2017. The report brings out the identified locations having these metal concentrations beyond the exceeding limits according to the BIS 10500:2012.

I would like to place on record my appreciation of Shri Pradeep Kumar, Member (River Management), CWC, Shri Ravi Shankar, Chief Engineer (P&D), CWC and his team for excellently bringing out second edition of this publication.

I hope this report will provide meaningful tool to all concerned agencies in identifying remedial measures to check pollution caused by these metal elements in Indian rivers.

New Delhi
17 April, 2018

(S. Masood Husain)
PREFACE

River pollution is an environmental problem in the world. Because of unprecedented development, human beings are responsible for choking several aquatic ecosystems to death. Storm water runoff and carry out of sewage into rivers are two common ways that various nutrients and other pollutants enter the aquatic ecosystems resulting in pollution. Heavy metal contamination particularly the non-essential elements may have distressing effects on the ecological balance of the recipient aquatic environment with a diverse of organisms including fish. It has particular significance in ecotoxicology, since the heavy metals are highly persistent and have the potential to bio-accumulate and bio-magnify in food chain and become toxic to living organisms at higher trophic levels in nature. Trace & toxic metals, as their name indicates present in water in very minute quantity and a few of them are somewhat essential for proper nutrition, but may prove hazardous if their presence exceeds the permissible limit in the water. "Toxic metals" are one of the environmental problems. Today, there are new dimensions of the problem, such as the production of metals in developing countries, leading to occupational exposure and exposure to the general public through the ambient air, drinking water, food, and consumer products.

In CWC, the water quality data generated, as a result of analysis of water samples, are utilised in publication of various water quality Year-Books basin-wise. To observe the current status of toxic metal content of Indian Rivers, river water samples from the water quality monitoring stations spread over 16 river basins of Central Water Commission were collected in three different seasons viz, monsoon (August, 2016 and August, 2017), summer (May, 2014; April, 2016 and April, 2017) and winter (November, 2014; February 2015, December, 2015 and December, 2016). These samples were analyzed for selected eight trace and toxic metals at National River Water Quality Laboratory, Central Water Commission, New Delhi.

I appreciate the commendable efforts put by Shri Ravi Shankar (Chief Engineer, P & D) for bringing out 2nd edition of this book. Efforts put in by the officers of River Data Directorate-2, Shri Rajesh Kumar, Director, Manoj Kumar, Dy. Director, Dr. Jakir Hussain, Research Officer, Shri Sunil Chauhan, Assistant Research Officer, Shri N. Prabhakar Rao and Dr Sakshi Sharma, Senior Research Assistant in the preparation of the report are also appreciated. I also express sincere thanks to all field Chief Engineers of CWC for making arrangements for collection and submission of river water samples to the National River Water Quality Laboratory, CWC, New Delhi.

I hope this publication will provide a vision of state of Trace & Toxic Metals in Indian rivers to all stake holders and then ponder to search for remedial measures to check the pollution.

New Delhi
13th April, 2018

(Pradeep Kumar)
Member (RM), CWC
EXECUTIVE SUMMARY

In the developing countries like India, facilities of drinking water treatment before supply are not always available or possible. In many parts of the country people take water directly from the source for their domestic use. Because of the rapid urbanization and industrialization, availability of good quality and quantity of water is a threat.

To observe the current status of toxic metal content of Indian Rivers, river water samples from the water quality monitoring stations spread over 16 river basins of Central Water Commission were collected in three different seasons viz, monsoon (August, 2016 and August, 2017), summer (May, 2014; April, 2016 and April, 2017) and winter (November, 2014; February 2015, December, 2015 and December, 2016). These samples were analyzed for selected eight trace and toxic metals at National River Water Quality Laboratory, Central Water Commission, New Delhi. Toxic metal wise summary of the results are as under:

**Arsenic (As)**

Total 1734 numbers of water samples from 414 water quality monitoring stations were collected and analyzed for arsenic content in Indian Rivers in the period May, 2014

Maximum arsenic concentration (9.53 µg/L) was observed at Buxar water quality monitoring station on Ganga River during April, 2016. During the study period, all the River water quality stations are reported that arsenic concentration well within the acceptable limits according to the Bureau of Indian Standards (BIS) and no toxicity of arsenic in the River waters is observed.

**Cadmium (Cd)**

Out of 2349 water samples, thirty eight water quality stations from Ganga, Kopili, Rapti, Thungabhadra and Yamuna rivers were found to have cadmium content more than one station above the acceptable limits. The highest cadmium concentration (70.51 µg/L) was observed in the Vautha water quality monitoring station at Sabarmati River during February, 2015. It is also observed that a Cadmium concentration exceeds the acceptable limit during non-monsoon period.
**Chromium (Cr)**

BIS (Bureau of Indian Standard) 10500-2012 have recommended an acceptable limit of 50 µg/L of chromium in drinking water. Chromium concentration was 450.26 µg/L at Paliakalan water quality monitoring station on Sharda River in August 2016, which is reported as the maximum concentration during entire study period. Out of 2400 water samples, total 41 numbers of water samples from 28 water quality monitoring stations located on 21 major Indian Rivers were found above the tolerance limit of 50µg/L with respect to chromium. Some Indian Rivers viz. Ganga, Ghagra and Rapti have two or more water quality monitoring stations which are polluted with respect to chromium concentration.

**Copper (Cu)**

2400 water samples from 414 water quality stations were collected and analyzed for copper content from May, 2014 to August, 2017. Out of 2451 water samples, 13 samples were found to contain copper concentrations above the acceptable limits of 50 µg/L during the study period, the maximum Copper concentration 314.93 µg/L was observed at Pingalwada water quality station on Dhadher River in April, 2017. Total 13 numbers of water samples exceeded the BIS prescribed acceptable limit at 12 numbers of WQ monitoring stations situated on 10 Indian Rivers during the study period. Dikhow, Brahmaputra, Buridehing, Damanganga, Dhadher, Ganga, Pranhitha, Sabarmati, Subarnarekha and Tel are the rivers where one or two water quality monitoring stations were found contaminated with copper.

**Iron (Fe)**

According to BIS the acceptable limit for Iron is 0.3 mg/L (300µg/L). Higher concentration of iron >300 µg/L has been observed in 524 water samples collected from 234 WQ stations of 137 Indian Rivers during the study period. The highest concentration of 14.55 mg/L is observed at Chenimari on Buridehing River. Bagmathi, Baitarni, Bhadar, Brahmani, Brahmaputra, Buridehing, Cauvery,
Desang, Dhansiri, Dikhow, Gandak, Ganga, Ghagra, Godavari, Gomti, Hemavathi, Indravathi, Jaldhaka, Kanhan, Kamala-Balan, Kopili, Krishna, Lohit, Mahananda, Mahi, Narmada, Neo dihing, Purna, Puthimari, Raidak-I, Rapti, Sai, Sone, Subansiri, Subarnarekha, Tapi, Teesta, Thungabhadra, Tors and Wainganga are the Rivers where three or more water quality stations have been found to have iron concentration above the acceptable limit throughout the study period.

### Lead (Pb)

As per Bureau of Indian Standard (10500, 2012) has recommended that the acceptable limit for lead is 0.01 mg/L or 10µg/L in drinking water. Lead concentration was maximum (374.58 µg/L) at Lowara water quality station on Sheturni River during April, 2016. 122 water samples from 91 water quality monitoring stations were observed having lead concentrations above the acceptable limit for drinking water in 69 Indian Rivers during the study period. Brahmaputra, Buridehing, Cauvery, Ganga, Ghagra, Gomti, Ramganga, Rapti, Sone, Thungabhadra, and Yamuna are the rivers where two or more numbers of WQ monitoring stations were found contaminated with lead.

<table>
<thead>
<tr>
<th>Pb Permissible Limit as BIS 10500; 2012</th>
<th>10 µg/L</th>
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<tbody>
<tr>
<td>No of Samples Tested</td>
<td>2400</td>
</tr>
<tr>
<td>No. of Samples Exceed the Limit</td>
<td>122</td>
</tr>
<tr>
<td>No. of Stations</td>
<td>91</td>
</tr>
<tr>
<td>No.of Rivers</td>
<td>69</td>
</tr>
<tr>
<td>No. of Rivers where it exceeded more than one WQ Stations</td>
<td>11</td>
</tr>
</tbody>
</table>

### Nickel (Ni)

It is observed that Nickel concentration found more than the prescribed limit in 35 water samples out of 2023 samples according to the BIS limits. Nickel concentration at Lowara water quality station on Sheturni river in February, 2015 is reported to be the maximum (184.64 µg/L) during the entire study period. Seonath, Subarnarekha and Thungabhadra are the rivers where 2 or more WQ monitoring stations were found contaminated with Nickel. 35 water samples from 32 water quality monitoring stations over 29 Indian Rivers were observed to have nickel concentration that exceed the acceptable limit during the study period.

<table>
<thead>
<tr>
<th>Ni Permissible Limit as BIS 10500; 2012</th>
<th>20 µg/L</th>
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<tbody>
<tr>
<td>No of Samples Tested</td>
<td>2023</td>
</tr>
<tr>
<td>No. of Samples Exceed the Limit</td>
<td>35</td>
</tr>
<tr>
<td>No. of Stations</td>
<td>31</td>
</tr>
<tr>
<td>No.of Rivers</td>
<td>25</td>
</tr>
<tr>
<td>No. of Rivers where it exceeded more than one WQ Stations</td>
<td>3</td>
</tr>
</tbody>
</table>

### Zinc (Zn)

Total 2400 water samples from the 414 water quality monitoring stations were analyzed during the reporting period. Maximum Zinc concentration (2.65 mg/L) was observed at Manot water quality monitoring station on Narmada River during August, 2016. In the study area, all the River water quality stations are
reported to have zinc concentration well within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of Zinc in the River waters is observed.

<table>
<thead>
<tr>
<th>Zn Permissible Limit as BIS 10500; 2012</th>
<th>5000 µg/L</th>
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<tbody>
<tr>
<td>No of Samples Tested</td>
<td>2400</td>
</tr>
<tr>
<td>No. of Samples Exceed the Limit</td>
<td>0</td>
</tr>
<tr>
<td>No. of Stations</td>
<td>0</td>
</tr>
<tr>
<td>No.of Rivers</td>
<td>0</td>
</tr>
<tr>
<td>No. of Rivers where it exceeded more than one WQ Stations</td>
<td>0</td>
</tr>
</tbody>
</table>
GUIDANCE

Shri S. Masood Husain, Chairman, CWC, New Delhi
Shri Pradeep Kumar, Member (River Management), CWC, New Delhi
Shri N.K. Mathur, Member (D & R), CWC, New Delhi
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# Table of Contents

Foreword  
Preface  
Abbreviations  
Executive Summary  
Contributions  
Abbreviations

1. **INTRODUCTION**  
   1.1 Sources of Metal Pollution  
   1.2 Other Sources of Metal Pollution  

2. **INDIAN WATER RESOURCES SCENARIO**  

3. **INDIAN RIVER SYSTEM**  
   3.1. Indus River Basin  
   3.2. Brahmaputra River Basin  
   3.3. Ganga River Basin  
   3.4. Barak River Basin  
   3.5. Narmada River Basin  
   3.6. Tapi River Basin  
   3.7. Godavari River Basin  
   3.8. Krishna River Basin  
   3.9. Cauvery River Basin  
   3.10. Mahanadi River Basin  
   3.11. Subernarekha and Burhabalang River Basin  
   3.12. Brahmani and Baitarni Basin  
   3.13. Pennar Basin  
   3.15. Sabarmati Basin  
   3.16. West Flowing Rivers Basin from Tapi to Tadri  
   3.17. West Flowing Rivers Basin from Tadri to Kanyakumari  
   3.18. West Flowing Rivers of Kutch and Saurashtra including Luni  
   3.19. East Flowing Rivers between Mahanadi and Pennar  
   3.20. East Flowing Rivers between Pennar and Kanyakumari

4. **RIVER WATER MONITORING BY CWC**  

5. **REVIEW OF TRACE & TOXIC METALS**  

6. **Metal Toxicity:**  
   6.1. Toxicity of Arsenic  
   6.2. Toxicity of Cadmium  
   6.3. Toxicity of Chromium  
   6.4. Toxicity of Copper  
   6.5. Toxicity of Iron  
   6.6. Toxicity of lead  
   6.7. Toxicity of Nickel
6.8. Toxicity of Zinc ................................................................................................................. 28

7. WATER QUALITY CRITERIA ........................................................................................... 30
  7.1. Drinking Water Standards ............................................................................................. 30
  7.2. Quality Criteria for Livestock ......................................................................................... 32
  7.3. Water Quality for Irrigation ......................................................................................... 32

8. STUDY AREA .................................................................................................................. 34

9. METHODOLOGY .............................................................................................................. 34
  9.1. Metal Detection Techniques ......................................................................................... 34
  9.2. Chemicals and Reagents ............................................................................................... 35
  9.3. Method .......................................................................................................................... 35

10. RESULTS AND DISCUSSION ...................................................................................... 36
  10.1. Summary of ARSENIC content in Indian Rivers .......................................................... 41
  10.2. Summary of CADMIUM content in Indian Rivers ....................................................... 41
  10.3. Summary of CHROMIUM content in Indian rivers ...................................................... 43
  10.4. Summary of COPPER content in Indian rivers ........................................................... 44
  10.5. Summary of LEAD content in Indian rivers ............................................................... 45
  10.6. Summary of NICKEL content in Indian rivers ............................................................ 48
  10.7. Summary of ZINC content in Indian rivers ............................................................... 49
  10.8. Summary of IRON content in Indian rivers ................................................................. 50

11. CONCEPT OF NORMALIZATION: ............................................................................... 56

12. INDEX VALUE CALCULATION: .................................................................................... 82

13. CONCLUSION .................................................................................................................. 89

14. RECOMMENDATIONS .................................................................................................... 92

15. REFERENCE .................................................................................................................... 93

List of Annexures

<table>
<thead>
<tr>
<th>Annexure-1</th>
<th>Details of Water Quality Monitoring Stations under Central Water Commission</th>
<th>99-119</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annexure-2</td>
<td>Details of the Indian rivers and their sites where the water was found fit for use in terms of toxic metal contamination in the study period.</td>
<td>120-122</td>
</tr>
<tr>
<td>Annexure-3</td>
<td>Details of WQ Monitoring Stations where the water was found unfit for use due to the presence of only Iron above the acceptable limits during the study period</td>
<td>123-126</td>
</tr>
<tr>
<td>Annexure-4</td>
<td>Details of WQ Monitoring Stations where the water was found unfit for use due to presence of more than two toxic metals above acceptable limits during the study period</td>
<td>127-128</td>
</tr>
<tr>
<td>Annexure-5</td>
<td>Details of water quality sites, Rivers and the level of toxic metal concentration found above the acceptable limits as prescribed by BIS during the study period</td>
<td>129-145</td>
</tr>
<tr>
<td>Annexure-6</td>
<td>Seasonal average values of Trace and Toxic metals with total no of water quality samples found above / below the acceptable limit as prescribed by BIS 10500: 2012</td>
<td>146-225</td>
</tr>
</tbody>
</table>
List of Tables

Table 1: The anthropogenic sources of heavy metals in the environment .................................3
Table 2: Classification of River Basin in India. ........................................................................4
Table 3: Basin-wise hydrological observation Stations of Central Water Commission ..........19
Table 4: State wise Water Quality Stations of Central Water Commission .............................20
Table 5: Drinking Water Standards for Trace & Toxic metals (BIS-10500-2012). ...............30
Table 6: Maximum acceptable limits of several toxic heavy metal ions in the surface waters based on WHO and Us EPA regulations ..................................................................................31
Table 7: Drinking water quality criteria for trace metals which might affect public health ....31
Table 8: Recommendations for levels of toxic substances in drinking water for livestock ....32
Table 9: Recommended limits for constituents in reclaimed water for irrigation .....................33
Table 10: The wavelength, current, slit and method used for chemical analysis by AAS ........35
Table 11: Minimum and Maximum of Metal during the May, 2014 to August, 2017 ..........36
Table 12: Summary and statistical analysis of analytical results of water samples (From May 2014 to August 2017). .........................................................................................................................37
Table 13: Number of samples analysed and found above acceptable limits of toxic metals ....39
Table 14: Rivers and WQ stations where Cadmium exceeded the acceptable limits ............42
Table 15: Rivers and WQ stations where Chromium exceeded the acceptable limits ..........43
Table 16: Rivers and WQ stations where Copper exceeded the acceptable limit .................44
Table 17: Rivers and WQ stations where Lead exceeded the acceptable limit ....................46
Table 18: Rivers and WQ stations where Nickel exceeded the acceptable limit ..................49
Table 19: Rivers and WQ stations where Iron exceeded the acceptable limit .......................50
List of Figures

Figure 1: Indian River Basin. .................................................................................. 5
Figure 2: Indus River Basin. ................................................................................... 5
Figure 3: Brahmaputra River Basin. ...................................................................... 6
Figure 4: Ganga River Basin. ............................................................................... 7
Figure 5: Barak River Basin. .................................................................................. 8
Figure 6: Narmada River Basin. .......................................................................... 8
Figure 7: Tapi River Basin. ................................................................................... 9
Figure 8: Godavari River Basin. .......................................................................... 10
Figure 9: Krishna River Basin. .......................................................................... 10
Figure 10: Cauvery River Basin. ........................................................................ 11
Figure 11: Mahanadi River Basin. ....................................................................... 12
Figure 12: Subernrekha and Burhabalang River Basin. ........................................... 12
Figure 13: Brahmani and Baitarni River Basin. ...................................................... 13
Figure 14: Pennar River Basin. ........................................................................... 14
Figure 15: Mahi River Basin. ............................................................................... 14
Figure 16: Sabarmati River Basin. ...................................................................... 15
Figure 17: West Flowing Rivers Basin from Tapi to Tadri. ..................................... 16
Figure 18: Order of higher occurrence in non-monsoon period .......................... 40
Figure 19: Order of higher occurrence in monsoon period. .............................. 40
List of Graphs

Graph 1: Normalization of Ganga River (Monsoon and Non-monsoon) ..................................................57
Graph 2: Normalization of Yamuna River (Monsoon and Non-monsoon) ...........................................59
Graph 3: Normalization of Chambal River (Monsoon and Non-monsoon) ........................................60
Graph 4: Normalization of Brahmaputra River (Monsoon and Non-monsoon) ................................61
Graph 5: Normalization of Ramganga River (Monsoon and Non-monsoon) ....................................62-63
Graph 6: Normalization of Rapti River (Monsoon and Non-monsoon) .............................................64
Graph 7: Normalization of Narmada River (Monsoon and Non-monsoon) ....................................65
Graph 8: Normalization of Sone River (Monsoon and Non-monsoon) ............................................66-67
Graph 9: Normalization of Godavari River (Monsoon and Non-monsoon) ....................................68
Graph 10: Normalization of Wainganga River (Monsoon and Non-monsoon) ................................69
Graph 11: Normalization of Krishna River (Monsoon and Non-monsoon) ....................................70-71
Graph 12: Normalization of Tungabhadra River (Monsoon and Non-monsoon) ..........................72
Graph 13: Normalization of Mahanadi River (Monsoon and Non-monsoon) ..................................73
Graph 14: Normalization of Brahmani River (Monsoon and Non-monsoon) ................................74-75
Graph 15: Normalization of Subernarekha River (Monsoon and Non-monsoon) ............................76
Graph 16: Normalization of Cauvery River (Monsoon and Non-monsoon) ...................................77
Graph 17: Normalization of Pennar River (Monsoon and Non-monsoon) .....................................78
Graph 18: Normalization of Palar River (Monsoon and Non-monsoon) ..........................................79
Graph 19: Normalization of Gomti River (Monsoon and Non-monsoon) ........................................80-81
Graph 20: Index Value Trends of Yamuna River .................................................................................82
Graph 21: Index Value Trends of Ganga River .................................................................................82
Graph 22: Index Value Trends of Krishna River ..............................................................................83
Graph 23: Index Value Trends of Godavari River .............................................................................83
Graph 24: Index Value Trends of Brahmani River .........................................................................83
Graph 25: Index Value Trends of Brahmaputra River ...................................................................84
Graph 26: Index Value Trends of Cauvery River ............................................................................84
Graph 27: Index Value Trends of Chambal River ...........................................................................84
Graph 28: Index Value Trends of Gomti River ..............................................................................85
Graph 29: Index Value Trends of Mahanadi River .........................................................................85
Graph 30: Index Value Trends of Narmada River .................................................................85-86
Graph 31: Index Value Trends of Palar River ................................................................................86
Graph 32: Index Value Trends of Pennar River .............................................................................86
Graph 33: Index Value Trends of Ramganga River ....................................................................86-87
Graph 34: Index Value Trends of Rapti River ..............................................................................87
Graph 35: Index Value Trends of Sone River .................................................................................87
Graph 36: Index Value Trends of Subernarekha ............................................................................87
Graph 37: Index Value Trends of Tungabhadra River ................................................................88
Graph 38: Index Value Trends of Wainganga River ...................................................................88
**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>µg/dL</td>
<td>Microgram per Deci Liter</td>
</tr>
<tr>
<td>AAS</td>
<td>Atomic Absorption Spectrophotometer</td>
</tr>
<tr>
<td>APHA</td>
<td>American Public Health Association</td>
</tr>
<tr>
<td>As</td>
<td>Arsenic</td>
</tr>
<tr>
<td>BCM</td>
<td>Billion Cubic meter</td>
</tr>
<tr>
<td>BIS</td>
<td>Bureau of Indian Standards</td>
</tr>
<tr>
<td>Cd</td>
<td>Cadmium</td>
</tr>
<tr>
<td>Cr</td>
<td>Chromium</td>
</tr>
<tr>
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<td>Copper</td>
</tr>
<tr>
<td>Fe</td>
<td>Iron</td>
</tr>
<tr>
<td>Hg</td>
<td>Mercury</td>
</tr>
<tr>
<td>ICMR</td>
<td>Indian Council of Medical Research</td>
</tr>
<tr>
<td>IUPAC</td>
<td>International Union of Pure and Applied Chemistry</td>
</tr>
<tr>
<td>kms</td>
<td>kilo meters</td>
</tr>
<tr>
<td>M. ha</td>
<td>Million hectares</td>
</tr>
<tr>
<td>MCL</td>
<td>Maximum Contaminant Level</td>
</tr>
<tr>
<td>mm</td>
<td>milli meter</td>
</tr>
<tr>
<td>MSL</td>
<td>Mean Sea Level</td>
</tr>
<tr>
<td>Ni</td>
<td>Nickel</td>
</tr>
<tr>
<td>NRWQL</td>
<td>National River Water Quality Laboratory</td>
</tr>
<tr>
<td>Pb</td>
<td>Lead</td>
</tr>
<tr>
<td>ppb</td>
<td>Parts Per Billion</td>
</tr>
<tr>
<td>ppm</td>
<td>Parts Per Million</td>
</tr>
<tr>
<td>TEL</td>
<td>Tetra Ethyl Lead</td>
</tr>
<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organisation</td>
</tr>
<tr>
<td>WQ</td>
<td>Water Quality</td>
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<tr>
<td>Zn</td>
<td>Zinc</td>
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1. INTRODUCTION

The environmental pollution is caused by a variety of pollutants in water, air and soil. One of the major concerned pollutants of living environment is “Hazardous Metals” also termed as “Trace Elements or heavy metals”. The term “heavy metal” refers to any metal and metalloid element that has a relatively high density ranging from 3.5 to 7 g/cm$^3$ and is toxic or poisonous at low concentrations, and includes mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), zinc (Zn), nickel (Ni), copper (Cu) and lead (Pb). Although “heavy metals” is a general term defined in the literature, it is widely documented and frequently applied to the widespread pollutants of soils and water bodies (Duffus, 2002).

According to the World Health Organization (WHO), 2011 the common toxic ‘heavy metals’ that can be of public health concerns include beryllium (Be), aluminium (Al), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), molybdenum (Mo), silver (Ag), cadmium (Ca), tin (Sn), antimony (Sb), barium (Ba), mercury (Hg), thallium (Tl) and lead (Pb). This beryllium, which is the second lightest metallic element (an alkaline earth metal) after lithium with an atomic number of four, as well as aluminium, one of the most widely used industrial light metals with a density of 2.7 g/cm$^3$, and arsenic and selenium, which are not even metals, but a metalloid and a non-metal, respectively.

These metals are found widely in the earth’s crust and are non-biodegradable in nature. They enter into the human body via air, water and food. Metals in environmental waters arise from both natural and anthropogenic sources. In many cases, anthropogenic inputs of metals exceed natural inputs. Living organisms require some metals as essential nutrients, including calcium, sodium, potassium, magnesium, iron, zinc, chromium, cobalt, copper, nickel, manganese, molybdenum, and selenium. Excessive levels or certain oxidation states of some essential metals, however, are detrimental to living organisms. In addition to non-nutrient metals generally recognized as toxic, such as antimony, arsenic, beryllium, cadmium, lead, and mercury, health-based water quality standards will also include the nutrient metals chromium, copper, nickel, selenium, and zinc, all of which can be toxic at too-high levels or in certain oxidation states (Weiner, E.R. 2013).

1.1 Sources of Metal Pollution

Environmental pollution caused by the rapid industrialization and urbanization is one of the most significant problems of the last century. The main sources of heavy metal pollution are mining, milling, plating and surface finishing industries that discharge a variety of toxic metals such as Cr, Cu, Cd, Ni, Co, Zn and Pb into the environment. Over the last few decades, the concentration of these heavy metals in river water and sediments has increased rapidly. Consequently, concentrations of toxic metals in grains and vegetables grown in contaminated soils have increased at alarming rates. This poses a serious threat to humans and the environment because of its toxicity, non-biodegradability and bioaccumulation (Bahadir et al., 2007; Perez-Marin et al., 2008; Reddad et al., 2003).
Metal Pollution from Mining and Processing Ores

Digging a mine, removing ore from it, and extraction and processing of the minerals sometimes cause environmental damage. For example, mining operations can destroy habitat, farmland, and homes; produce soil erosion; and pollute waterways via toxic drainage. Emission of toxic materials from smelters such as arsenic (As), selenium (Se), lead (Pb), cadmium (Cd), and sulfur oxides, among others — causes serious air pollution. Surface mining produces about eight times as much waste as underground mining, but deep mining can produce even worse problems, such as earthquakes. When underground mines cave in, not only do they kill miners but they also cause subsidence of the surface, forming holes into which roads and houses may collapse. As near-surface minerals are depleted, miners have to dig deeper to find the mineral. A study by the National Academy of Science predicted that copper (Cu) mining operations in the year 2000 would produce three times as much waste per ton of copper output compared to the same activities in 1978.

Exposure of pyrite (FeS) and other sulfide minerals to atmospheric oxygen and moisture results in oxidation of this mineral and the formation of acid-mine drainage water. The release of acid-mine drainage from active and abandoned mines, particularly coal mines, has been widely associated with serious water quality problems. It dissolves toxic elements from tailings and soils and carries them into waterways and even groundwater. Water quality problems involve relatively high levels of metals such as iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), nickel (Ni) and cobalt (Co).

Ore processing, smelting, and refining operations can cause deposition of large quantities of trace metals such as lead (Pb), zinc (Zn), copper (Cu), arsenic (As) and silver (Ag), into drainage basins or direct discharge into aquatic environments.

1.2 Other Sources of Metal Pollution

1.2.1 Domestic Wastewater Effluents

Domestic wastewater effluents contain large amounts of trace metals from metabolic waste products, corrosion of water pipes - copper (Cu), lead (Pb), zinc (Zn), and cadmium (Cd), and household products, such as detergents - iron (Fe), manganese (Mn), chromium (Cr), nickel (Ni), cobalt (Co), zinc (Zn), boron (B), and arsenic (As). Wastewater treatment usually removes less than 50% of the metal content of the influent, leaving the effluent with significant metal loading. The sludge resulting from wastewater treatment is also rich in metals. Domestic wastewater and the dumping of domestic and industrial sludge are the major artificial sources of cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), and mercury (Hg) pollution (Csuros & Csuros, (2002).

Stormwater Runoff

Stormwater runoff from urbanized areas is a significant source of metal pollution in the receiving water streams. Metal composition of urban runoff water is dependent on many factors, such as city planning, traffic, road construction, land use, and the physical characteristics and climatology of the watershed (Csuros & Csuros, (2002).
Industrial Wastes and Discharges

In general the concentration of heavy metals in industrial effluents is much greater than their prescribed permissible limits in the aqueous solutions, so there is an urgent need to treat the metal containing effluents before they are discharged into the aquatic bodies. Metals and their concentrations in industrial waste discharges are specifically depend on the profile of that particular industry (Csuros & Csuros, (2002).

Table 1: The anthropogenic sources of heavy metals in the environment

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Pollutant</th>
<th>Major sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Arsenic</td>
<td>Arsenic containing fungicides, pesticides and herbicides, metal smelters, by products of mining activities, chemical wastes</td>
</tr>
<tr>
<td>2.</td>
<td>Cadmium</td>
<td>Cadmium producing industries, electroplating, welding. Byproducts from refining of Pb, Zn and Cu, fertilizer industry, pesticide manufacturers, cadmium–nickel batteries, nuclear fission plants, production of TEL used as additives in petrol</td>
</tr>
<tr>
<td>3.</td>
<td>Chromium</td>
<td>Metallurgical and chemical industries, processes using chromate compounds, cement and asbestos units</td>
</tr>
<tr>
<td>4.</td>
<td>Copper</td>
<td>Iron and steel industry, fertilizer industry, burning of wood, discharge of mine tailings, disposal of fly ash, disposal of municipal and industrial wastes are the sources of copper in the atmosphere</td>
</tr>
<tr>
<td>6.</td>
<td>Lead</td>
<td>Automobile emissions, lead smelters, burning of coal and oil, lead arsenate pesticides, smoking, mining and plumbing</td>
</tr>
<tr>
<td>7.</td>
<td>Mercury</td>
<td>Mining and refining of mercury, organic mercury’s used in pesticides, laboratories using mercury</td>
</tr>
<tr>
<td>8.</td>
<td>Nickel</td>
<td>Metallurgical industries using nickel, combustion of fuels containing nickel additives, burning of coal and oil, electroplating units using nickel salts, incineration of nickel containing substances</td>
</tr>
<tr>
<td>9.</td>
<td>Zinc</td>
<td>Zinc refineries, galvanizing processes, brass manufacture, metal plating, plumbing</td>
</tr>
</tbody>
</table>

Sanitary Landfills

The metal contents and average concentrations of sanitary-landfill leachates are Cu (5 ppm), Zn (50 ppm), Pb (0.3 ppm), and Hg (60 ppb) (Csuros & Csuros, (2002).

Agricultural Runoff

The metal content of agricultural runoff originates in sediments and soils saturated by animal and plant residues, fertilizers, specific herbicides and fungicides, and use of sewage and sludge as plant nutrients (Csuros & Csuros, (2002).

Fossil Fuel Combustion

Fossil fuel combustion is a major source of airborne metal contamination of natural waters(Csuros & Csuros, (2002).
2. INDIAN WATER RESOURCES SCENARIO

2.1 WATER RESOURCES:

India lies in the south-central peninsula of the Asian continent. Besides the main land, there are two groups of islands, namely Lakshadweep in the Arabian Sea and Andaman & Nicobar Islands in the Bay of Bengal. The mainland of India lies between 8°4′N and 37°6′ N latitude and 68°7′ E and 97°25′E longitude. India occupies 3.29 million km² geographical areas, which forms 2.4% of world’s land area. It however supports over 15% of world’s population.

The geographical area of India is 3,287,590 km². The length of its Coastline is about 7500 kms. 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 envitably endowed in respect of water resources. The country is literally cress-crossed with Rivers and blessed with high precipitation mainly due to the southwest monsoon, which accounts for 75% of the annual rainfall.

Out of the total annual precipitation, including snowfall, of 4000 BCM on the entire Indian land mass, the rainfall during monsoon months (June-September) is of the order of 3000 BCM. It has also been estimated that 700 BCM is immediately lost to the atmosphere, 2150 BCM soaks into the ground and 1150 BCM flows as surface runoff. There are also very large temporal and spatial variations of rainfall during monsoon period. While the average annual rainfall of the country is about 1170 mm, the rainfall varies 100 mm in the western parts of Rajasthan to 10,000 mm at Cherrapunji in Meghalaya.

2.2 RIVER BASIN OF INDIA

India is blessed with many rivers. A river basin is the natural context in which water occurs and is perhaps the most appropriate unit for planning, development and management of water resources. The drainage area of a system of rivers normally flowing into a common terminus constitutes a drainage basin.

Table 2: Classification of River Basin in India.

<table>
<thead>
<tr>
<th>River Basin</th>
<th>Catchment Area (in km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td>Basin catchment area is more than 20,000</td>
</tr>
<tr>
<td>Medium</td>
<td>Basin catchment area is between 2000-20,000</td>
</tr>
<tr>
<td>Minor</td>
<td>Basin catchment area is below than 2,000</td>
</tr>
</tbody>
</table>

On the basis of size, the river basins of India could be divided into three groups, major, medium and minor river basin. According to the above classification, the numbers of major and medium river basins are 12 and 46 respectively and these contribute nearly 92% of the total runoff in the country. Minor rivers account for about 8% of the total runoff. Of the major rivers, the Ganga-Brahmaputra – Meghana system is the biggest with a catchment area of about 1.10 million km², which is more than 43% of the catchment area of all the major rivers in the country. The other major rivers with a catchment area more than 0.10 million km² are Indus, Godavari, Krishna and Mahanadi. The catchment area of medium rivers is about 0.25 million km² and Subarnarekha with 19,300 km² catchment area is the largest river among the medium rivers in the country. The classification of River basin based on catchment area is given in Table 2.
There are few desert Rivers, which flows till some distance and get lost in deserts. There are complete arid areas where evaporation equals to rainfall and hence there is 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 kms, and hence the Riverine length is also about 100 kms 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 kms. 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. **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 (Fig. 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 BASIN**

The Indus basin lies in four countries viz. Afghanistan, Pakistan, India and China. The basin is bounded on the north by the Karakoram and the Haramosh ranges, on the east by the Himalayas, on the south east by the Arabian Sea and on the west by the Sulaiman and Kirthar ranges. In
India, the basin lies in the States of Jammu & Kashmir, Punjab, Himachal Pradesh, Haryana and Rajasthan.

The upper portion of the basin lies in J&K and Himachal Pradesh is mountainous and the lower portion lies in Punjab, Haryana and Rajasthan consist of fertile plains. Total drainage area of the basin is 11,65,000 km², out of which 3,21,289 km² lies in India. The Indus River rises from Mansarovar in Tibet at an elevation of about 5,182 m and flows for about 1,100 kms in India before entering into Pakistan. Main tributaries of the River are the Sutlej, the Beas, the Ravi, the Chenab and the Jhelum.

3.2 - BRAHMAPUTRA RIVER BASIN

As per the Hindu belief, Brahmaputra means 'son of the creator, Lord Brahma'. The Brahmaputra rises in Tibet where it is known as the Tsangpo. In India, it emerges from the foothills in Arunachal Pradesh where it is known as the Siang and the Dihang and it becomes the Brahmaputra after being joined by the Dibang and the Lohit Rivers in its flow through the Assam valley.

The Brahmaputra River travels a distance of 2880 kms before joining the Bay of Bengal through three countries, viz. China, India and Bangladesh. It has total catchment area of 580,000 km². The basin lies between 23⁰N to 32⁰N latitude and 82⁰E to 97⁰50' E longitude. The River has a smaller catchment than either the Ganga or the Indus and gathers in its long course through Tibet, India and Bangladesh, waters of the Raka, Tsangpo, the Ngang Chu, the Giamdachu, the Dibang, the Lohit, the Subansiri, the Kameng, the Manas, the Tista, the Burhi Dihing, the Disang, the Kopili and the Dhansiri. After entering in Bangladesh near Dhubri, it flows southward to join the Ganga at Goalundo.
Undoubtedly, the Ganga is the most sacred River of India. The catchment areas of the River Ganga are in four countries viz. India, Nepal, Tibet (China) & Bangladesh. The major part of the geographical area of the Ganga basin lies in India. After merging of the two rivers the Alaknanda & Bhagirathi at Deoprayag, it is named as “Ganga”. Many important tributaries of Ganga originate in the Himalayas in India and Nepal; Bangladesh lies in the deltaic region of the basin. Ganga flows towards south and then south-east through the great plains of India in Uttar Pradesh, Bihar, Madhya Pradesh and Bengal, which is the apex of the Ganga delta. The total length of the Ganga River is 2,525 kms which makes it the 20th longest River in Asia. The index map of the basin is given in figure 4. The Ganga basin lies between east longitudes 73°30’ to 89°00’ and north latitudes 22°30’ to 31°30’. The drainage area lying in India is 861452 km² which is nearly 26.2% of the total geographical area of the country. In its long course through the foot hills and plains, it gathers the waters of the Ram Ganga, the Yamuna, the Tons, the Gomati, the Ghaghara, the Sone, the Gandak, the Burhi Gandak, the Bhagirathi, the Kosi and the Mahananda.

The river Yamuna, a major tributary of river Ganges, originates from the Yamunotri glacier near Banderpooch peaks (38°59’ N 78°27’ E) in the Mussourie range of the lower Himalayas at an elevation of about 6387 meters above mean sea level in district Uttarkashi (Uttrakhand). The catchments of Yamuna river system cover parts of Uttar Pradesh, Uttrakhand, Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh & Delhi states. The Yamuna, after receiving water through other important tributaries, joins the river Ganga and the underground Saraswati at Prayag (Allahabad) after traversing about 950 Km. The Chambal and the Betwa are the two important sub-tributaries of Yamuna. Some channels which flow in north south direction run into Bay of Bengal. Most important of these are the Bhagirathi-Hooghly, the Jalangi, the Bhairab, the Mathabhanga and the Gorai. The Damodar which rises in the hills of Chhota Nagpur flows into the Hooghly which is a branch of the Ganga.
3.4 - BARAK RIVER BASIN

The Barak sub-basin drains areas in India, Bangladesh and Burma. The drainage area of the sub-basin lying in India is 41723 km$^2$, which is nearly 1.38% of the total geographical area of the country. It is be on the north by the Barail range separating it from the Brahmaputra sub-basin, on the east by the Na Lushai hills and on the south and west by Bangladesh. The sub-basin lies in the States of Meghalaya, Manipur, Mizoram, Assam, Tripura and Nagaland. Barak raises in the Manipur hills and enters the plains near Lakhimpur. The River enters Bangladesh as Surma and Kushiyara. Later, the River is called the Meghna and receives the combined flow of the Ganga and Brahmaputra. The principal tributaries of Barak are the Jiri, the Dhaleswari, the Singla, the Longai, the Sonai and the Katakhal.

3.5 - NARMADA RIVER BASIN

Narmada is the largest West flowing River in India. It drains a large area in Madhya Pradesh besides some area in the states of Maharashtra and Gujarat. It flows through the Decan trap in between the Vindhyachal and the Satpura Range of hills before falling into the Gulf of Khambhat in the Arabian Sea. The total drainage area of the basin is 98,796 km$^2$. Out of which nearly 87% lies in Madhya Pradesh. In general, the hilly regions are forested. The soils are red, yellow, shallow black in upper reaches, medium black in middle reaches and medium & deep black in the lower reaches of the basin.

The Narmada River originates from a Kund (spring) at an elevation of 1,057 m at Amarkantak in the Maikal hill in Shahdol district of Madhya Pradesh and flows through Gujarat, Madhya Pradesh.
and Maharashtra states between Vindhya and Satpura hill ranges before falling into the Gulf of Khambhat in the Arabian Sea about 10 kms north of Bharuch. The total length of this west flowing River is 1,312 kms. For the first 1,079 kms, it runs in Madhya Pradesh and thereafter forms the common boundary between Madhya Pradesh and Maharashtra, and Maharashtra and Gujarat for 74 kms in Gujarat State, it stretches for 159 kms.

The major tributaries joining the river from the left bank are the Burhner, the Banjar, the Sher, the Shakkar, the Dudhi, the Tawa, the Ganjal, the Chhota Tawa, the Kundi and the Karjan. From the right bank some other tributaries joins the river viz. the Hiran, the Barna, the Tendoni, the Kolar, the Kanar, the Man, the Uri and the Orsang.

### 3.6 - TAPI RIVER BASIN

Tapi is the second largest west flowing River. It originates from Multai (Betul district) in Madhya Pradesh and flows through the states of Madhya Pradesh, Maharashtra and Gujarat and joins the Arabian Sea about 15 kms west of Surat. The Tapi River has a length of about 724 kms and its basin extends over an area of 65,145 km², which is situated in Deccan plateau between East longitude 72°- 38' to 78°- 17' and North latitude 20°- 05' to 22°- 03'. The Tapi basin is bounded on the north by the Satpura Range, on the east by the Mahadeo Hills, on the south by the Ajanta Range and the Satmala Hills and on the west by the Arabian Sea. The Gawilgarh Hills form the dividing line between the upper Tapi and the Purna sub basins. The basin has elongated shape with a maximum length of 587 kms from east to west and a maximum width of 210 kms from north to south. This basin has two well defined physical region viz. the hilly regions and the plains. The hilly regions cover the Satpura, the Satmala the Mahadeo, the Ajanta and the Gawilgarh Hills and are well forested. The plains cover the Khandesh and the Gujarat plains which are broad and fertile areas suitable for cultivation. The major tributaries which join Tapi are the Aner, the Purna, the Waghur, the Girna, the Bori, the Panjhra and the Burdy.
3.7 - Godavari River Basin

Godavari river basin extends over an area of 3,12,812 km² which is nearly 9.5% of the total geographical area of the country. It is bounded on the north by the Satmala Hills, the Ajanta Range and the Mahadeo Hills, on the east and south by the Eastern Ghats and on the west by the Western Ghats. The basin lies in the States of Madhya Pradesh, Odisha, Maharashtra, Karnataka and Andhra Pradesh.

Except the hills along the boundary of the basin including the Sahyadri range of the Western Ghats, the entire drainage area comprises rolling and undulating country. It consists of large undulating plains divided by low flat-topped hill ranges. A wide belt of River borne alluvium forms the delta of the basin. The important soil types found in the basin are black cotton soils, red soils, laterites and lateritic soils, alluvium, mixed soils and saline and alkaline soils. The cultivable area in the basin is about 18.93 M ha, which is 9.7% of the total cultivable area of the country.

The River Godavari rises in the Nashik district of Maharashtra, about 80 kms from the Arabian Sea, at an elevation of 1067 m and after flowing for about 1465 kms in a generally south-east direction, through Maharashtra and Andhra Pradesh it outfalls into the Bay of Bengal. River Pravara, Manjira and Maner are notable right bank tributaries and the Purna, the Pranhita, the Indravathi and the Sabari are important left bank tributaries of Godavari.

3.8 - Krishna River Basin

Krishna basin extends over an area of 2,58,948 km², which is nearly 8% of the total geographical area of the country. It is bounded on the north by the range separating it
from the Godavari basin, on the south and east by the Eastern Ghats and on the west by the Western Ghats. The basin lies in the States of Maharashtra, Karnataka and Andhra Pradesh.

Most part of this basin comprises rolling and undulating country except the western border which is formed by an unbroken line of ranges of the Western Ghats. The important soil types found in the basin are black soils, red soils, laterite and lateritic soils, alluvium, mixed soil, red and black cotton soil and saline and alkaline soils. The cultivable area in the basin is about 20.59 M ha, which is 10.4% of the total cultivable area of the country.

The Krishna River rises in the Western Ghats at an elevation of about 1337 m. just north of Mahabaleswar in Maharashtra, about 64 kms from the Arabian Sea and flows for about 1,400 kms before out falling into the Bay of Bengal. The principal tributaries joining Krishna are the Ghataprabha, the Malaprabha, the Bhima, the Tungabhadra, the Musi and the Munneru.

3.9 - Cauvery River Basin

Cauvery Basin extends over an area of 81,155 km² which is nearly 2.7% of the total geographical area of the country. It is bounded on the west by the Western Ghats, on the east and south by the Eastern Ghats and on the north by the ridges separating it from Tungabhadra and Pennar basins.

The basin lies in the states of Tamil Nadu, Karnataka and Kerala. Physio-graphically, the basin can be divided into three parts - The Western Ghats, the Plateau of Mysore and the Delta. The delta area is the most fertile tract in the basin. The principal soil types found in the basin are black soils, red soils, laterites, alluvial soils, forest soils and mixed soils. Red soils occupy large areas in the basin. Alluvial soils are found in the delta areas. The cultivable area of the basin is about 5.8 Mha, which is about 3% of the cultivable area of the country.

The Cauvery, which is the 4th largest of the east flowing Rivers, is one River whose potential has been almost completely utilized. Cauvery River rises at Talakaveri on the Brahmagiri Range in the Western Ghats in Karnataka at an elevation of about 1,841 m and flows for about 800 kms before it outfalls into the Bay of Bengal. It is joined in its course through Karnataka and Tamil Nadu by a large number of Rivers such as the Harangi, the Hemavathi, the Arkavathi, the Lakshmantirtha, the Kabini and the Bhavani. Near Srirangam, in Tamilnadu it divides into branches, the northern
arm taking the name Coteroon which remains the main River, and the southern arm which retains the name of Cauvery.

### 3.10 - Mahanadi River Basin

The River Mahanadi is one of the major inter-state east flowing Rivers in peninsular India. In the course of its traverse, it drains fairly large areas of Madhya Pradesh & Odisha and comparatively small areas in the States of Bihar & Maharashtra.

The basin is physically bounded in the north by the Central India hills, in the south and east by the Eastern Ghats and in the West by Maikala Hill Range. The total catchment area of the basin is 1,41,589 km². The River Mahanadi originates at an elevation of about 442 m above MSL near Pharsiya village in Raipur district of Madhya Pradesh. The total length of the River from its origin to its out fall into the Bay of Bengal is about 851 kms, of which, 357 kms is in Madhya Pradesh and the remaining 494 kms is in Odisha.

During its traverse, a number of tributaries join the River on both the banks. The important tributaries are the Seonath, the Hasdeo, the Mand, the Ib, the Bhadar, the Jonk, the Ong and the Tel.

### 3.11 - Subernarekha and Burhabalang River Basin

The Subernarekha & Burhabalang basin extends in an area of 23,751 km². The Subernarekha River drains large areas of Bihar and some parts of West Bengal and Odisha and the Burhabalang covers parts of the areas in Mayurbhanj and Balasore districts of Odisha. The basins lie between latitude 21°- 22' N to 23°- 32’ N and longitude 85°- 09 E to 87°- 27 E and is situated in the north-east corner of the peninsular India. It is bounded on the north-west b-y
the Chhotanagpur Plateau, in the south-west by Brahmani basin, in the south by the Baitarni basin and in the south-east by the Bay of Bengal.

The Subernarekha River originates near Nagri village in Ranchi district of Bihar at an elevation of 600 m. The total length of the River is about 395 kms. The principal tributaries of the River are the Kanchi, the Kharkai and the Karkari. The Burhabalang is a flashy River which originates at an elevation of 800 m and after traversing a distance of 125 kms drops into the Bay of Bengal. The River drains parts of areas in Mayurbhanj and Balasore districts of Odisha.

3.12 - Brahmani and Baitarni Basin

The Brahmani and the Baitarni Rivers are the major inter-state east flowing Rivers amongst the peninsular Rivers in India. The basin is bounded in the north by the Chhotanagpur Plateau, in the north-east by Subernarekha and Burhabalang basin, in the west and south by Mahanadi basin and in the east by the Bay of Bengal. The basin lies in the states of Madhya Pradesh, Jharkhand and Odisha and drains an area of about 51,822 km².

The Brahmani, known as the South Koel in the upper reaches, originates near Nagri village in Ranchi district of Jharkhand at an elevation of about 600m. The total length of its run is about 799 kms. The principal tributaries of this River are the Sankh, the Tikra and the Karo. The Baitarani River rises in the hill ranges of Keonjhar District of Odisha near Mankarancho village at an elevation of about 900 m above MSL. On its way, many tributaries join the River from both the banks. Salandi River is the main tributary of the River. The River is flashy in nature having a total length of 355 kms, with the upper reach up to Anandpur in the hilly region.

3.13 - Pennar Basin

Pennar Basin extends over an area of 55,213 km² which is nearly 1.7% of the total geographical area of the country. It is bounded on the north by the Erramala Range, on the east by the Nallamala and Velikonda Ranges of the Eastern Ghats, on the south by the Nadidurg Hills and on
the west by the narrow ridge separating it from the Vedavati Valley of the Krishna basin. The basin lies in the states of Andhra Pradesh and Karanataka.

Pennar River rises from the Chenna Kesava hills of the Nandi Ranges of Karnataka and flows for about 597 Kms before out-falling into the Bay of Bengal. The principal tributaries of the River are the Kunderu, the Sagileru, the Chitravathi, the Papagni and the Cheyyuru.

3.14 - Mahi Basin

The River Mahi is one of the major interstate Rivers of India, draining into the Gulf of Khambhat. The basin is bounded on the north and the north-west by the Aravalli Hills, on the east by the ridge separating it from the Chambal basin, on the south by the Vindhyas and on the west by the Gulf of Khambhat. The basin has a maximum width of about 250 kms. Mahi River originates on the northern slope of Vindhyas at latitude 22°- 35 N and longitude 74°- 58 E near the village of Sardarpur in the Dhar district of Madhya Pradesh at an elevation of 500 m above MSL.

Its length is 583 kms and traverses through the states of Madhya Pradesh, Rajasthan and Gujarat. The Mahi River drains an area of 34,842 km². Initially the River flows towards north passing through Dhar and Jhabua districts of Madhya Pradesh State, and then turns left and passes through the Ratlam district of Madhya Pradesh State. There after the river turns to north-west and enters in the Banswara district of Rajasthan and flows in south-western direction and finally enters in the Panchmahal district of the Gujarat State. The River continuously flows in the same direction through Kheda district of Gujarat and finally falls into the Mahi Sagar in the Gulf of Khambhat in the Arabian Sea. The River receives several tributaries on both the banks; some of them are the Som, the Anas and the Panam.
3.15 - Sabarmati Basin

The Sabarmati is one of the major interstate Rivers in India, which is draining into the Gulf of Khambhat. The basin is bounded by the Aravali Hills in the north and the north-east, by ridge separating it from basins of minor streams and draining into the Rann of Kutch in the west and by Gulf of Khambhat in the south.

The basin has a maximum length of 300 kms and maximum width of 105 kms. It is triangular in shape with the main River as the base and the source of the Watrak as the apex point. It originates in the Aravali Hills at latitude 24°- 40' N and longitude 73°- 20' E in the Rajasthan State at an elevation of 762 m above MSL. The Sabarmati drains with an area of 21, 674 km².

The Sabarmati River with its origin in Rajasthan flows generally in south-west direction and after entering in the Gujarat state, it passes through the Dharoi Gorge. Emerging from the gorge it flows through the plains in the same direction and joins the Gulf of Kambhhat in the Arabian Sea.

The River is joined by the Wakal, the Harnav and the Hathmathi Rivers from the left bank and the Sei on the right bank, the Hathmathi River is its major tributary. River Sabarmati continuing to flow in south-west direction, the River passes through Ahmedabad. The River is further joined by another major tributary, the Watrak on the left bank before it out-falls in the Gulf of Khambhat.

![Figure 16: Sabarmati River Basin.](image)

3.16 - West Flowing Rivers Basin from Tapi to Tadri

The West Flowing Rivers Basin between Tapi to Tadri is a composite basin lying in Gujarat and Maharashtra states. The basin consists of a number of small independent River systems of peninsular India. The basin is bounded on the north by Tapi basin, on the east by Western Ghat and on the west by the Arabian Sea.

All the Rivers in the basin originate from Western Ghat and exhibit similar character. The Rivers have steep high banks. Important Rivers in the basin are the Purna, the Ambica, the Damanganga,
the Vaitarna, the Ulhas, the Kal, the Gad the Mandovi etc. Brief description of the Rivers is as follows:-

- **The River Purna** is one of the important western flowing Rivers in Gujarat state. It originates from the Satpura Hill Ranges and after flowing for a length of 142 kms falls in the Arabian Sea. The catchment area of the Purna basin is 2,431 km\(^2\).

- **The Damanganga** is one of the main westward draining interstate River basins. The River originates at an elevation of 930.5 m in Sahyadri Hills in Nashik district. Majority of its catchment area lies in the state of Maharashtra besides some catchment area lying in the state of Gujarat and the Union Territory of Dadra & Nagar Haveli and Daman. The Damanganga drains an area of 2,318 km\(^2\).

- **The River Vaitarna** originates from the hilly terrain of Maharashtra at Trimbak, in district Nashik. After running for 120 kms in Maharashtra towards west, it falls in the Arabian Sea. The catchment area of the basin is 3,637 km\(^2\).

- **The Ulhas River** raises from the Sahyadri hill Ranges in the Raigad district of Maharashtra at an elevation of 600 m above MSL. The total length of this west flowing River from its origin to its out fall into the Arabian Sea is 122 kms. The River drains an area of 4,637 km\(^2\) which lies completely in Maharashtra state.

- **The Kal River** is one of the western flowing Rivers in Maharashtra state. This is a major tributary of the River Savitri. The River rises from the Sahyadri Hill Ranges in the Raigad district of Maharashtra at an elevation of 652 m above MSL. The total length of the River from its origin to its confluence with the Savitri River is 40 Kms. The River drains an area of 670 km\(^2\) which lies completely in the Raigad district.

- **The Gad River** rises from the Sahyadri Hill Ranges in the Sindhudurg district of Maharashtra at an elevation of 600 m above MSL. The total length of the west flowing River from its origin to its out fall into the Arabian Sea is 66 kms. The River drains an area of 890 km\(^2\) which lies completely in Sindhudurg district of Maharashtra state.

Figure 17: West Flowing Rivers Basin from Tapi to Tadri.
3.17 - West Flowing Rivers Basin from Tadri to Kanyakumari

The basin extends over states of Kerala, Karnataka, Tamil Nadu and Union Territory of Puducherry having an area of 56,177 km² which is 1.73 % of total geographical area of the country with a maximum length and width of 777 km and 135 km. It spreads between 74°25’ to 77°36’ east longitudes and 8°3’ to 14°24’ north latitudes. The basin is bounded by Sahyadri hills on the north, by the Western Ghats on the east, by Indian Ocean on the south and by the Arabian Sea on the west. The major independent rivers (directly draining into Arabian Sea) in the basin are the Varahi, the Netravati, the Payaswani, the Valapattanam, the Chaliyar, the Kadalundi, the Bharathapuzha, the Periyar, the Muvattupula, the Minachil, the Pamba, the Achankovil, the Kallada and the Vamanapuram.

3.18 - WEST Flowing Rivers of Kutch and Saurashtra including Luni

The basin extends over large areas in Rajasthan and Gujarat and covers whole of Diu having an area of 3,21,851 km² with maximum length and width of 865 km and 445 km. It lies between 67°52’ to 75°19’ east longitudes and 20°53’ to 26°57’ north latitudes. The basin is bounded by Aravali range and Gujarat plains on the east, by Rajasthan desert on north, and by the Arabian Sea on the south and the west.

Luni is the major river system of the basin and it originates from western slopes of the Aravalli ranges at an elevation of 772 m in Ajmer district of Rajasthan. The total length of the river is 511 km and it drains a total area of 32,879 km². The river flows up to Rann of Kutch forming a delta where the water spreads out and does not contribute any runoff. The main tributaries of Luni joining from left are the Lilri, the Guhiya, the Bandi (Hemawas), the Sukri, the Jawai, the Khari Bandi, the Sukri Bandi and the Sagi whereas the Jojri joins it from right. Other independent rivers of the basin are the Shetrunji, the Bhadar, the Machhu, the Rupen, the Saraswati and the Banas. The Shetrunji drains into the Gulf of Khambhat, the Bhadar outfalls into Arabian Sea, and the Machhu, the Rupen, the Saraswati and the Banas drains into Little Rann of Kutch.

3.19 - EAST Flowing Rivers between Mahanadi and Pennar

The basin spreads over states of Andhra Pradesh and Odisha having an area of 86,643 km² and stretches between 78°40’ to 85°1’ east longitudes and 14°34’ to 20°22’ north latitudes. It is bounded by the Eastern Ghats on the north and west, by Nallamala Range and Andhra plains on the south and by the Bay of Bengal on the east. This composite basin comprises of three river systems. The river systems between Mahanadi and Godavari covers an area of 49,685 km² and the river systems between Krishna and Pennar extends over an area of 24,669 km². In addition, there is also a small area between Godavari and Krishna drained mainly by the small stream of Palleru. This minor portion of the basin has an area of about 12,289 km².

The independent rivers (directly draining into Bay of Bengal) in the basin from north to south are the Rushikulya, the Bahuda, the Vamsadhara, the Nagavali, the Sarada, the Varaha, the Tandava, the Eluru, the Gundlakamma, the Musi, the Paleru and the Manneru.

3.20 - EAST Flowing Rivers between Pennar and Kanyakumari

The basin extends over states of Tamil Nadu, Andhra Pradesh, Karnataka and Union Territory of Puducherry having a total area of 1,00,139 km² and accounts for 3.08% of the total geographical area of the country. The basin extends between 77°1’ to 80°17’ east longitudes and 8°11’ to
14°27’ north latitudes. It is bounded by the Eastern Ghats on the north, by Tamil Nadu uplands on the west, by the Indian Ocean on the south and by the Bay of Bengal on the east.

The composite basin comprises of the river systems between Pennar and Cauvery having an area of 65,049 km² and the river systems between Cauvery and Kanyakumari with an area of 35,090 km². The independent rivers (directly draining into Bay of Bengal) are the Kandleru, the Swarnamukhi, the Arani, the Korttalaiyar, the Cooum, the Adyar, the Palar, the Gingee, the Ponnaiyar, the Vellar, the Varshalei, the Vaigai, the Gundar, the Vaippar and the Tambraparni.
4. RIVER WATER MONITORING BY CWC

Central Water Commission is monitoring River water quality at 429 key locations covering all the major River basins of India. The details of basin wise water quality stations are given below. The basin wise WQ stations monitored by Central Water Commission are depicted in Table 3.

Table 3: Basin-wise Water Quality Stations of Central Water Commission

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<th>Sr.</th>
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<th>Type of Stations</th>
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Note: GQ = Gauge & Water Quality; GDQ= Gauge, discharge & Water Quality; GDSQ= Gauge, Discharge, Sediment & Water Quality
The State wise WQ stations monitored by Central Water Commission are depicted in Table 4.

### Table 4: State wise Water Quality Stations of Central Water Commission

<table>
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<th>S.No</th>
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5. REVIEW OF TRACE & TOXIC METALS

Heavy metals are one of the most widespread causes of pollution both in water and the soil; further, increasing levels of these metals concentration in the environment is causing serious concern in public opinion owing to the toxicity shown by most of them. Heavy metals are usually defined as metals with high atomic number, atomic weight and a density greater than 5.0 g/cm³, but in the literature it is possible to find so many different definitions. Recently, International Union of Pure and Applied Chemistry (IUPAC) defined the term “heavy metal” as a confusing and misleading one. Generally speaking, metals are natural components of the Earth’s crust and some of them (e.g. copper, selenium, and zinc) are essential as trace elements to maintain the metabolism of the human body although at higher concentrations, they may show toxic effects. Many other metals (e.g. mercury, cadmium, lead, etc.) have direct toxic effects on human health. Owing to their chemical characteristics, metals remain in the environment, in many cases only changing from one chemical state to another one and eventually accumulating in the food chain. These pollutants enter the environment through a variety of human activities such as mining, refining and electroplating industries. The effluents produced by these industries contain a variety of heavy metals such as cadmium, copper, chromium, nickel, lead and zinc, subsequent release of these effluents into water bodies may significantly contribute to the increment in loads of toxic heavy metals in aquatic environments. Because of their high water solubility, heavy metals can be easily absorbed by living organisms and, due to their mobility in natural water ecosystems and their toxicity to living forms, have been ranked as major inorganic contaminants in surface and ground waters. Even if they may be present in dilute, almost undetectable quantities, their recalcitrance to degradation and consequent persistence in water bodies imply that, through natural processes such as bio-magnification, their concentration may become elevated to such an extent that they begin exhibiting toxic effects. Out of the 35 metals considered dangerous for human health, 23 have been defined as heavy metals: antimony, arsenic, bismuth, cadmium, cerium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, nickel, platinum, silver, tellurium, thallium, tin, uranium, vanadium, and zinc. However, the major lethal effects to human health caused by these heavy metals are associated with exposure to lead, cadmium, mercury and arsenic (this element is a metalloid but it is usually defined as a heavy metal). Large amounts of any of these metals may cause acute or chronic toxicity (poisoning), resulting in damaged or reduced mental and central nervous functions, modify blood composition, damage the lung, kidney, liver, and other vital organs.

Long-term exposure to the above-mentioned heavy metals may result in slowly progressing physical, muscular, and neurological degenerative processes that mimic Alzheimer’s disease, Parkinson’s disease, muscular dystrophy and multiple sclerosis. Allergies are not uncommon and repeated long term contact with some metals or their compounds may even cause cancer. Heavy metals may enter the human body through food, water and air, or it may be absorbed through the skin when they enter into contact with humans in agriculture and in manufacturing, pharmaceutical, industrial or residential settings. Although several adverse health effects of heavy metals have been known since a long time, exposure to these metals is continuing and even increasing in some parts of the world. Thus, the control of heavy metal dumplings and the removal of toxic heavy metals from waters has become a challenge for the twenty-first century.
6. METAL TOXICITY:

Important issues related to selected toxic metals like occurrences in nature, sources of water pollution, toxic effects etc. are described here under:

6.1 - Toxicity of Arsenic

Arsenic is ubiquitous and ranks 20th in natural abundance, comprising about 0.00005% of the earth’s crust, 14th in the seawater, and 12th in the human body (Mandal and Suzuki, 2002). Arsenic occurs in the environment in rocks, soil, water, air and in biota.

The element occurs in the environment in different oxidation states e.g. As as As(V), As(III), As(0) and As(-III). The chemical forms and oxidation states of arsenic are more important as regards to toxicity. Generally, inorganic forms are more toxic and mobile than organo-arsenic species, while arsenite is considered to be more toxic than arsenate. It has been reported that As(III) is 4 to 10 times more soluble in water than As(V) (Squibb and Fowler 1983; Xu et al. 1988; Lambe and Hill 1996; US EPA, 2002). Moreover, it has been found that As(III) is 10 times more toxic than As(V) and 70 times more toxic then Mono Methyl Arsonate (MMA(V)) and Di Methyl Arsinate (DMA(V)). However, the trivalent methylated arsenic species, i.e., MMA(III) and DMA(III) have been found to be more toxic than inorganic arsenic because they are more efficient at causing DNA breakdown (Styblo et al. 2000; Dopp et al. 2004). Arsenic enters the human body through ingestion, inhalation or skin absorption. Most ingested and inhaled arsenic is well absorbed through the gastrointestinal tract and lung into the bloodstream.

People drinking arsenic contaminated water generally show arsenical skin lesions, which are a late manifestation of arsenic toxicity. Long term exposure to arsenic contaminated water may lead to various diseases such as conjunctivitis, hyperkeratosis, hyperpigmentation, cardiovascular diseases, disturbance in the peripheral vascular and nervous systems, skin cancer, gangrene, leucomelonisis, non pitting swelling, hepatomegaly and splenomegaly (Kiping, 1977; WHO, 2001; Pershagen, 1983). Chronic symptoms caused by a long exposure to As are unspecific (weight loss, chronic weakness) but a long exposure provokes arsenicism, cardiovascular diseases, skin lesions among other organ function disorders (Bissen and Frimmel 2003). Arsenicism is a chronic illness resulting from drinking water with high As level over a long period of time (Kapaj et al. 2006). The effects on the lungs, uterus, genitourinary tract and other parts of the body have been detected in the advance stages of arsenic toxicity. Besides, high concentrations of arsenic in drinking water also result in an increase in stillbirths and spontaneous abortions (Csavanady and Straub, 1995).

6.2 - Toxicity of Cadmium

Cadmium is an element that occurs naturally in the earth’s crust. It is uniformly distributed in the Earth’s crust, where it is estimated to be present at an average concentration of between 0.10 and 0.50 µg/L. Cadmium occurs in nature in the form of various inorganic compounds and as complexes with naturally occurring chelating agents; organo-cadmium compounds are extremely unstable and have not been detected in the natural environment. Cadmium is produced during extraction of zinc and is used in plating industry, pigments, in manufacture of plastic material, batteries and alloys. The water is contaminated with cadmium by industrial discharge, leaches
from land filled area. Drinking water is generally contaminated with galvanized iron pipe, plated plumbing fitting of the water distribution pipes.

Cadmium ranks next to mercury in its toxicity. Exposure at low levels usually does not produce immediate health effects, but may cause severe health problems over long periods. The gastrointestinal tract is the major route of Cd uptake in both humans and animals. Cadmium is toxic to humans, animals, micro-organisms and plants, however only a small amount of cadmium intake is absorbed by the body and will be stored mainly in bones, liver and, in case of chronic exposure, in kidneys. In the last few years there have been some evidences that relatively low cadmium exposure may give rise skeletal damage due to low bone mineral density (osteoporosis) and fractures. The toxicity of the metal lies in that, after absorption, it accumulates in soft tissues. Animal tests have shown that cadmium may be a risk factor for cardiovascular disease (Jarup, 2003). For acute exposure, absorbed cadmium can cause symptoms such as salivation, difficulty in breathing, nausea, vomiting, a pain, anemia, kidney failure, and diarrhoea. Inhalation of cadmium dust or smoke may cause dryness of the throat, headache, chest pain, coughing, increased uneasiness and bronchial complications (Lu et al., 2007). The adverse health effects caused by ingestion or inhalation of Cd include renal tubular dysfunction due to high urinary Cd excretion, high blood pressure, lung damage and lung cancer.

Furthermore, cadmium accumulation in animals and humans occurs throughout their life spans. The sites of greatest cadmium accumulation are the liver and kidney. After inhalation or absorption from the gastrointestinal, cadmium is concentrated in the kidney, where its half-life may exceed 10 to 20 years. One of the most widely known toxic effects manifested by Cd poisoning is nephro-toxicity. Adverse renal effects are more commonly seen with exposure to low levels of Cd. The effects are manifested by excretion of low-molecular-weight plasma proteins, such as β2-microglobulin and retinol-binding protein (RBP). The widely reported Cd poisoning *itai-itai byo* episode occurred in Japan after World War II. In Japan cadmium from mining and refinery factories polluted Jinzo River water which was used for irrigation purpose. The rice grown on such cadmium accumulated fields, which the humans consumed through water and food chain affected by ostomolacia and skeletal deformation. There was sever pain in body and joints and the people cried *ITAI—ITAI* (it hurts—it hurts).

### 6.3 - Toxicity of Chromium

Chromium can exist in valencies from -2 to 6 but it present in the environment mainly as trivalent or hexavalent state. Trivalent chromium (Cr [III]) is the most common naturally occurring state; most soils and rocks contain small amounts of chromic oxide (Cr$_2$O$_3$). Hexavalent chromium (Cr[VI]) occurs frequently in nature as chromates (CrO$_4^{2-}$) and dichromates (Cr$_2$O$_7^{2-}$) which are generally obtained from industrial and domestic emissions. Chromium is considered as an essential nutrient and a health hazard because Cr exists in more than one oxidation state. Specifically, Cr in oxidation state +6, written as Cr(VI), is considered harmful even in small intake quantity (dose) whereas Cr in oxidation state +3, written as Cr(III), is considered essential for good health in moderate intake. Chromium (III) is an essential nutrient for humans and shortages may cause heart conditions, disruptions of metabolisms and diabetes. Trivalent chromium is necessary for the synthesis of fat from glucose and also for the oxidation of fat to carbon dioxide. But the uptake of too much chromium (III) can cause health effects as well, for instance (NAS, 1974; NRCC, 1976; Chromium, Canada.ca, 1986).
Chromium (VI) is a danger to human health, mainly for people who work in the steel and textile industry. People who smoke tobacco also have a higher chance of exposure to chromium. Chromium (VI) is known to cause various health effects. When it is a compound in leather products, it can cause allergic reactions, such as skin rash. After breathing in, chromium (VI) can cause nose irritations and nosebleeds. Other health problems that are caused by chromium (VI) are:

- Skin rashes
- Upset stomachs and ulcers
- Respiratory problems
- Weakened immune systems
- Kidney and liver damage
- Alteration of genetic material
- Lung cancer
- Death

The health hazards associated with exposure to chromium are dependent on its oxidation state. The metal form (chromium as it exists in this product) is of low toxicity and the hexavalent form is toxic. Adverse effects of the hexavalent form on the skin may include ulcerations, dermatitis, and allergic skin reactions. Inhalation of hexavalent chromium compounds can result in ulceration and perforation of the mucous membranes of the nasal septum, irritation of the pharynx and larynx, asthmatic bronchitis, bronchospasms and edema. Respiratory symptoms may include coughing and wheezing, shortness of breath and nasal itch (lenntech.com-Cr).

Hexavalent chromium is toxic to plants and animals. It causes yellowing of leaves of wheat and paddy. Maximum permissible limit of chromium in drinking water as recommended by WHO is 0.05 mg/L.

6.4 - Toxicity of Copper

Copper is an essential micronutrient (Underwood 1977; Goyer 1991). The Food and Nutrition Board (FNB) recommends dietary copper intake for adults of 1.53 mg/day (NRC, 1989). Three major valence states: copper metal Cu(0), Cu(I) and Cu(II). Copper is commonly found in ores. Copper occurs in nature as the metal and in minerals, most commonly cuprite (Cu₂O) and malachite (Cu₂CO₃(OH)₂). The principal copper ores are sulphides, oxides, and carbonates.

Copper is both essential and toxic to living systems. As an essential metal, copper is required for adequate growth, cardiovascular integrity, lung elasticity, neovascularization, neuroendocrine functions, and iron metabolism. An average adult human ingests about 1 mg of copper per day in the diet; about half of which is absorbed (Harris 1997). Copper is obligatory for enzymes involved in aerobic metabolism, such as cytochrome oxidase in the mitochondria, lysyl oxidase in connective tissue, dopamine mono-oxygenase in brain, and ceruloplasmin. As a co-factor for apo-copper-zinc superoxide dismutase (apoCuZnSOD), copper protects against free-radical damage to proteins, membrane lipids, and nucleic acids in a wide range of cells and organs. Severe copper deficiencies, either gene defects due to mutations or low dietary copper intakes, although relatively rare in humans, have been linked to mental retardation, anemia, hypothermia,
neutropenia, diarrhea, cardiac hypertrophy, bone fragility, impaired immune function, weak
connective tissue, impaired central-nervous-system (CNS) functions, peripheral neuropathy, and
loss of skin, fur (in animals), or hair color (CCREM, 1987; Linder and Goode 1991; Uauy et al. 1998;
Cordano 1998; Percival 1998).

Long-term exposure to copper can cause irritation of the nose, mouth and eyes and it causes
headaches, stomachaches, dizziness, vomiting and diarrhea. Intentionally high uptakes of copper
may cause liver and kidney damage and even death. Whether copper is carcinogenic has not
been determined yet. There are scientific articles that indicate a link between long-term exposure
to high concentrations of copper and a decline in intelligence with young adolescents. Whether
this should be of concern is a topic for further investigation. Industrial exposure to copper fumes,
dusts, or mists may result in metal fume fever with atrophic changes in nasal mucous
membranes. Chronic copper poisoning results in Wilson’s Disease, characterized by a hepatic
cirrhosis, brain damage, demyelination, renal disease, and copper deposition in the cornea.
(Schroeder, 1966; Hoogenraad 1978; CCREM, 1987).

Excess amount of copper sulphate also shows detrimental effect on botanical environment.
Copper in ionic form is very toxic to the photosynthesis of the green algae, Chlorella pyrenoidosa
and the diatom, Nitzchiz palea in concentrations of copper normally found in natural waters.
Copper accumulates progressively in soils where copper fungicides are used, particularly in
vineyards and orchards, which are spread repeatedly. Thus, it is seen that though copper is
essential of life and health, its deficiency or excesses both cause adverse effects.

6.5 - Toxicity of Iron

Iron is essential to almost all living things, from micro-organisms to humans. Iron is the fourth
most abundant element in the earth’s crust and the most abundant heavy metal; it is present in
the environment mainly as Fe (II) or Fe (III). Iron is generally present in surface waters as salts
containing Fe (III) when the pH is above 7. Most of those salts are insoluble and settle out or
adsorbed onto surfaces; therefore, the concentration of iron in well-aerated waters is seldom
high. Under reducing conditions, which may exist in groundwater, some lakes or reservoirs, and
in the absence of sulphide and carbonate, high concentrations of soluble Fe(II) may be found.
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 (Hem,

Iron, an essential element in human nutrition, is an integral component of cytochromes,
porphyrins and metalloenzymes. Dietary iron requirements vary according to sex and age; older
infants, children and women of menstrual age are most vulnerable to iron deficiency. Iron is an
essential constituent in plant metabolism. It is indispensable for the synthesis of chlorophyll in
green plants, although it does not enter in the constituent of the chlorophyll molecules. Most of
the iron in plants is present as a constituent of organic molecules, enzymes and carries catalase,
peroxide and cyto-chromes which play important role in cellular metabolism. Iron is
indispensable for the synthesis of chlorophyll molecules. Deficiency of iron in plants causes
chlorosis. It is one of the most immobile elements in plants (DNHW, 1983; CCREM, 1987).
Iron is also widely distributed in human body where it exists in the ionic (loosely bound, inorganic iron) and nonionic (tightly bound organic form) state. It is also a constituent of hemoglobin molecule. It is more often suggested that iron deficiency predispose children to lead poisoning. Deficiency of iron with other trace elements is the cause of pica (a morbid appetite for unusual or unfit food, as clay, chalk, ashes, bricks etc., showing itself especially in hysteria, pregnancy and chlorosis). Iron deficiency also affects the transport of lead to the tissue. According to Dr. Ronald Hoffman, depending upon the age, sex and body weight, minimum daily requirement of iron varies from 6 mg/day to 30 mg/day. Following are the recommendations for intakes of iron, according to Dr. Hoffman:

- Infants up to 6 months require 6 mg/day.
- From 6 months to 1 year, 10 mg/day is required.
- Children age 1 to 10 years, require 10 mg/day.
- Males age 11 to 18 years, require 12 mg/day.
- Males age 19 to 51+ years, require 10 mg/day.
- Females age 11 to 50 years, require 15 mg/day.
- Females over 51 years, require 10 mg/day.
- Pregnant women require 30 mg/day.
- Lactating women require 15 mg/day.

Thus while normal amount of iron is essential, the normally large amount adversely affects the human system, which may result in haemochromatosis. Iron absorption is enhanced by heme, ascorbic acid, amino acids and inhibited by tannins, calcium, phosphate, phytic acid and fibers. Although the human body contains only about 0.004% iron, this element plays a central role in the life processes. As a constituent of the respiratory pigment haemoglobin, iron is essential for the functioning of every organ and tissue of the human body. Over half of the iron is present in the form of haemoglobin; the remaining iron is stored mainly in the liver. Nutritional anaemia is one of the most prevalent deficiency diseases throughout the world. Although anaemia may result from many different causes, the form most frequently encountered is iron deficiency anaemia (Tsai, 1975). Anaemia is a major health problem in India, with over half of ever-married woman having the condition. The problem clearly requires immediate attention and intervention (Ming, 2005).

Iron usually exists in natural water both in ferric and ferrous form. The form of iron however may be altered as a result of oxidation or reduction due to the growth of bacteria in the water during storage, usually the ferric form is predominant in the most of the natural waters. Iron in water may be either in true solution or in a colloidal state or in the form of relatively coarse suspended particles. The iron determination is helpful in assessing the extent of corrosion and aiding in the solution of these problems. Research on corrosion and methods of corrosion control requires the use of many types of tests to evaluate the extent of metal loss. The most important one of them is the iron determination (Sawyer, 1978). In drinking water 0.3 mg/L is the highest desirable limit and 1 mg/L the maximum permissible limit of iron in absence of alternative sources.

6.6 - Toxicity of lead

Lead is the most common in the heavy elements. Several stable isotopes exist in nature, $^{208}$Pb being the most abundant. Lead is used mainly in the production of lead-acid batteries, solder and
alloys. The organo-lead compounds tetraethyl and tetramethyl lead have also been used extensively as antiknock and lubricating agents in petrol, although their use for these purposes in many countries is being phased out. Owing to the decreasing use of lead containing additives in petrol and of lead containing solder in the food processing industry, concentrations in air and food are declining, and intake from drinking water constitutes a greater proportion of total intake (Greenwood & Earnshaw, 1984; RSC, 1986; CCREM, 1987; Ming, 2005)

Lead toxicity has been known for over two thousand years. The early Greeks used Pb as a glazing for ceramic pottery and became aware of its harmful effects when it was used in the presence of acidic foods. Researchers suggest that some Roman emperors became ill and even died as a result of Pb poisoning from drinking wines contaminated with high levels of Pb.

Lead is found in all human tissues and organs though it is not needed nutritionally. It is known as one of the systemic poisons because, once absorbed into the circulation it will distribute throughout the body, where it affects various organs and tissues. It inhibits hematopoiesis (formation of blood or blood cells) because it interferes with heme synthesis, and Pb poisoning may cause anaemia. Pb also affects the kidneys by inducing renal tubular dysfunction. This, in turn, may lead to secondary effects. Effects of Pb on the gastrointestinal tract include nausea, anorexia, and severe abdominal cramps (lead colic) associated with constipation. Pb poisoning is also manifested by muscle aches and joint pain, lung damage, difficulty in breathing, and diseases such as asthma, bronchitis, and pneumonia. Pb poisoning can also damage the immune system, interfering with cell maturation and skeletal growth. Pb can pass the placental barrier and may reach the fetus, causing miscarriage, abortions and stillbirths (Ming, 2005).

According to the CDC, lead poisoning is the most common and serious environmental disease affecting young children. Children are much more vulnerable to Pb exposure than adults because of their more rapid growth rate and metabolism. Pb absorption from the gastrointestinal tract in children is also higher than in adults (25% vs. 8%), and ingested Pb is distributed to a smaller tissue mass. Children also tend to play and breathe closer to the ground, where Pb dust concentrates. One particular problem has been the Pb poisoning of children who ingest flakes of lead-based paint. This type of exposure accounts for as much as 90% of childhood Pb poisoning. The main health concern in children is retardation and brain damage. High exposure may be fatal (USNRC, 1980; Ryan, et al., 2004; Ming, 2005)

Plants grown in lead mining area are known to accumulate high levels of lead. Plants near highways accumulate atmospheric dust containing Pb as foliar deposits, from the combustion of petrol as well as absorb if from soil.

6.7- Toxicity of Nickel

Nickel is the 24th most abundant element (twice as Cu) and comprises approximately 0.008% of the content of the earth’s crust; hence, it is a natural component of soil (parent material) and water (Alloway 1995; Hostynek and Maibach 2002; Hedfi et al. 2007). It is the 5th most abundant element in the biosphere, Ni was only discovered through the mining of other metals. Its principal ores are nickelite (NiAs), millerite (NiS), and pentlandite ([Ni, Fe]S).
Nickel is released into the environment from a variety of natural and anthropogenic sources. Among industrial sources, a considerable amount of environmental Ni derives from the combustion of coal, oil, and other fossil fuels. Other industrial sources that contribute to nickel emissions are mining and refining processes, nickel alloy manufacturing (steel), electroplating, and incineration of municipal wastes (Sharma 2005; Ensink et al. 2007). Wastewater from municipal sewage treatment plants also contributes to environmental metal accumulation (van der Hoek et al. 2002).

In small quantities nickel is essential, but when the uptake is too high it can be a danger to human health. Humans may be exposed to nickel by breathing air, drinking water, eating food or smoking cigarettes. Skin contact with nickel-contaminated soil or water may also result in nickel exposure. The most common type of Ni exposure for the public is through direct skin contact with Ni plating. Ni(CO)_4 gas is the most toxic out of the Ni compounds and it is the first to cause deaths in refineries. The immediate symptoms included headaches, nausea, weakness, dizziness, vomiting, and epigastric pain. There was a latency period of 1 to 5 days, followed by secondary symptoms which included chest constriction, chills and sweating, shortness of breath, coughing, muscle pains, fatigue, gastrointestinal discomfort and in severe cases, convulsions and delirium.

Nickel fumes are respiratory irritants and may cause pneumonitis. Exposure to nickel and its compounds may result in the development of a dermatitis known as “nickel itch” in sensitized individuals. The first symptom is usually itching, which occurs up to 7 days before skin eruption occurs. The primary skin eruption is erythematous or follicular which may be followed by skin ulceration. Nickel sensitivity once acquired appears to persist indefinitely. High level occupational exposure has been associated with renal problems, vertigo and dyspnoea (Commission of European Communities, 1976). Nickel and certain nickel compounds have been listed by the National Toxicology Program (NTP) as being reasonably anticipated to be carcinogens. The International Agency for Research on Cancer (IARC) has listed nickel compounds within group 1 (there is sufficient evidence for carcinogenicity in humans) and nickel within group 2B (agents which are possibly carcinogenic to humans).

6.8- Toxicity of Zinc

Zinc is the twenty-fifth most abundant element. It is widely found in nature and makes up 0.02% by weight of the earth’s crust (Budavari, 1989). Zinc normally appears dull grey owing to coating with an oxide or basic carbonate. It is extremely rare to find zinc metal free in nature (Beliles, 1994). The major source of zinc is sphalerite, smithsonite, hemimorphite and franklinite. The largest natural emission of zinc to water results from erosion. Natural inputs to air are mainly due to igneous emissions and forest fires. Anthropogenic and natural sources are of a similar magnitude. The main anthropogenic sources of zinc are mining, zinc production facilities, iron and steel production, corrosion of galvanized structures, coal and fuel combustion, waste disposal and incineration, and the use of zinc-containing fertilizers and pesticide (Ming, 2005).

Zinc is an essential element for both animals and man which is necessary for the functioning of various enzyme systems. Nutritional zinc deficiency in humans has been reported in a number of countries. In Egypt endemic zinc deficiency syndrome among young men has been reported (Prasad, et al., 1961; Halsted et al., 1972). This syndrome having characters of retarded growth,
signs of immaturity and anemia is probably caused by low intestinal absorption of zinc. Its complete cure was observed by administration of large doses of zinc sulfate.

Acute toxicity arises from the ingestion of excessive amounts of zinc salts, either accidentally or deliberately as an emetic or dietary supplement. Vomiting usually occurs after the consumption of more than 500 mg of zinc sulfate. Mass poisoning has been reported following the drinking of acidic beverages kept in galvanized containers; fever, nausea, vomiting, stomach cramps and diarrhea occurred 3–12 h after ingestion. Food poisoning attributable to the use of galvanized zinc containers in food preparation has also been reported; symptoms occurred within 24 h and included nausea, vomiting, and diarrhea, sometimes accompanied by bleeding and abdominal cramps (ATSDR, 2003).

Symptoms of zinc toxicity in humans include vomiting dehydration, electrolyte imbalance, abdominal pain, nausea lethargy, dizziness and lack of muscular co-ordination (Prasad and Oberleas, 1976). Acute renal failure caused by zinc chloride has also been reported (Csata, 1968). Zinc unlike Hg, Pb or Cd is an essential trace element for organisms and plays a vital role in the physiological and metabolic processes of many organisms. However, zinc can be toxic to the organisms in high concentrations (Kapaj, 2006).

Zinc is an essential trace element for plants and animals including human beings and it plays vital role in metabolic processes. The most common effect of zinc poisoning in human are non fatal ‘metal fume’ fever caused by inhalation of zinc oxide fumes and illness arising from the ingestion of acidic foods prepared in zinc galvanized containers. Particularly, zinc chloride in Zn salts produce dermatitis upon contact with the skin (ATSDR, 2003).
7. WATER QUALITY CRITERIA

As it is a well-known fact that the sources of usable water on the earth are limited, any kind of pollution in such sources will further reduce its availability. Polluted water cannot be utilized for drinking because of its inherent health risk. Water with high salt contents is not suitable for agriculture and most industries. The quality of water also interferes with the aesthetic and economic pursuits of water bodies by affecting marine and fresh water life. However, the water which is not suitable for irrigation may be quite suitable for industrial cooling. Every use of water requires a certain minimum quality standards with regards to the presence of dissolved and suspended materials of both chemical and biological nature. The desirable quality of water ensures no harm to the user.

To maintain the minimum quality standard for diverse user has led to the formulation of water quality criteria and water quality standards. Water quality criteria can be considered as specific requirements on which a decision or judgment to support a particular use will be based. The criteria for the various uses are developed based on the experimental data and our current knowledge of the health, ecology and other issues and assessing its overall economical effect these are not a set of fixed values, but subject to modification as the scientific data get updated and more and more knowledge is gathered. The term standard applies to any definite principle or measure established by an authority by limiting concentration of different constituents in water to ensure the safe use of water and safeguard the environment.

7.1 - 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 resource in the National Water Policy. In India, agencies like the Bureau of Indian Standards (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 as international standards. Drinking water standards for trace and toxic metals according to BIS code 10500-2012 are given below in table 5.

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Toxic metal</th>
<th>Requirement (Acceptable Limit) (mg/L)</th>
<th>Permissible Limit in the Absence of Alternative Source (mg/L)</th>
<th>Permissible Limit in the Absence of Alternative Source (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total arsenic as As</td>
<td>0.01</td>
<td>10</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>Cadmium as Cd</td>
<td>0.003</td>
<td>3</td>
<td>No relaxation</td>
</tr>
<tr>
<td>3</td>
<td>Total Chromium as Cr</td>
<td>0.05</td>
<td>50</td>
<td>No relaxation</td>
</tr>
<tr>
<td>4</td>
<td>Copper as Cu</td>
<td>0.05</td>
<td>50</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>Iron as Fe</td>
<td>0.30</td>
<td>300</td>
<td>No relaxation</td>
</tr>
<tr>
<td>6</td>
<td>Lead as Pb</td>
<td>0.01</td>
<td>10</td>
<td>No relaxation</td>
</tr>
<tr>
<td>7</td>
<td>Mercury as Hg</td>
<td>0.001</td>
<td>1</td>
<td>No relaxation</td>
</tr>
<tr>
<td>8</td>
<td>Nickel as Ni</td>
<td>0.02</td>
<td>20</td>
<td>No relaxation</td>
</tr>
<tr>
<td>9</td>
<td>Zinc as Zn</td>
<td>5</td>
<td>5000</td>
<td>15</td>
</tr>
</tbody>
</table>
Regulatory Limits of Heavy Metals US Environmental Protection Agency (US EPA)

Several types of toxic heavy metals frequently pollute surface water bodies and their maximum permissible limits according to WHO and US EPA are presented in Table 6. These limits are mandatory for all water supply systems. Naturally occurring water (both surface and groundwater) frequently contains some of these heavy metals at concentrations 100 or 1000 times more than the prescribed MCL values. Since these heavy metals are valuable resources for different industrial applications, their removal, recovery and recycling assume greater significance.

Table 6: Maximum acceptable limits of several toxic heavy metal ions in the surface waters based on WHO and US EPA regulations.

<table>
<thead>
<tr>
<th>Heavy Metal</th>
<th>Toxicity rank</th>
<th>WHO (µg/L)</th>
<th>USEPA (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>1</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Lead</td>
<td>2</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Mercury</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Cadmium</td>
<td>8</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Chromium</td>
<td>17</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Nickel</td>
<td>57</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td>Zinc</td>
<td>75</td>
<td>NGL</td>
<td>5000</td>
</tr>
<tr>
<td>Copper</td>
<td>125</td>
<td>2000</td>
<td>1300</td>
</tr>
<tr>
<td>Iron</td>
<td>-</td>
<td></td>
<td>300</td>
</tr>
</tbody>
</table>

Note: NGL = NO Guideline

In accordance with toxicity data obtained from human clinical investigations, and various other studies such as animal experiments, drinking water standards have been proposed by various governmental bodies. A brief summary is given in Table 7 compiled by Hattingh, 1977.

Table 7: Drinking water quality criteria for trace metals which might affect public health

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>10</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>100</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Barium</td>
<td>1,000</td>
<td>–</td>
<td>4,000</td>
<td>1,000</td>
<td>–</td>
<td>–</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>–</td>
</tr>
<tr>
<td>Cadmium</td>
<td>10</td>
<td>–</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>50</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Chromium</td>
<td>50</td>
<td>50</td>
<td>100</td>
<td>50</td>
<td>–</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Copper</td>
<td>1,000</td>
<td>10,000</td>
<td>100</td>
<td>50</td>
<td>50</td>
<td>1,000</td>
<td>1,000</td>
<td>10,000</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Lead</td>
<td>50</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Mercury</td>
<td>–</td>
<td>1</td>
<td>5</td>
<td>–</td>
<td>1</td>
<td>–</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Selenium</td>
<td>10</td>
<td>–</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>–</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Silver</td>
<td>50</td>
<td>–</td>
<td>–</td>
<td>50</td>
<td>–</td>
<td>–</td>
<td>50</td>
<td>–</td>
<td>50</td>
<td>–</td>
</tr>
<tr>
<td>Zinc</td>
<td>5,000</td>
<td>100</td>
<td>1,000</td>
<td>5,000</td>
<td>5,000</td>
<td>5,000</td>
<td>5,000</td>
<td>5,000</td>
<td>–</td>
<td>2,000</td>
</tr>
</tbody>
</table>

a As proposed by the World Health Organization (WHO), US Public Health Service (USPHS), South African Bureau of Standards (SABS), Russia (USSR), USA National Academy of Sciences (NAS), Australia, Japan and Environmental Protection Agency (EPA) of the USA. All concentrations in µg/l. Compiled by Hattingh (1977), except for F.R.G. data (Schöttler, 1977).
Finally, it is worth noting that maximum permissible concentrations (USSR) and threshold limit values (US) have been established within the field of occupational hygiene (Roschin and Timofeevskaya, 1975). These values pertain to the control of occupational exposure with regard to airborne particulates. In consequence, they are of no relevant importance in the present context.

### 7.2 - Quality Criteria for Livestock

A safe water supply is essential for healthy livestock. Contaminated water can affect growth, reproduction and productivity of animals as well as safety of animal products for human consumption. Contaminated water supplies for livestock and poultry can also contaminate human drinking water. For these reasons, farm water supplies should be protected against contamination from bacteria, nitrates, sulfates, and pesticides. The Environmental Protection Agency has set drinking water standards for human consumption, but no set of standards exists for drinking water for livestock or poultry. However, The National Academy of Science has recommended maximum levels for some contaminants.

The permissible daily intake of substances is greatly dependent on the concentration of the substances and the quality of water ingested. The daily water requirement of animals vary with a number of factors such as temperature and humidity, the water content in the food, the degree of exertion of the animal and the salinity of the water supply. Therefore, the recommended concentrations of specific substance are based on typical usage.

Excessive salinity in livestock drinking water can upset the animals’ water balance and cause even death. High levels of specific ions in water can cause animal health problems and death. The National Academy of Sciences offers upper limits for toxic substances in water (Table 8).

**Table 8: Recommendations for levels of toxic substances in drinking water for livestock**

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Toxic metal</th>
<th>Upper Limit in mg/L</th>
<th>Sr.</th>
<th>Toxic metal</th>
<th>Upper Limit in mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Arsenic</td>
<td>0.2</td>
<td>5.</td>
<td>Iron as Fe</td>
<td>-</td>
</tr>
<tr>
<td>2.</td>
<td>Cadmium as Cd</td>
<td>0.05</td>
<td>6.</td>
<td>Mercury as Hg</td>
<td>0.01</td>
</tr>
<tr>
<td>3.</td>
<td>Chromium as Cr</td>
<td>1.0</td>
<td>7.</td>
<td>Zinc as Zn</td>
<td>24</td>
</tr>
<tr>
<td>4.</td>
<td>Copper as Cu</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ayers, R.S. and D.W. Wescot, Water Quality for Agriculture, Food and Agriculture Organization of the United Nations, Rome, 1976

### 7.3 - Water Quality for Irrigation

Nearly all waters contain dissolved salts and trace elements, many of which results from the natural weathering of the earth’s surface. In addition, drainage waters from irrigated lands and effluent from city sewage and industrial waste water can impact water quality. In most irrigation situations, the primary water quality concern is salinity levels, since salts can affect both the soil structure and crop yield. However, a number of trace elements are found in water which can also limit its use for irrigation.
The required quality of irrigation water varies substantially, depending upon the salinity, soil permeability, toxicity and some miscellaneous concerns such as excessive nitrogen loading or unusual pH of water. Some elements in irrigation water may be directly toxic to crops. Establishing toxicity limits in water is complicated by reactions which take place once the water is applied to the soil. When an element is added to the soil from irrigation, it may be inactivated by chemical reactions or it may build up in the soil until it reaches a toxic level. An element at a given concentration in water may be immediately toxic to a crop because of foliar effects if sprinkler irrigation is used. If furrow irrigation is used, it may require a number of years for the element to accumulate to toxic levels, or it may be immobilized in the soil and never reach toxic levels. The recommended water quality for irrigation is shown in Table 9.

**Table 9: Recommended limits for constituents in reclaimed water for irrigation.**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Long-term use (mg/L)</th>
<th>Short-term use (mg/L)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum (Al)</td>
<td>5.0</td>
<td>20</td>
<td>Can cause nonproductivity in acid soils, but soils at pH 5.5 to 8.0 will precipitate the ion and eliminate toxicity.</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>0.10</td>
<td>2.0</td>
<td>Toxicity to plants varies widely, ranging from 12 mg/L for Sudan grass to less than 0.05 mg/L for rice.</td>
</tr>
<tr>
<td>Beryllium (Be)</td>
<td>0.10</td>
<td>0.5</td>
<td>Toxicity to plants varies widely, ranging from 5 mg/L for kale to 0.5 mg/L for bush beans.</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>0.75</td>
<td>2.0</td>
<td>Essential to plant growth, with optimum yields for many obtained at a few-tenths mg/L in nutrient solutions. Toxic to many sensitive plants (e.g., citrus) at 1 mg/L. Most grasses relatively tolerant at 2.0 to 10 mg/L.</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>0.01</td>
<td>0.05</td>
<td>Toxic to beans, beets, and turnips at concentrations as low as 0.1 mg/L in nutrient solution. Conservative limits recommended.</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>0.1</td>
<td>1.0</td>
<td>Not generally recognized as essential growth element. Conservative limits recommended due to lack of knowledge on toxicity to plants.</td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>0.05</td>
<td>5.0</td>
<td>Toxic to tomato plants at 0.1 mg/L in nutrient solution. Tends to be inactivated by neutral and alkaline soils.</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>0.2</td>
<td>5.0</td>
<td>Toxic to a number of plants at 0.1 to 1.0 mg/L in nutrient solution.</td>
</tr>
<tr>
<td>Fluoride (F⁻)</td>
<td>1.0</td>
<td>15.0</td>
<td>Inactivated by neutral and alkaline soils.</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>5.0</td>
<td>20.0</td>
<td>Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of essential phosphorus and molybdenum.</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>5.0</td>
<td>10.0</td>
<td>Can inhibit plant cell growth at very high concentrations.</td>
</tr>
<tr>
<td>Lithium (Li)</td>
<td>2.5</td>
<td>2.5</td>
<td>Tolerated by most crops at up to 5 mg/L; mobile in soil. Toxic to citrus at low doses recommended limit is 0.075 mg/L.</td>
</tr>
<tr>
<td>Manganese (Mg)</td>
<td>0.2</td>
<td>10.0</td>
<td>Toxic to a number of crops at a few-tenths to a few mg/L in acid soils.</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>0.01</td>
<td>0.05</td>
<td>Nontoxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high levels of available molybdenum.</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>0.2</td>
<td>2.0</td>
<td>Toxic to a number of plants at 0.5 to 1.0 mg/L; reduced toxicity at neutral or alkaline pH.</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>0.02</td>
<td>0.02</td>
<td>Toxic to plants at low concentrations and to livestock if forage is grown in soils with low levels of added selenium.</td>
</tr>
<tr>
<td>Vanadium (V)</td>
<td>0.1</td>
<td>1.0</td>
<td>Toxic to many plants at relatively low concentrations.</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>2.0</td>
<td>10.0</td>
<td>Toxic to many plants at widely varying concentrations; reduced toxicity at increased pH (6 or above) and in fine-textured or organic soils.</td>
</tr>
</tbody>
</table>

Source: Rowe and Abdel-Magid, 1995
8. STUDY AREA

A total number of 414 water quality stations covering all the major River Basins of CWC right from East to West and North to South were studied for Trace and Toxic metals during May, 2014; November, 2014; February, 2015; December, 2015; April, 2016; August, 2016; December, 2016; April, 2017 and August 2017. The details of the 414 monitoring stations on the Indian Rivers with their latitude, longitude, district and states are enclosed as Annexure-1. River water samples were collected by Punjab type sampler. The water samples were stored in acid leached polyethylene bottles and preserved by adding ultra pure nitric acid as recommended (APHA, 2012). During the study period, water samples from other than the registered water quality monitoring stations of CWC were also received at National River Water Quality Laboratory, CWC, New Delhi.

9. METHODOLOGY

Living organisms require trace amounts of some metals including cobalt, copper, iron, manganese, molybdenum, vanadium, strontium and zinc. Excessive levels of these essential metals are detrimental to the organisms. Non-essential metals like cadmium, chromium, mercury, lead, arsenic and antimony are of more concern to surface water system because these metals produce undesirable effects on human and animal life. Once these metals enter into the system, they remain for relatively longer periods. Once absorbed, inorganic metals are capable of reacting with a variety of binding sites in the human body and have strong attraction to biological tissues. Natural water contains toxic metals in traces. Industrial wastes containing metals have aggravated the problem of metal pollution. Electroplating, metallurgical industry, galvanising plants, tanneries and thermal power stations are few of the major contributors of metal pollution in surface water. All metals exist in surface water in colloidal, particulate and dissolved forms, although dissolved concentrations are generally low. The soluble forms are generally ions or unionized, organo-metallic chelates or complexes. The solubility of trace metals in surface water is predominately controlled by pH, the type and concentration of legends on which the metal can absorb and the oxidation state of the mineral components.

9.1 - Metal Detection Techniques

The analytical methods commonly used in estimation of heavy metals in water and waste waters are:

- Inductively coupled plasma analyser (ICP)
- Atomic absorption spectrophotometry (AAS)
- Colorimetric methods
- Polarographic estimation
- Ion Selective Electrodes (ISE)

Inductively coupled plasma (ICP) techniques and atomic absorption spectrophotometry are applicable over a broad linear range and are especially sensitive for refractory elements. In general, detection limits for ICP methods are higher than AAS. Colorimetric methods are applicable when interferences are known to be within the limit of the particular method. Extreme care should be taken in sampling and analysis to prevent contamination.
In the present study, samples were collected in polyethylene containers. These water samples were prepared for the determination of heavy metals, viz., arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel and zinc by atomic absorption spectrophotometer. This instrumental technique was developed by Asian Walsh in 1955 by means of Atomic Absorption Spectrophotometer (AAS) and since then AAS techniques have been considered as most reliable and have become more common in recent times although the colorimetric/spectrophotometric techniques have also been in use because of the exorbitant cost of the AAS. AAS techniques are usually favored due to its rapidity, accuracy and controllability while other methods do not respond if the metals are present in traces. It is generally employed when exact quantity of interfering radicals or ions is known. The study was carried out on Agilent 240FS atomic absorption spectrophotometer by graphite tube analyzer (GTA) using argon gas and Iron analyzed by flame operation using air and acetylene gas.

9.2 - Chemicals and Reagents

All chemicals and reagents used in the chemical analysis during the study were of analytical reagent grade (Merck). Standard solutions of metals ions were procured from Merck, Germany. De-ionized water was used throughout the study. All glassware and containers used were thoroughly cleaned by soaking in detergent followed by soaking in 10% nitric acid for 48hrs and finally rinsed with de-ionized water several times prior to use.

9.3 - Method

Trace and toxic metals were analysed by using Agilent 240FS atomic absorption spectrophotometer. The wave length, current, slit and method employed using atomic absorption spectrophotometer is given in Table 10.

<table>
<thead>
<tr>
<th>Sr.</th>
<th>Parameter</th>
<th>Wave length (nm)</th>
<th>Current (mA)</th>
<th>Slit (nm)</th>
<th>Method used for analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arsenic</td>
<td>193.7</td>
<td>10</td>
<td>12</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Recommended</strong></td>
<td><strong>Maximum</strong></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Cadmium</td>
<td>228.8</td>
<td>4</td>
<td>10</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Recommended</strong></td>
<td><strong>Maximum</strong></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Chromium</td>
<td>357.9</td>
<td>7</td>
<td>15</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Recommended</strong></td>
<td><strong>Maximum</strong></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Copper</td>
<td>324.8</td>
<td>4</td>
<td>10</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Recommended</strong></td>
<td><strong>Maximum</strong></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Iron</td>
<td>248.3</td>
<td>7</td>
<td>10</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Recommended</strong></td>
<td><strong>Maximum</strong></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Lead</td>
<td>217</td>
<td>10</td>
<td>12</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Recommended</strong></td>
<td><strong>Maximum</strong></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Nickel</td>
<td>232</td>
<td>4</td>
<td>10</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Recommended</strong></td>
<td><strong>Maximum</strong></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Zinc</td>
<td>213.9</td>
<td>5</td>
<td>10</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Recommended</strong></td>
<td><strong>Maximum</strong></td>
<td></td>
</tr>
</tbody>
</table>
10. RESULTS AND DISCUSSION

Details of the Indian rivers and their water quality monitoring sites where the water was found fit for use in terms of toxic metal contamination in the study period is presented in Annexure-2. Details of WQ monitoring stations where the water was found unfit for use due to excess presence of Iron only above the acceptable limits during the study period is presented in Annexure-3. Details of WQ monitoring stations where the water was found unfit for use due to presence of more than two toxic metals above acceptable limits during the study period is presented in Annexure-4. Toxic metal-wise details of water quality monitoring stations where the respective metal concentration was found above the acceptable limits as prescribed by BIS is presented in Annexure-5.

Surface/ground water contamination through toxic metals is a problem since long. Many countries in the world have experienced menace of metal pollution in water and large number of people has been affected. Causes of this pollution have been well documented. However, the main sources of metal toxicity in surface water have been thought to be natural occurrence and subsequent degradation of the environment.

The analytical results obtained from the trace and toxic metal analysis in the water samples of Indian Rivers are expressed in µg/L (Microgram per Litre) throughout the report. During the entire period of study, maximum concentration of all eight metals in the Indian Rivers observed are as: Arsenic (9.530 µg/L), Cadmium (70.518 µg/L), Chromium (450.260 µg/L), Copper (314.930 µg/L), Lead (374.580 µg/L), Nickel (304.640 µg/L), Zinc (2.658 mg/L) and Iron (14.555 mg/L).

Table 11: Minimum and Maximum concentration of Metal during the May, 2014 to August, 2017

<table>
<thead>
<tr>
<th>Metal</th>
<th>Min/Max</th>
<th>WQS</th>
<th>River</th>
<th>Month/Year</th>
<th>Season</th>
<th>Con.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>Minimum</td>
<td>Ram M.Bagh</td>
<td>Jhelum</td>
<td>May, 2014</td>
<td>Summer</td>
<td>0.010 µg/L</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>Buxar</td>
<td>Ganga</td>
<td>April, 2016</td>
<td>Summer</td>
<td>9.530 µg/L</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Minimum</td>
<td>Jammu Tawi</td>
<td>Chenab/Tawi</td>
<td>November, 2014</td>
<td>Winter</td>
<td>0.010 µg/L</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>Vautha</td>
<td>Sabarmati</td>
<td>February, 2015</td>
<td>Winter</td>
<td>70.518 µg/L</td>
</tr>
<tr>
<td>Chromium</td>
<td>Minimum</td>
<td>Tuini</td>
<td>Tuini</td>
<td>April, 2016</td>
<td>Summer</td>
<td>0.002 µg/L</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>Paliakalan</td>
<td>Sharda</td>
<td>August, 2016</td>
<td>Monsoon</td>
<td>450.26 µg/L</td>
</tr>
<tr>
<td>Copper</td>
<td>Minimum</td>
<td>Nellithurai</td>
<td>Bhavani</td>
<td>November, 2014</td>
<td>Winter</td>
<td>0.003 µg/L</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>Pingalwada</td>
<td>Dhadher</td>
<td>April, 2017</td>
<td>Summer</td>
<td>314.93 µg/L</td>
</tr>
<tr>
<td>Nickel</td>
<td>Minimum</td>
<td>Chapra</td>
<td>Jalangi</td>
<td>April, 2017</td>
<td>Summer</td>
<td>0.005 µg/L</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>Lowara</td>
<td>Sheturni</td>
<td>February, 2015</td>
<td>Winter</td>
<td>304.64 µg/L</td>
</tr>
<tr>
<td>Lead</td>
<td>Minimum</td>
<td>Y.Nagar</td>
<td>Giri</td>
<td>April, 2016</td>
<td>Summer</td>
<td>0.003 µg/L</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>Lowara</td>
<td>Sheturni</td>
<td>April, 2016</td>
<td>Summer</td>
<td>374.58 µg/L</td>
</tr>
<tr>
<td>Zinc</td>
<td>Minimum</td>
<td>Y.Nagar</td>
<td>Giri</td>
<td>August, 2016</td>
<td>Monsoon</td>
<td>0.0003 mg/L</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>Manot</td>
<td>Narmada</td>
<td>August, 2016</td>
<td>Monsoon</td>
<td>2.6579 mg/L</td>
</tr>
<tr>
<td>Iron</td>
<td>Minimum</td>
<td>Safapora</td>
<td>Jhelum</td>
<td>April, 2016</td>
<td>Summer</td>
<td>0.001 mg/L</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>Chenimari</td>
<td>Buridehing</td>
<td>August, 2017</td>
<td>Monsoon</td>
<td>14.555 µg/L</td>
</tr>
</tbody>
</table>
Results were statistically analysed and minimum, maximum, average and standard deviation were calculated using MS Excel (Table 12).

**Table 12: Summary and statistical analysis of analytical results of water samples**

*(From May, 2014 to August, 2017)*

<table>
<thead>
<tr>
<th>Period</th>
<th>Particulars</th>
<th>As</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Ni</th>
<th>Pb</th>
<th>Fe</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>May, 2014</td>
<td>Minimum</td>
<td>0.01</td>
<td>0.01</td>
<td>0.04</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>8.95</td>
<td>10.39</td>
<td>40.65</td>
<td>58.34</td>
<td>83.83</td>
<td>19.76</td>
<td>5.34</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>3.97</td>
<td>0.30</td>
<td>2.85</td>
<td>5.11</td>
<td>6.93</td>
<td>2.07</td>
<td>0.21</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>2.44</td>
<td>0.88</td>
<td>4.29</td>
<td>6.53</td>
<td>8.37</td>
<td>2.52</td>
<td>0.50</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Total Analysis</td>
<td>296</td>
<td>313</td>
<td>313</td>
<td>313</td>
<td>313</td>
<td>313</td>
<td>313</td>
<td>313</td>
</tr>
<tr>
<td></td>
<td>Unfit</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>10</td>
<td>4</td>
<td>51</td>
<td>0</td>
</tr>
<tr>
<td>November, 2014</td>
<td>Minimum</td>
<td>0.03</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td>0.07</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>6.30</td>
<td>11.77</td>
<td>230.90</td>
<td>269.63</td>
<td>37.32</td>
<td>28.41</td>
<td>9.06</td>
<td>1.50</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>2.09</td>
<td>0.28</td>
<td>13.46</td>
<td>8.53</td>
<td>2.81</td>
<td>1.93</td>
<td>0.39</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>1.44</td>
<td>0.69</td>
<td>34.09</td>
<td>16.47</td>
<td>10.11</td>
<td>0.10</td>
<td>0.11</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>Total Analysis</td>
<td>20</td>
<td>355</td>
<td>355</td>
<td>355</td>
<td>355</td>
<td>355</td>
<td>355</td>
<td>355</td>
</tr>
<tr>
<td></td>
<td>Unfit</td>
<td>0</td>
<td>1</td>
<td>14</td>
<td>2</td>
<td>4</td>
<td>24</td>
<td>81</td>
<td>0</td>
</tr>
<tr>
<td>February, 2015</td>
<td>Minimum</td>
<td>0.03</td>
<td>0.00</td>
<td>0.01</td>
<td>0.19</td>
<td>0.01</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>4.28</td>
<td>70.52</td>
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Analytical results obtained were also compared with the Indian Standards, prescribed as acceptable toxic metal content in the drinking water by the Bureau of Indian Standards (“Drinking Water – Specification”, 10500:2012). Number of water samples analysed for each of nine metals and total number of water samples exceeded the acceptable limits during the study period are summarized for all five sampling occasions here under in Table 13.

Table 13: Number of samples analysed and found above acceptable limits of toxic metals.

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A - Total No. of samples analyzed; B - Total No. of samples exceeded the acceptable limits

From the above table, it is evident that Iron ranks first among the metals that exceeded their respective acceptable limits on maximum occasions followed by Lead, Chromium, Cadmium, Nickel, and Copper. Exceeding the acceptable limits in Indian River waters by Lead, Cadmium, Nickel, Chromium and Copper are more common in non-monsoon periods while Iron, Lead, Chromium and Copper are the metals whose concentrations have exceeded their tolerance limits in monsoon periods most of the time. This kind of tendency to exceed the tolerance limits is not seen in case of other metals like Arsenic and Zinc. Arsenic and Zinc are the two toxic metals whose concentration was always obtained within the limits throughout the study period.

During the study period, the samples were collected during monsoon (August, 2016 and August, 2017), non-monsoon (May, 2014; November, 2014; February 2015, December, 2015; April, 2016; December, 2016 and April, 2017). For these monsoon and non-monsoon occasions of analysis, seasonal average values of the toxic metal concentration were evaluated and shown in Pie charts (Figures 18-19). From these figures, it is observed that out of eight metals analysed, the concentration of Iron is always found maximum in all the time during monsoon and non-monsoon period.
During all the monsoon and non-monsoon period, the pattern of higher concentration occurrence of these toxic metals is almost same but the percentage of the other metals except iron is less during the monsoon season. The order of higher occurrence of these toxic metals in Indian Rivers during non-monsoon period is Fe > Zn > Cr > Cu > Pb > Ni > As > Cd (Figure-18).

Order of higher occurrence of these eight metals is different in different seasons. In monsoon periods, the levels of many toxic metals like Zn, Ni and Cu fall down significantly. The order of higher occurrence in monsoon period is Fe > Zn > Cr > Cu > Pb > As > Cd > Ni (Figure-19).
The parameter wise discussion on the results obtained from the trace and toxic metal analysis in the water samples collected from the 414 water quality monitoring stations functioning under Central Water Commission are given in subsequent paragraphs.

**Summary of ARSENIC content in Indian Rivers**

Arsenic (As) is a ubiquitous element that is comparatively rare, but widely distributed in the atmosphere, soils and rocks, natural waters and organisms. It is mobilised in the environment through a combination of natural processes such as weathering reactions, biological activity and volcanic emissions as well as through a range of anthropogenic activities. Most environmental arsenic problems are the result of mobilisation under natural conditions, but man has had an important impact through mining activity, combustion of fossil fuels, the use of arsenical pesticides, herbicides and crop desiccants and the use of arsenic as an additive to livestock feed, particularly for poultry. Although the use of arsenical products such as pesticides and herbicides has decreased significantly in the last few decades, their use for wood preservation is still common. The impact on the environment of the use of arsenical compounds, at least locally, will remain for some years.

BIS has recommended 0.01 mg/L (10µg/L) as acceptable concentration of arsenic in drinking water. Total 1765 numbers of water samples were analysed and collected from 414 water quality monitoring stations for arsenic content in Indian Rivers in the period May, 2014 to August 2017. The arsenic concentration varies from 0.01 to 9.53 µg/L. Maximum arsenic concentration (9.53 µg/L) was observed at Buxur water quality monitoring station on Ganga River during April, 2016. From reported data of all River water quality stations, it was found that arsenic concentration well within the acceptable limits as per Bureau of Indian Standards (BIS) and no toxicity of arsenic in the River waters is observed during the study period.

**Summary of CADMIUM content in Indian Rivers**

Cadmium is a rare natural element which is widely distributed in the earth's crust in very small amount. It is uniformly distributed in the Earth’s crust, where it is generally estimated to be present at an average concentration of between 0.15 and 0.2 mg/kg. Cadmium may be present in the aquatic environment at relatively low levels as inorganic complexes such as carbonates, hydroxides, chlorides or sulphates, or as organic complexes with humic acids. Even in polluted rivers the cadmium levels in aqueous phase may be significantly low and even sometimes below detection limit.

A maximum acceptable concentration for cadmium in drinking water has been established on the basis of health considerations. BIS proposed the maximum desirable limit of cadmium is 0.003 mg/L or 3µg/L and there is no relaxation in maximum permissible limit in absence of another source. The concentration of cadmium in unpolluted fresh waters is generally less than 0.001 mg/L. Surface waters containing in excess of a few micrograms of cadmium per litre have probably been contaminated by industrial wastes from metallurgical plants, plating works, plants manufacturing cadmium pigments, textile operations, cadmium-stabilized plastics, or nickel–cadmium batteries, or by effluents from sewage treatment plants.
2349 numbers of river water samples from 414 WQ monitoring stations were collected and analyzed for cadmium content during the study period from May 2014 to August 2017. Out of 2349 water samples, thirty eight water quality stations from Ganga, Kopili, Rapti, Thungabhadra and Yamuna rivers were found to have cadmium content in more than one station above the acceptable limits. The highest cadmium concentration (70.51 µg/L) was observed in the Vautha water quality monitoring station at Sabarmati River during February, 2015. It is also observed that, the acceptable limit exceed only during non-monsoon period. Annexure-5 shows the names of the water quality monitoring stations and the Rivers affected by high cadmium content than the acceptable limits and these WQ stations are hot spots from the point of view of cadmium pollution in the Indian Rivers.

Table 14: Rivers and WQ monitoring stations where Cadmium exceeded the acceptable limits

<table>
<thead>
<tr>
<th>Sr.</th>
<th>River</th>
<th>WQ Sites (Period)</th>
<th>Total number of WQ sites</th>
<th>Total number of water samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arkavathi</td>
<td>T. Bekuppe (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Buridehing</td>
<td>Chenimari (May, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Dareng</td>
<td>Sibbari (Dec, 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Dikhow</td>
<td>Sivasagar (May, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Ganga</td>
<td>Mirzapur (April, 2017); Shahzadpur (April, 2017);</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Ghagra</td>
<td>Elginbridge (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Hagari</td>
<td>T. Ramapuram (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Hindon</td>
<td>Galeta (Dec, 2015; April, 2016)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>Kamang</td>
<td>Seppa (May, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Kopili</td>
<td>Dharamtul (May, 2014); Kampur (May, 2014)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>Noyyal</td>
<td>Elunuthimanagalam (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Orsang</td>
<td>Chanwada (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Ponnaiyar</td>
<td>Vazhavachanur (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Rapti</td>
<td>Balrampur (Feb, 2015); Bansi (April, 2017); Regauli (Feb, 2015)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>Sabarmati</td>
<td>Vautha (Nov, 2014 ; Feb, 2015);</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>Saryu</td>
<td>Ayodhya (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>Sharda</td>
<td>Paliakalan (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>Sheturni</td>
<td>Lowara (May, 2014 ; Feb, 2015 ; April, 2016)</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>19</td>
<td>Sone</td>
<td>Chopan (April, 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>Thungabhadra</td>
<td>Bawapuram (Feb, 2015); Mantralayam (Feb, 2015)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>21</td>
<td>Tirap</td>
<td>Udaipur (April, 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>Ulhas</td>
<td>Badlapur (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>23</td>
<td>Vaitarna</td>
<td>Durvesh (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td>Yamuna</td>
<td>Delhi Rly Bridge (Dec, 2015; April, 2016); Mathura (Dec, 2015; April, 2016) ; Mohana(Dec, 2015; April, 2016)</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>31</td>
<td>38</td>
</tr>
</tbody>
</table>
Summary of CHROMIUM content in Indian rivers

Chromium is used to call as metal with two faces, that it can be either beneficial or toxic to animals and humans depending on its oxidation state and concentrations (Zayed et al., 1998). It can exist in valences from -2 to 6 but is present in the environment mainly in the trivalent or hexavalent state. Cr(III) is considered to be a trace element essential for the proper functioning of living organisms (Wang et al., 2009). Nutritionally, at lower concentrations, Cr(III) is an essential component of a balanced human and animal diet for preventing adverse effects in the metabolism of glucose and lipids, e.g., impaired glucose tolerance, increased fasting insulin, increased cholesterol and triglycerides, and hypoglycemic symptoms (Zayed and Terry, 2003). Cr(III) at increased concentrations can interfere with several metabolic processes because of its high capability to coordinate various organic compounds resulting in inhibition of some metalloenzyme systems (Zayed et al., 1998).

On a worldwide basis, the major chromium source in aquatic ecosystems is domestic waste water effluents (32.2% of the total) (Barceloux 1999). The other major sources are metal manufacturing (25.6%), ocean dumping of sewage (13.2%), chemical manufacturing (9.3%), smelting and refining of nonferrous metals (8.1%), and atmospheric fallout (6.4%) (Nriagu and Pacyna 1988). Annual anthropogenic input of chromium into water has been estimated to exceed anthropogenic input into the atmosphere (Nriagu and Pacyna 1988). However, land erosion, a natural source of chromium in water, was not included in the Nriagu and Pacyna (1988) estimation of chromium contributions to the aquatic environment.

BIS (Bureau of Indian Standard) 10500-2012) have recommended an acceptable limit of 50 µg/L of chromium in drinking water. Total 2400 numbers of water samples from 414 water quality stations were collected and analyzed for chromium content during the study period. Data reveals that 41 water samples have the Chromium concentrations above the acceptable limit of 50 µg/L. Chromium concentration at Paliakalan water quality monitoring station on Sharda River in August 2016, which is reported as the maximum concentration 450.26 µg/L during the entire study period. Annexure-5 shows the names of the WQ stations and the Rivers affected by high chromium concentration (>50 µg/L) and these WQ stations are hot spots from point of view of chromium pollution.

Total 41 numbers of water samples from 28 water quality monitoring stations located on 21 major Indian Rivers were found to have chromium concentration exceeding the tolerance limit of 50µg/L. Some Indian Rivers viz. Ganga, Ghagra and Rapti have two or more water quality monitoring stations which are polluted with chromium.
**Table 15:** Rivers and WQ monitoring stations where Chromium exceeded the acceptable limits.

<table>
<thead>
<tr>
<th>Sr.</th>
<th>River</th>
<th>WQ Sites (Period)</th>
<th>Total number of WQ sites</th>
<th>Total number of water samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Brahmaputra</td>
<td>Tezpur (Aug, 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Churni</td>
<td>Hanskhali (Nov, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Desang</td>
<td>Desangpani (Aug, 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Dikhow</td>
<td>Bihubar (April, 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Gad</td>
<td>Beline Bridge (Aug, 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Ganga</td>
<td>Bhitaura (Nov, 2014); Fatehgarh (Nov, 2014); Kachlabridge (Nov, 2014; Aug, 2016); Kanpur (Nov, 2014);</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Ghagra</td>
<td>Elginbridge (Nov, 2014; Aug, 2016); Turtipar (Aug, 2016)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Hamp</td>
<td>Andhiyar Kore (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Jiabharali</td>
<td>Jiabharali NT Road Xing (Aug, 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Kal</td>
<td>Mangaon (Aug, 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Krishna</td>
<td>Karad (Aug, 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Mahi</td>
<td>Khanpur (Dec, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Mahananda</td>
<td>Labha (Nov, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Purna</td>
<td>Mahuwa (Aug, 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>Ramganga</td>
<td>Moradabad (Nov, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>Rapti</td>
<td>Balrampur (Nov, 2014; Aug, 2016; Dec, 2016); Bansi (Nov, 2014; April, 2016; April, 2017) ; Birdghat (Nov, 2014; Aug, 2016; Dec, 2016); Regauli (Nov, 2014; Aug, 2016; Dec, 2016)</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>17</td>
<td>Sai</td>
<td>Raibareli (Dec, 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>Sarju</td>
<td>Ghat (Nov, 2014; April, 2017)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>Sharda</td>
<td>Paliakalan (Nov, 2014; Aug, 2016; Dec, 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>Surma/Myntdu</td>
<td>Kharkhana (Aug, 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>Tel</td>
<td>Kantamal (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>28</td>
<td>41</td>
</tr>
</tbody>
</table>

**Summary of COPPER content in Indian rivers**

Copper is a very common substance that occurs naturally in the environment and spreads to the environment through natural phenomena. Humans widely use copper. For instance it is applied in the industries and in agriculture. The production of copper has lifted over the last decades. Due to this, copper quantities in the environment have increased. It is an essential element in human metabolism, and it is well-known that deficiency results in a variety of clinical disorders, including nutritional anaemia in infants. BIS, 10500, 2012 has recommended an acceptable limit of 0.05 mg/L (50µg/L) of copper in drinking water; this concentration limit can be extended to 1.5 mg/L (1500 µg/L) of copper in case no alternative source of water with desirable concentration is available. The intake of large doses of copper has resulted in adverse...
health effects. Copper and its compounds are widely distributed in nature, and copper is found frequently in surface water and in some groundwater.

2451 water samples from 414 water quality stations were collected and analyzed for copper content from May, 2014 to August 2017. Out of 2451 water samples, 13 samples were found to contain copper concentrations above the acceptable limits of 50µg/L throughout the study period, the maximum Copper concentration 314.93 µg/L was observed at Pingalwada water quality station on Dhadher River in April, 2017. Annexure-5, shows the names of water quality stations and the Rivers affected by high copper concentration (>50 µg/L) and these WQ stations are water quality hot spots from the point of view of copper contamination in Indian Rivers.

Total 13 numbers of water samples from 12 numbers of WQ monitoring stations exceeded according to the BIS prescribed acceptable limit situated on 10 Indian Rivers during the study period. Dikhow, Brahmaputra, Buridehing, Damanganga, Dhadher, Ganga, Pranhitha, Sabarmati, Subarnarekha and Tel are the rivers where one or two water quality monitoring stations were contaminated with copper (Table 16).

<table>
<thead>
<tr>
<th>Sr.</th>
<th>River</th>
<th>WQ Sites (Period)</th>
<th>Total number of WQ sites</th>
<th>Total number of water samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dikhow</td>
<td>Bihubar (April, 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Brahmaputra</td>
<td>Tezpur (April, 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Buridehing</td>
<td>Margherita (Nov. 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Damanganga</td>
<td>Vapi (April 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Dhadher</td>
<td>Pingalwada (April, 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Ganga</td>
<td>Kachlabridge (Nov., 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Pranhitha</td>
<td>Tekra (April, 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Sabarmati</td>
<td>Vautha (May, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Subarnarekha</td>
<td>Ghatsila (Feb., 2015; Aug., 2017); Jamsolghat (Aug. 2017)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Tel</td>
<td>Kantamal (Feb., 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total</strong></td>
<td><strong>11</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>

Summary of LEAD content in Indian rivers

Lead is the one of the most common of the heavy elements. It has therefore been used extensively since Roman times and, as a result, has become widely distributed throughout the environment. The acceptable limit (AL) for lead in drinking water is 0.010 mg/L (10μg/L). Above the acceptable limit lead is a cumulative general poison, with foetuses, infants, children up to six years of age and pregnant women (because of their foetuses) being most susceptible to adverse health effects. Lead can severely affect the central nervous system. Overt signs of acute intoxication include dullness, restlessness, irritability, poor attention span, headaches, muscle tremor, hallucinations and loss of memory. Signs of chronic lead toxicity, including tiredness, sleeplessness, irritability, headaches, joint pain and gastrointestinal symptoms, may appear in adults. After one or two years of exposure, muscle weakness, gastrointestinal symptoms, lower
scores on psychometric tests, disturbances in mood and symptoms of peripheral neuropathy were observed in occupationally exposed populations.

Bureau of Indian Standard (10500, 2012) have recommended an acceptable limit of lead is 0.01 mg/L or 10µg/L in drinking water. India some rivers have lead concentration above the acceptable limit prescribed by Bureau of Indian Standards, 10500; 2012. 2400 numbers of water samples from 414 water quality monitoring stations across India were collected and analyzed for lead content using AAS. It is observed that the lead concentrations in 122 water samples are greater than the acceptable limits of lead in drinking water i.e. 10 µg/L as set by BIS. Lead concentration was maximum (374.58 µg/L) at Lowara water quality station on Sheturni River during April, 2016. One hundred twenty two water samples from 91 water quality monitoring stations are observed to have lead concentrations exceeding the acceptable limits in drinking water in 69 Indian Rivers during the study period (Table 17). Brahmaputra, Buridehing, Cauvery, Ganga, Ghagra, Gomti, Ramganga, Rapti, Sone, Thungabhadra, and Yamuna are the rivers where two or more numbers of WQ monitoring stations are contaminated with lead.

Table 17: Rivers and WQ monitoring stations where Lead exceeded the acceptable limit.

<table>
<thead>
<tr>
<th>Sr.</th>
<th>River</th>
<th>WQ Sites (Period)</th>
<th>Total number of WQ sites</th>
<th>Total number of water samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Achankovil</td>
<td>Thumpamon (April, 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Aliyar</td>
<td>Ambarampalayam (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Arkavathi</td>
<td>T. Bekuppe (Feb, 2015; Dec, 2016)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Barak</td>
<td>Fulertal (Dec, 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Brahmani</td>
<td>Gomlai (April, 2017)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Brahmaputra</td>
<td>Pancharatna (Aug., 2016); Pandu (Aug., 2016); Dibrugarh (Aug., 2016);</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>Bugi</td>
<td>Dimapara (Aug., 2016; April, 2017)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Buridehing</td>
<td>Chenimari (Aug., 2016); Margherita (Dec, 2016)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>Cauvery</td>
<td>Kodumudi (Feb, 2015); Urachikottai (Feb, 2015)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Chhoti Sarju</td>
<td>Akarbarpur (Feb, 2015); Dec., 2015)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>Damanganga</td>
<td>Vapi (Aug., 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Dhadher</td>
<td>Pingalwada (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Digaru</td>
<td>Sonapur (Aug., 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Dikhow</td>
<td>Sivasagar (Aug., 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>Dudhnai</td>
<td>Dudhnai (Aug., 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>Ganga</td>
<td>Shahzadpur (Feb, 2015); Bhitaura (Nov, 2014; Feb, 2015); Fatehgarh (Nov, 2014); Kachlabridge (Nov, 2014; Feb, 2015); Kanpur (Nov, 2014; Feb, 2015); Azmabad (Feb, 2015); Buxar (Feb, 2015); Hathidah (Feb, 2015); Ankinghat (Nov, 2014);</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>17</td>
<td>Ghagra</td>
<td>Elginbridge (Nov, 2014); Turtipar (Nov, 2014; Feb, 2015)</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>18</td>
<td>Godavari</td>
<td>Polavaram (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>Gomti</td>
<td>Lucknow (Nov, 2014; Dec, 2016); Neemsar (Nov, 2014; Feb, 2015; Dec, 2016))</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>Hagari</td>
<td>T. Ramapuram (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sr.</td>
<td>River</td>
<td>WQ Sites (Period)</td>
<td>Total number of WQ sites</td>
<td>Total number of water samples</td>
</tr>
<tr>
<td>-----</td>
<td>-----------</td>
<td>----------------------------------------</td>
<td>---------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>21</td>
<td>Haladi</td>
<td>Haladi (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>Hemavathi</td>
<td>Sakleshpur (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>23</td>
<td>Hindon</td>
<td>Galeta (Nov, 2014)</td>
<td>1</td>
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<tr>
<td>24</td>
<td>Indravathi</td>
<td>Nowrangpur (April, 2016)</td>
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<td>25</td>
<td>Jaldhaka</td>
<td>Jaldhaka NH-31 (Nov, 2014)</td>
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<td>26</td>
<td>Jia Bharali</td>
<td>Jiabharali NT Road Xing (Feb, 2015)</td>
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<tr>
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<td>Pattazhy (Feb, 2015; April, 2016)</td>
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<td>Kamang</td>
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<td>Kanhan</td>
<td>Ramakona (Feb, 2015)</td>
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<td>Kharkai</td>
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<td>Kheronighat (Feb, 2015)</td>
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<td>Krishna</td>
<td>Huvin Hedgi (Feb, 2015)</td>
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<td>Kunderu</td>
<td>Alladupalli (Feb, 2015; April, 2017)</td>
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<td>36</td>
<td>Longai</td>
<td>Fakirabazar (May, 2014)</td>
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<td>37</td>
<td>Mahananda</td>
<td>Champasari (Feb, 2015)</td>
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</tr>
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<td>38</td>
<td>Mahi</td>
<td>Khanpur (Dec, 2015)</td>
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</tr>
<tr>
<td>39</td>
<td>Munneru</td>
<td>Keesara (Feb, 2015)</td>
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</tr>
<tr>
<td>40</td>
<td>Narmada</td>
<td>Garudeshwar (Feb, 2015)</td>
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</tr>
<tr>
<td>41</td>
<td>Neo dihing</td>
<td>Miao (Feb, 2015; Dec, 2016)</td>
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<tr>
<td>42</td>
<td>Noyyal</td>
<td>Elunuthimanagalam (Feb, 2015)</td>
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</tr>
<tr>
<td>43</td>
<td>Orsang</td>
<td>Chanwada (Feb, 2015; Aug, 2016)</td>
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<td>44</td>
<td>PagladiYa</td>
<td>Pagladiya N.T. Road Crossing (Aug, 2016)</td>
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<td>45</td>
<td>Palar</td>
<td>Arcot (Aug, 2016)</td>
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<tr>
<td>46</td>
<td>Pennar</td>
<td>Chennur (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>47</td>
<td>Ponnaiyar</td>
<td>Gummanur (Feb, 2015)</td>
<td>1</td>
<td>1</td>
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<tr>
<td>48</td>
<td>Purna</td>
<td>Gopalkheda (Feb, 2015; Aug, 2016)</td>
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<tr>
<td>49</td>
<td>Puthimari</td>
<td>Puthimari D.R.F. (Feb, 2015)</td>
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<tr>
<td>50</td>
<td>Raidak-I</td>
<td>Tufanganj (Feb, 2015)</td>
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<tr>
<td>51</td>
<td>Ramganga</td>
<td>Bareilly (Nov, 2014); Dabri (Nov, 2014; Feb, 2015); Moradabad (May, 2014; Nov, 2014; Feb, 2015)</td>
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<tr>
<td>52</td>
<td>Rapti</td>
<td>Balrampur (Nov, 2014); Bansi (Nov, 2014); Birdghat (May, 2014; Nov, 2014; Feb, 2015); Regauli (May, 2014; Nov, 2014; Feb, 2015)</td>
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<tr>
<td>53</td>
<td>Sabarmati</td>
<td>Vautha (Nov, 2014; Dec, 2015; Dec, 2016)</td>
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</tr>
<tr>
<td>54</td>
<td>Sai</td>
<td>Raibareli (Nov, 2014; Dec, 2016)</td>
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<tr>
<td>55</td>
<td>Sankosh</td>
<td>Sankosh LRP (Feb, 2015)</td>
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</tr>
<tr>
<td>56</td>
<td>Saryu</td>
<td>Ayodhya (Nov, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>57</td>
<td>Seonath</td>
<td>Simga (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>58</td>
<td>Sheturni</td>
<td>Lowara (April, 2016; Dec, 2016)</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Summary of NICKEL content in Indian rivers

Nickel is a nutritionally essential trace metal for at least several animal species, micro-organisms and plants, and therefore either deficiency or toxicity symptoms can occur when, respectively, too little or too much Ni is taken up. According to BIS-10500 (2012) the acceptable limit of nickel in drinking water is 20 μg/L.

Nickel and nickel compounds have many industrial and commercial uses, and the progress of industrialization has led to increased emission of pollutants into ecosystems. Nickel is easily accumulated in the biota, particularly in the phytoplankton or other aquatic plants, which are sensitive bio-indicators of water pollution. It can be deposited in the sediment by such processes as precipitation, complexation and adsorption on clay particles and via uptake by biota.

Total 2023 numbers of water samples from 414 WQ monitoring stations of Central Water Commission were collected and analyzed for Nickel content in Indian Rivers. From the results, it is observed that Nickel concentration in 35 water samples are more than the prescribed limits of BIS. Nickel concentration at Lowara water quality station on Sheturni river in February, 2015 is reported to be the maximum (184.64 μg/L) during the entire study period. Seonath, Subarnarekha and Thungabhadra are the rivers where 2 or more WQ monitoring stations are observed being contaminated with Nickel (Table 18).

35 water samples from 32 water quality monitoring stations over 29 Indian Rivers were observed to have nickel concentration that exceed the acceptable limit during the study period (Table-15). Water quality monitoring stations and Rivers affected by high nickel concentration (>20 μg/L) are presented in Annexure-5 and these WQ stations are hot spots from point of view of nickel pollution.
Table 18: Rivers and WQ monitoring stations where Nickel exceeded the acceptable limit

<table>
<thead>
<tr>
<th>Sr.</th>
<th>River</th>
<th>WQ Sites (Period)</th>
<th>Total number of WQ sites</th>
<th>Total number of water samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Arkavathi</td>
<td>T. Bekuppe (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Brahmani</td>
<td>Panposh (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Ganga</td>
<td>Kachlabridge (Nov, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Hagari</td>
<td>T. Ramapuram (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Hasdeo</td>
<td>Bamnidihih (May, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Ib</td>
<td>Sundergarh (Nov, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Jiabharali</td>
<td>Bhalukpong (May, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Jonk</td>
<td>Rampur (May, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Ken</td>
<td>Banda (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Krishna</td>
<td>Huvin Hedgi (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>Kunderu</td>
<td>Alladupalli (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>Mahanadi</td>
<td>Basantpur (May, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Mand</td>
<td>Kurubhata (May, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Narmada</td>
<td>Barmanghat (Feb, 2015; Dec., 2016)</td>
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<td>2</td>
</tr>
<tr>
<td>15</td>
<td>Noyyal</td>
<td>Elunuthimangalam (Feb, 2015)</td>
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<td>1</td>
</tr>
<tr>
<td>16</td>
<td>Ong</td>
<td>Salebhata (May, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>Orsang</td>
<td>Chanwada (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>Pennar</td>
<td>Chennur (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>Periyar</td>
<td>Vandiperiyar (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>Purna</td>
<td>Gopalkheda (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>Sabarmati</td>
<td>Vautha (Nov, 2014; Feb, 2015)</td>
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<td>2</td>
</tr>
<tr>
<td>22</td>
<td>Saryu</td>
<td>Ayodhya (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>23</td>
<td>Seonath</td>
<td>Ghatora (May, 2014); Simga (May, 2014)</td>
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<td>2</td>
</tr>
<tr>
<td>24</td>
<td>Sharda</td>
<td>Paliakalan (August, 2016)</td>
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<td>1</td>
</tr>
<tr>
<td>25</td>
<td>Sheturni</td>
<td>Lowara (Feb, 2015; April, 2016)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>26</td>
<td>Siang</td>
<td>Passighat (Nov, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>27</td>
<td>Subarnarekha</td>
<td>Ghatsila (May, 2014); Jamshedpur (May, 2014)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>28</td>
<td>Thunganbhadra</td>
<td>Bawapuram (Feb, 2015); Mantraloyam (Feb, 2015)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>29</td>
<td>Vaitarna</td>
<td>Durvesh (Feb, 2015)</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total** 32 35

Summary of ZINC content in Indian rivers

Zinc is an essential element for all living things, including man. Zinc-containing proteins and enzymes are involved in every aspect of metabolism, including the replication and translation of genetic material. BIS has recommended 5 mg/L (5000 µg/L) acceptable concentration of zinc in drinking water, which can be extended to 15 mg/L in case no alternative source of water is available, but the water with more than 5000 µg/L zinc content is not suitable for drinking purpose.
Total 2451 water samples from the 414 water quality monitoring stations were collected and analyzed for zinc content in Indian Rivers in the period between May, 2014 and August 2017. Maximum Zinc concentration (2.65 mg/L) was observed at Manot water quality monitoring station on Narmada River during August, 2016. In the study area, all the River water quality stations are reported to have zinc concentration well within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of Zinc in the River waters is observed during the study period.

**Summary of IRON content in Indian rivers**

According to BIS the acceptable limit of Iron is 0.3 mg/L (300µg/L). The occurrences of iron in River water above maximum acceptable limit (>300 µg/L) have been shown in the table 18. Total 2400 numbers of water samples from 414 WQ monitoring stations were collected and analyzed. Higher concentration of iron >300 µg/L has been observed in 524 water samples collected from 234 WQ stations of 137 Indian Rivers during the study period. The highest concentration of 14.55 mg/L is observed at Chenimari on Buridehing River. Table 19 shows the names of the water quality stations and the Rivers affected by high iron concentration 300 µg/L and these WQ stations are hot spots in terms of Iron concentration (Annexure-5).

Bagmathi, Baitarni, Bhadar, Brahmani, Brahmaputra, Buridehing, Cauvery, Desang, Dhansiri, Dikhow, Gandak, Ganga, Ghagra, Godavari, Gomti, Hemavathi, Indravathi, Jaldhaka, Kanhan, Kamala-Balan, Kopili, Krishna, Lohit, Mahananda, Mahi, Narmada, Neo dihing, Purna, Puthimari, Raidak-I, Rapti, Sai, Sone, Subansiri, Subarnarekha, Tapi, Teesta, Thungabhadra, Tors and Wainganga are the Rivers where three or more water quality stations have been found to have Iron concentration that exceed the limits throughout the study period.

**Table 19: Rivers and WQ monitoring stations where Iron exceeded the acceptable limit**

<table>
<thead>
<tr>
<th>Sr.</th>
<th>River</th>
<th>WQ Sites (Period)</th>
<th>Total number of WQ sites</th>
<th>Total number of water samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aghanashini</td>
<td>Santeguli (Nov, 2014; Aug, 2017)</td>
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<tr>
<td>2</td>
<td>Aie</td>
<td>Aie NH Crossing (Nov, 2014)</td>
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<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Alakananda</td>
<td>Srinagar (Nov, 2014)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Alaknanda</td>
<td>Rudraprayag (May, 2014; Nov, 2014; April, 2016)</td>
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</tr>
<tr>
<td>5</td>
<td>Ambika</td>
<td>Gadat (Aug, 2016; Aug, 2017)</td>
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<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Arkavathi</td>
<td>T. Bekuppe (Dec, 2016)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Bagh</td>
<td>Rajegaon (Aug, 2016; Aug, 2017)</td>
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<tr>
<td>9</td>
<td>Baitarni</td>
<td>Anandpur (Aug, 2017); Champua (Aug, 2017)</td>
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<tr>
<td>10</td>
<td>Balason</td>
<td>Matigara (May, 2014; Nov, 2014)</td>
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</tr>
<tr>
<td>11</td>
<td>Banas</td>
<td>Kamalpur (Aug, 2017)</td>
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<tr>
<td>12</td>
<td>Banjar</td>
<td>Bamni (Aug, 2016; Aug, 2017)</td>
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</tr>
<tr>
<td>13</td>
<td>Barak</td>
<td>B.P. Ghat (Aug, 2017)</td>
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<td>1</td>
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<tr>
<td>Sr.</td>
<td>River</td>
<td>WQ Sites (Period)</td>
<td>Total number of WQ sites</td>
<td>Total number of water samples</td>
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<tr>
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</tr>
<tr>
<td>14</td>
<td>Beki</td>
<td>Beki Road Bridge (Nov, 2014); Beki Mathanguri (May, 2014; Nov, 2014)</td>
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<tr>
<td>15</td>
<td>Bhadar</td>
<td>Ganod (Dec, 2015; Aug, 2017); Holehonnur (Aug, 2017)</td>
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<tr>
<td>16</td>
<td>Bhadra</td>
<td>Holehonnur (Aug, 2017)</td>
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<td>17</td>
<td>Bhagirath</td>
<td>Deoprayag (May, 2014; Nov, 2014); Koteswar (Nov, 2014); Tehri (May, 2014); Uttarkashi (May, 2014; Nov, 2014)</td>
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<tr>
<td>18</td>
<td>Bhagirathi</td>
<td>Katwa (Nov, 2014)</td>
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<td>1</td>
</tr>
<tr>
<td>19</td>
<td>Bhavani</td>
<td>Nellithurai (Nov, 2014)</td>
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</tr>
<tr>
<td>21</td>
<td>Brahmaputra</td>
<td>Pancharata (May, 2014; Nov, 2014; Aug, 2017); Pandu (May, 2014; Aug, 2017; Aug, 2017); Bhomoraguri (Dec, 2015; April, 2016; Aug, 2016; Dec, 2016; April, 2017; Aug, 2017); Dibrugarh (April, 2016; Aug, 2016; April, 2017; Aug, 2017); Dhubri (Nov, 2014); Neamatighat (April, 2016; Aug, 2016; April, 2017; Aug, 2017); Tezpur (Dec, 2015; Aug, 2016; Dec, 2016; April, 2017; Aug, 2017)</td>
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<td>Bugi</td>
<td>Dimapara (Dec, 2016)</td>
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<td>23</td>
<td>Burhabalang</td>
<td>Govindapur (Aug, 2017)</td>
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<tr>
<td>24</td>
<td>Burhi Gandak</td>
<td>Sikandarpur (Aug, 2017)</td>
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<td>1</td>
</tr>
<tr>
<td>26</td>
<td>Buridehing</td>
<td>Chenimari (April, 2016; Aug, 2016; Dec, 2016; April, 2017; Aug, 2017; Margherita (April, 2016; Aug, 2016; Dec, 2016; April, 2017; Aug, 2017); Naharkatia (Dec, 2015; April, 2016; Aug, 2016; Dec, 2016; April, 2017; Aug, 2017)</td>
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<td>16</td>
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<tr>
<td>27</td>
<td>Burisuti</td>
<td>Panbari (Nov, 2014)</td>
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</tr>
<tr>
<td>28</td>
<td>Cauvery</td>
<td>Chuchankatte (Aug, 2017); Kudige (Dec, 2015; Aug, 2017)</td>
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</tr>
<tr>
<td>29</td>
<td>Champamati</td>
<td>Bahalpur (Nov, 2014)</td>
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<tr>
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<td>Chel</td>
<td>Chel (May, 2014; Nov, 2014)</td>
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<tr>
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<td>Chhoti Sarju</td>
<td>Akabarpur (Aug, 2016)</td>
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<td>Hanskhali (Nov, 2014)</td>
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<td>33</td>
<td>Damanganga</td>
<td>Vapi (Nov, 2014; Aug, 2016; April, 2017; Aug, 2017)</td>
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<tr>
<td>35</td>
<td>Dhadher</td>
<td>Pingalwada (Aug, 2016; April, 2017; Aug, 2017)</td>
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<tr>
<td>36</td>
<td>Dhansiri</td>
<td>Bokajan (Dec, 2015; Aug, 2016; Dec, 2016; April, 2017; Aug, 2017); Golaghat (Aug, 2016; Dec, 2016; April, 2017)</td>
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</tr>
<tr>
<td>Sr.</td>
<td>River</td>
<td>WQ Sites (Period)</td>
<td>Total number of WQ sites</td>
<td>Total number of water samples</td>
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<tr>
<td>-----</td>
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<tr>
<td>37</td>
<td>Digaru</td>
<td>Sonapur (May, 2014; Dec, 2015; April, 2017)</td>
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<td>Harohar/Phalgu</td>
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<td>Indravathi</td>
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<td>River</td>
<td>WQ Sites (Period)</td>
<td>Total number of WQ sites</td>
<td>Total number of water samples</td>
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<td>Jiabharali</td>
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<td>Meenachi</td>
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<td>Murti</td>
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<td>Total number of water samples</td>
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<td>Pagladiya</td>
<td>Pagladiya N.T.Road Crossing (May, 2014)</td>
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<td>P.G.Bridge (Aug, 2016)</td>
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<td>WQ Sites (Period)</td>
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<td>Total number of water samples</td>
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11. CONCEPT OF NORMALIZATION:

In statistics and applications of statistics like data interpretation, normalization can have a range of meanings. In the simplest cases, normalization of ratings means adjusting values measured on different scales to a notionally common scale, often prior to averaging. In more complicated cases, normalization may refer to more sophisticated adjustments where the intention is to bring the entire probability distributions of adjusted values into alignment. In another usage in statistics, normalization refers to the creation of shifted and scaled versions of statistics, where the intention is that these normalized values allow the comparison of corresponding normalized values for different datasets in a way that eliminates the effects of certain gross influences, as in an anomaly time series.

In this present case normalization concept is adopted to normalize the water quality Trace & Toxic parameters for data interpretation to attain alignment in representation and to make its respective permissible limit value into one unique value as 1 (one).

**Normalized Value:** Each parameter is divided with its own permissible limit. Following that, permissible limit for all parameters also turns as 1 (one) and taking it as Threshold Value.

**Threshold Value for all parameters is - 1**

Seasonal wise normalized value graphs plotted here by considering the parameters such as Cadmium (Cd), Chromium (Cr) and Lead (Pb) with respect to their lethal capacity and Iron (Fe) taken into account because of its more availability as pollutant during the study period.

11.1 GANGA RIVER

The Ganga is the 20th longest river in the Asia and the 41st longest in the world (Source: Philips World Atlas). The headwaters region of Ganga is the Himalayas dotted by number of mighty tributaries. The Bhagirathi river that rises from the Gangotri glacier near Gomukh at an elevation of about 7,010 m above mean sea level in the Uttarkashi district of Uttarakhand is considered as the source of Ganga river. It descends down the valley up to Devprayag where after joining another hill stream Alaknanda, it is called Ganga. Flowing downhill, the river is joined by a number of streams, such as the Mandakini, the Dhuli Ganga and the Pindar. The principal tributaries joining the river from right are the Yamuna and the Son. The Ramganga, the Ghagha, the Gandak, the Kosi and the Mahananda join the river from left. The total length of river Ganga (measured along the Bhagirathi and the Hooghly) up to its outfall into Bay of Bengal is 2,525 km with 631 km navigable length.

Ganga has been a cradle of human civilization since time immemorial. Millions depend on this great River for physical and spiritual sustenance. It is a life-line, a symbol of purity and virtue for countless people of India. But due to rapid industrialization, increase in urban population, change in lifestyle, use of artificial fertilizer has led to deterioration in water quality of holy river Ganga. At certain stretches the river water is grossly polluted mostly due to industrial and municipal sewage discharge in the river Ganga. There are 18 water quality stations at Deoprayag, Rishikesh, Haridwar, Garhmukteshwar, Kachlabridge, Fatehgarh, Ankinghat, Kanpur, Bhitura,
Shahzadpur, Chhatnag Allahabad, Mirzapur, Varanasi, Buxar, Gandighat (Patna), Hathidah, Azamabad and Farakka on the main stream of the river Ganga.

Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except iron from Ankighat to Azmabad stretch during monsoon. In this study area, all the Ganga River water quality stations data reported that arsenic and zinc concentration lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of arsenic and zinc in the River waters is observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Ganga River are 0.002-3.936µg/L; 0.080-205.82 µg/L; 0.020-36.91 µg/L and 0.002-1.53 mg/L respectively during the May, 2014 and August 2017. The chromium and lead are very
toxic metal originates mainly from industrial effluents. During the study period 3% and 8% samples are found above the permissible limit in respect of chromium and lead. Generally elementary iron dissolves in water under normal conditions. The iron concentration in the River Ganga was varied 0.002-1.53 mg/L.

11.2 YAMUNA RIVER

Yamunotri, which is north of Haridwar in the Himalayan Mountains, is the source of the Yamuna. The river Yamuna, a major tributary of river Ganges, originates from the Yamunotri glacier near Banderpoorch peaks (38° 59' N 78° 27' E) in the Mussourie range of the lower Himalayas at an elevation of about 6387 meters above mean sea level in district Uttarkashi (Uttarakhand). The track along the river bank is quite magnificently dominated by wide panorama of mountains. In its first 170 km stretch, the tributaries Rishi Ganga Kunta, Hanuman Ganga, Tons and Giri join the main river.

Arising from the source, river Yamuna flows through a series of valleys for about 200 Kms, in lower Himalayas and emerges into Indo-Gangetic plains. In the upper reaches, the main valley is overlooked by numerous hanging valleys, carved by glaciers during the last ice ages. The gradient of the river is steep here and the entire geomorphology of the valley has been influenced by the passage of the river. In the upper stretch of 200 Km, it draws water from several major streams. The combined stream flows through the Shivalik range of hills of Himachal Pradesh and Uttarakhand states of India and enters into plains at Dak Pathar in Uttarakhand where the river water is regulated through weir and diverted into canal for power generation. From Dak Pathar it flows through the famous Sikh religious place of Poanta Sahib. On the right side of the Yamuna basin is the Mussourie spur-along which, lies sprawled, the hill station of Mussourie. Flowing through Poanta Sahib it reaches Hathnikund/Tajewala in Yamuna Nagar district of Haryana state, where the river water is again diverted into Western Yamuna canal and Eastern Yamuna canal for irrigation. During dry season, no water is allowed to flow in the river downstream to Tajewala barrage and the river remains dry in some stretches between Tajewala & Delhi. The rivers regain water because of ground water accrual and contributions of feeding canal through Somnadi (seasonal stream) upstream of Kalanaur. It enters Delhi near Palla village after traversing a route of about 224 Km.

The river is again tapped at Wazirabad through a barrage for drinking water supply to Delhi. Generally, no water is allowed to flow beyond Wazirabad barrage in dry season, as the available water is not adequate to fulfill the demand of water supply of Delhi.

Whatever water flows in the downstream of Wazirabad barrage is the untreated or partially treated domestic and industrial wastewater contributed through several drains along with the water transported by Haryana Irrigation Department from Western Yamuna Canal (WYC) to Agra Canal via Nazafgarh Drain and the Yamuna. After 22 Km downstream of Wazirabad barrage there is another barrage, Okhla barrage, through which Yamuna water is diverted into Agra Canal for irrigation. No water is allowed to flow through barrage during dry season. Whatever water flows in the river beyond Okhla barrage is contributed through domestic and industrial wastewater generated from East Delhi, Noida and Sahibabad and joins the river through Shahdara drain. The Yamuna, after receiving water through other important tributaries, joins the river Ganga and the underground Saraswati at Prayag (Allahabad) after traversing about 950 Km. Thus, Yamuna river cannot be designated as continuous river particularly in dry seasons (almost 9 months), but can
be segmented in five distinguished independent segments due to characteristic hydrological and ecological conditions. The catchments of Yamuna river system cover parts of Uttar Pradesh, Uttarakhand, Himachal Pradesh, Haryana, Rajasthan, Madhya Pradesh & Delhi states. There are thirteen (13) water quality stations at Poanta, Kalanour, Mawi, Palla, Delhi, Mathura, Mohana, Agra, Auraiya, Etawah, Hamirpur, Rajapur and Pratappur on river Yamuna.

**Observations/Findings:**

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except iron at Agra during monsoon. In this study area, all the Yamuna River water quality stations data reported that arsenic, chromium, copper, nickel and zinc concentration lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of arsenic, chromium, copper, nickel and zinc in the River waters is observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Yamuna River are 0.002-9.166 µg/L; 0.002-
36.370 µg/L; 0.040-20.044 µg/L and 0.002-0.613 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 6%, 3% and 2% samples are found above the permissible limit in respect of Cadmium, lead and Iron.

### 11.3 RIVER CHAMBAL

The Chambal River, called Charmanvati in ancient times, is the largest of the rivers flowing through Rajasthan state. This tributary of Yamuna is 960km long. The total area drained by the Chambal up to its confluence with the Yamuna is 143,219 sq km out of which 76,854 sq km lies in M.P. state, 65,264 sq km in Rajasthan state and 1,101 sq km in Uttar Pradesh. River Chambal, the biggest tributary of Yamuna rises in Vindhyan range near Mhow in Indore District of Madhya Pradesh at an elevation of 354 m at north latitude 22° 28' and east longitude 75° 40'. Chambal basin is bound on north by the ridge separating it from Luni and Yamuna basins, on the south by Vindhyan range and on the west by Aravali range, on east lies the ridge separating it from Kunwari and Sind rivers of Yamuna basin. Chambal basin lies between north latitudes 22° 27' and 27° 20' and east longitudes 73° 20' and 79° 15'. Its total catchment area is 1,39,468 sq.km. There are three (03) water quality stations at Tal, Dholpur, and Udi on River Chambal.
Observations/Findings:
From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons all the parameters observed below the threshold value. In this study area, all the Chambal River water quality stations data reported that all trace and toxic metal (arsenic, cadmium, chromium, copper, nickel, lead, zinc and iron) concentration lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of aforesaid metals in the River waters is observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Chambal River are 0.002-1.251 µg/L; 0.680-12.290 µg/L; 0.010-5.070 µg/L and 0.020-0.276 mg/L respectively during the May, 2014 and August 2017.

11.4 BRAHMAPUTRA RIVER

The Brahmaputra River originates in the north from Kailash ranges of Himalayas at an elevation of 5,150 m just south of the lake called Konggyu Tsho and flows for about a total length of 2,900 km. In India, it flows for 916 km. The principal tributaries of the river joining from right are the Lohit, the Dibang, the Subansiri, the Jiabharali, the Dhansiri, the Manas, the Torsa, the Sankosh and the Teesta whereas the Buridehing, the Desang, the Dikhow, the Dhansiri and the Kopili joins it from left. There are 48 water quality stations in Brahmaputra basin out of which six (06) stations Bhomoraguri, Dibrugarh, Pancharatna, Pandu, Tezpur and Neamatighat are located on the main stream of Brahmaputra.
Observations/Findings:
From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron from Dibrugarh to Pandu stretch in both the seasons. In this study area, all the Brahmaputra River water quality stations data reported that arsenic, cadmium, nickel and zinc concentration lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of arsenic, cadmium, nickel and zinc in the River waters is observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Brahmaputra River are 0.002-1.314 µg/L; 0.070-53.100 µg/L; 0.020-21.480 µg/L and 0.008-9.872 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 2%, 2% and 46% of samples are found above the permissible limit with respect to Chromium, Copper and Iron.

11.5 RAMGANGA RIVER

Ramganga is the first major tributary joining Ganga. It rises at an altitude of about 3,110 m in the lower Himalayas near the Lohba village in the Garhwal district of Uttarakhand. The length of the Ramganga River from the source to the confluence with the Ganga is 596 km. During its course, the river flows through a mountainous terrain and has a number of falls and rapids. The river enters the plains at Kalagarh near the border of the Garhwal district, where the famous Ramganga dam has been constructed. Beyond Kalagarh, the river flows in a southeasterly direction and finally joins the Ganga on its left bank near Kanauj in the Fategarh district. The river flows entirely in the states of Uttar Pradesh and Uttarakhand. The catchment area of the basin is about 32,493 sq. km. The important tributaries that join the Ramganga River are the Kho, the Gangan, the Aril, the Kosi, and the Deoha (Gorra). There are three (03) water quality stations at Moradabad, Bareilly and Dabri on river Ramganga.

![Ramganga River (Monsoon)](image-url)

**BIS Standards:**
Cadmium-0.003mg/L (3µg/L); Chromium- 0.05mg/L (50µg/L)
Lead- 0.01 mg/L (10µg/L); Iron – 0.3 mg/L (300 µg/L)
From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron throughout the Ramganga river stretch in both the seasons. In this study area, all the Ramganga River water quality stations data reported that arsenic, cadmium, copper, nickel and zinc concentration lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of arsenic, cadmium, copper, nickel and zinc in the River waters is observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Ramganga River are 0.032-1.749 µg/L; 0.040-230.9 µg/L; 0.010-32.850 µg/L and 0.008-1.16 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 4%, 25% and 50% of samples are found above the permissible limit with respect to Chromium, Lead and Iron.

11.6 RAPTI RIVER

The Rapti is a tributary of Ghaghra river. The Rapti rises in the south of a prominent E-W ridgeline midway between the western Dhaulagiri Himalaya and the Mahabharat Range. A 3,500 metres summit on this ridgeline marks a triple divide. North of the triple divide the Karnali and Gandaki basins are adjacent; south of it the Rapti and similar but smaller Babai River separate the two larger basins. After crossing into India, the Babai and Rapti separately join the Karnali’s continuation called Ghaghara. The Ghaghara ultimately joins the Ganges, as does the Gandaki. Four (04) water quality monitoring stations at Balrampur, Birdghat, Reguli and Bansi are being operated by CWC on the Rapti River.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron throughout the rapti river stretch in both the seasons. In this study area, all the Rapti River water quality stations data reported that arsenic, copper, nickel and zinc concentration lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of arsenic, copper, nickel and zinc in the River waters is observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Rapti River are 0.009-3.493 µg/L; 0.043-229.73 µg/L; 0.030-18.650 µg/L and 0.006-1.362 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 10%, 39%, 26% and 45% of samples are found above the permissible limit with respect to Cadmium, Chromium, Lead and Iron.
11.7 NARMADA RIVER

Narmada is the largest west flowing river of the peninsular India. It rises from Maikala range near Amarkantak in Anuppur district of Madhya Pradesh, at an elevation of about 900 m. The total length of the river is 1,312 km and its important tributaries are the Burhner, the Banjar, the Sher, the Shakkar, the Dudhi, the Tawa, the Ganjal, the Kundi, the Goi and the Karjan which join from left whereas the Hiran, the Tendoni, the Barna, the Kolar, the Man, the Uri, the Hatni and the Orsang join from right. Narmada drains into the Arabian Sea through the Gulf of Khambhat. There are eight (08) water quality stations at Barmanghat, Dindori, Handia, Hoshangabad, Madleshwar, Manot, Garudeshwar and Sandia on the main stream of river Narmada while ten (10) water quality stations are located at its tributaries viz., Orsang, Banjar, Sakkar, Burhner, Sher, Ganjal, Uri, Kundi, Hiran and Goi. Narmada River has 41 tributaries. Of these, 22 are on the left bank and 19 are on the right.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron from manot to hoshangabad stretch during monsoon season. In this study area, all the Narmada River water quality stations data reported that arsenic, cadmium, chromium, copper and zinc concentration lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of arsenic, cadmium, chromium, copper and zinc in the river waters is observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Narmada River are 0.002-1.201 µg/L; 0.080-26.66 µg/L; 0.080-21.930 µg/L and 0.002-1.1 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 3%, 1% and 13% of samples are found above the permissible limit with respect to Nickel, Lead and Iron.

11.8 SONE RIVER

The river Sone is an important right bank tributary of the river Ganga. It originates from Amarkantak high lands in hills of Maikala range in Bilaspur district of Chhattisgarh at an elevation of 640 m and latitude 20°44' N and longitude 82°4'E. The river outfalls into the Ganga at about 16 km. upstream of Patna at latitude 25°14' N and longitude 84°42’ E. The total catchment area of river system is 70,055 sq.km. The catchment of the whole river system is surrounded by the Vindhachal range in the North, the Punpun river system and the Chotanagpur plateau on the East, the Baghelkhand plateau and the Chotanagpur plateau on the South and the forest clad Maikal and Bhamver ranges on the West. After flowing a distance of 655 km. through the states of Chhattisgarh, Madhya Pradesh and Uttar Pradesh, the river Sone enters in Jharkhand. Its important tributaries lying in the states of Chhattisgarh, Madhya Pradesh, Uttar Pradesh and Jharkhand are Johilla, Mahanadi, Banas, Gopad, Rihand, Ghaghar, Kanhar and North Koel. The river Kanhar, a tributary of Sone, flows South to North and in the downstream reach and forms boundaries between Jharkhand and Madhya Pradesh. The total length of the river is 784 km, out of which about 500 km lies in Madhya Pradesh, 82 km in Uttar Pradesh and the remaining 202 km in Bihar. There are five (05) water quality stations at Kuldah Dridge, Chopan, Goverdhey Ghat, Japla and Koelwar on river Sone.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron throughout sone river stretch during monsoon season. In this study area, all the Sone River water quality stations data reported that arsenic, chromium, copper, nickel and zinc concentration lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of arsenic, chromium, copper, nickel and zinc in the river waters is observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Sone River are 0.006-3.034 µg/L; 0.240-16.650 µg/L; 0.010-16.750 µg/L and 0.002-2.050 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 3%, 6% and 20% of samples are found above the permissible limit with respect to Cadmium, Lead and Iron.

11.9 GODAVARI RIVER

The Godavari River rises from Trimbakeshwar in the Nashik district of Maharashtra about 80 km from the Arabian Sea at an elevation of 1,067 m. The total length of Godavari from its origin to outfall into the Bay of Bengal is 1,465 km. Its principal tributaries joining from right are the Pravara and the Manjra whereas the Purna, the Penganga, the Wardha, the Wainganga, the Indravati and the Kolab joins from left. There are nine (09) water quality stations at Bhadrachalam, Perur, Polavaram, Mancherial, Dhaligaon, G.R. Bridge, Koperagaon, Nanded and Yelli on Godavari River.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron at mancherial in monsoon season. In this study area, all the Godavari River water quality stations data reported that arsenic, cadmium, chromium, copper, nickel and zinc concentration lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of arsenic, cadmium, chromium, copper, nickel and zinc in the river waters is observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Godavari River are 0.009-1.489 µg/L; 0.010-21.510 µg/L; 0.020-22.870 µg/L and 0.002-0.670 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 5% and 19% of samples are found above the permissible limit with respect to Lead and Iron.
11.10 WAINGANGA RIVER

The Wainganga River originates near village Partabpur or Mundara (21°57’N & 79°34’E) about 20 km from the town of Satapura plateau and flows in a wide half circle, bending and winding among the spurs of the hills from the west to the east of the Seoni District. Here it is directed to the South being joined by the Thanwar river from Mandla and forms boundary of Seoni for some Kilometers until it enters Balaghat. Subsequently emerging from the hills the river flows south & south-west through rich rice lands of Balaghat, Bhandara & Pauni. The principal tributaries of the river are Bagh in Balaghat, Bawanthar, Kanhan Chulband in Bhandara & Garvhi in Chandrapur. It then flows through Chandrapur & Gadchiroli Districts and after a course of about 570 km. joins the Wardha at Seoni in Chandrapur district. The total catchment area of the river upto its confluence with river Wardha is 51000 Sq. Km. There are four (04) water quality stations at Ashti, Keolari, Kumhari and Pauni on river Wainganga.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron throughout the complete wainganga river stretch during monsoon season. In this study area, all the Wainganga River water quality stations data reported that all trace & toxic metal (Arsenic, Cadmium, Chromium, Copper, Nickel, Lead and Zinc) concentrations excluding iron lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of above said trace & toxic metals in the river waters are observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Wainganga River are 0.003-0.741 µg/L; 0.110-12.710 µg/L; 0.060-5.380 µg/L and 0.012-0.740 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 19% of samples are found above the permissible limit with respect to Iron.

11.11 KRISHNA RIVER

The Krishna is the second largest eastward draining interstate river in Peninsular India. The Krishna River rises from the Western Ghats near Jor village of Satara district of Maharashtra at an altitude of 1,337 m just north of Mahabaleshwar in Maharashtra. Thirteen major tributaries join the Krishna River along its course, out of which six are right bank tributaries and seven are left bank tributaries. All the major tributaries draining the base of the triangle fall into the Krishna River in the upper two thirds of its length. Among the major tributaries, the Ghatprabha, the Malprabha and the Tungabhadr are the principal right bank tributaries which together account for 35.45% of the total catchment area, whereas the Bhima and the Musi are the principal left bank tributaries which together account 35.62% of the total catchment area. The total length of the river from origin to its outfall into the Bay of Bengal is about 1300 km. There are six (06) water quality stations at Wadenapally, Vijaywada, Kurundwad, Arjunwad, Huvenhedigi and Karad on Krishna River.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for Iron at arjunwad and huvinhedgi during monsoon season. In this study area, all the Krishna River water quality stations data reported that Arsenic, Cadmium, Copper and Zinc concentrations lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of Arsenic, Cadmium, Copper and Zinc in the river waters are observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Krishna River are 0.01-2.708 µg/L; 0.050-98.350 µg/L; 0.260-14.340 µg/L and 0.00 8-0.396 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 8%, 14%, 8% and 17% of samples are found above the permissible limit with respect to Chromium, Nickel, Lead and Iron.

11.12 TUNGABHADRA RIVER

Tungabhadra River is formed from the union of the two rivers, namely Tunga and Bhadra, which together rise in Varahagiri in the Western Ghats of Karnataka State at an altitude of about 1,196m. The two rivers confluence at a village called Kudali near Shimoga. The united Tungabhadra River flows for about 531 km in a generally northeasterly direction, through Mysore and Andhra Pradesh and joins the Krishna at an elevation of about 264 m beyond Karnool. The length of the river is 786 km. The important tributaries of the Tungabhadra River are the Varada, the Hagari, the Vedavati, and the Kumudvati. The total drainage area of the Tungabhadra is 71,417 km². There are four (04) water quality stations at Bawapuram, Harlahalli, Honnali and Holehonnur on Tungabhadra River.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron from honnalli to harlahalli stretch during monsoon season. In this study area, all the Thungabhadra River water quality stations data reported that Arsenic, Chromium, Copper and Zinc concentrations lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of Arsenic, Chromium, Copper and Zinc in the river waters are observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Thungabhadra River are 0.003-5.475 µg/L; 0.150-21.410 µg/L; 0.060-33.410 µg/L and 0.011-0.577 mg/L, respectively during the May, 2014 and August 2017. During the study period approximately 13%, 15%, 13% and 13% of samples are found above the permissible limit with respect to Cadmium, Nickel, Lead and Iron.
11.13 MAHANADI RIVER

The Mahanadi River is one of the major rivers which flow from west to east and finally drains into the Bay of Bengal. The Mahanadi River rises in a pool, 6km from Pharsiya village near Nagri town in Raipur district of Chhattisgarh at a height of 442m. The Mahanadi flows for a total length of about 851 km of which, 357km is in Chhattisgarh and the balance of 494 km is in Odisha. The river enters Odisha state below Baloda Bazaar and crosses the Eastern Ghats to enter the Plains of Odisha near Cuttack. It is finally debouches into the Bay of Bengal through a series of branches. The Seonath, the Jonk, the Hasdeo, the Mand, the Ib, the Ong and the Tel are the principal tributaries of Mahanadi. There are four (04) water quality stations at Tikarapara, Basantpur, Seorinarayan and Rajim on main stream of river Mahanadi.

BIS Standards-
Cadmium-0.003mg/L (3μg/L); Chromium- 0.05mg/L (50μg/L)
Lead- 0.01 mg/L (10μg/L); Iron – 0.3 mg/L (300 μg/L)
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron at Tikarpara in monsoon season. In this study area, all the Mahanadi River water quality stations data reported that Arsenic, Cadmium, Chromium, Copper, Lead and Zinc concentrations lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of Arsenic, Cadmium, Chromium, Copper, Lead and Zinc in the river waters are observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Mahanadi River are 0.015-0.836 µg/L; 0.260-31.620 µg/L; 0.040-7.180 µg/L and 0.009-0.557 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 11% and 10% of samples are found above the permissible limit with respect to Nickel and Iron.

11.14 BRAHMANI RIVER

The Brahmani River is the second largest river in the state of Odisha. In fact, two headwater streams, namely Sankh River and South Koel River originate in Chhattisgarh and Jharkhand states, respectively. After the confluence of Sankh River and South Koel River at Vedvyas, the combined river is known by the name Brahmani. The Brahmani River flows through the heart of Odisha till it joins the Bay of Bengal at Dhamara mouth. After the confluence at Vedvyas, the Brahmani River heads towards the southeast direction and traverses a total length 461 km before it joins the Bay of Bengal. It drains a total catchment area 39,269 km². There are four (04) water quality stations at Gomlai, Jenapur, Panposh and Talcher on river Brahmani.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron throughout Brahmani river stretch in monsoon season and at Panposh during non-monsoon. In this study area, all the Brahmani River water quality stations data reported that Arsenic, Cadmium, Chromium, Copper, Lead and Zinc concentrations lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of Arsenic, Cadmium, Chromium, Copper and Zinc in the river waters are observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Brahmani River are 0.006-0.688 µg/L; 0.100-36.960 µg/L; 0.030-77.420 µg/L and 0.008-1.793 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 5% and 29% of samples are found above the permissible limit with respect to Nickel and Iron.

11.15 SUBERNAREKHA RIVER

The Subernarekha River rises near Nagri village in the Ranchi District of Jharkhand at an elevation of 600 m. It flows for a length of 395 km before outfalling into the Bay of Bengal. Out of this, 269 km lies in Bihar, 64km in West Bengal and 62km in Odisha. There are three (03) water quality stations at Ghatsila, Jamshedpur, Jamsolghat and Muri on river Shernarekha. Its principal tributaries joining from right are the Kanchi, the Karkari and the Kharkai.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron throughout Subernarekha river stretch in monsoon season. In this study area, all the Subernarekha River water quality stations data reported that Arsenic, Cadmium, Chromium, and Zinc concentrations lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of Arsenic, Cadmium, Chromium, and Zinc in the river waters are observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Subernarekha River are 0.004-1.533 µg/L; 0.190-11.6 µg/L; 0.050-37.420 µg/L and 0.008-1.793 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 5% and 29% of samples are found above the permissible limit with respect to Nickel and Iron.
11.16 CAUVERY RIVER

The Cauvery River is one of the major rivers of the peninsula. It rises at an elevation of 1,341 m at TalaCauvery on the Brahmagiri range near Cherangala village of Kodagu district of Karnataka. The total length of the river from origin to outfall is 800 km. Its important tributaries joining from left are the Harangi, the Hemavati, the Shimsha and the Arkavati whereas the Lakshmantirtha, the Kabbani, the Suvarnavati, the Bhavani, the Noyyal and the Amaravati join from right. The river drains into the Bay of Bengal. There are seven (07) water quality stations at Biligundullu, Chuchankatte, Kollegal, Kudige, Kodumudi, Musiri and Urachikottai on the main stream of Cauvery river.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except for iron at chuchankatte and kudige stations in monsoon season. In this study area, all the Cauvery River water quality stations data reported that Arsenic, Cadmium, Chromium, Copper Nickel and Zinc concentrations lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of Arsenic, Cadmium, Chromium, Copper Nickel and Zinc in the river waters are observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Cauvery River are 0.008-1.609 µg/L; 0.150-35.36 µg/L; 0.010-16.670 µg/L and 0.004-0.416 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 6% and 8% of samples are found above the permissible limit with respect to Lead and Iron.

11.17 PENNAR RIVER

The Pennar (also known as Uttara Pinakini) is one of the major rivers of the peninsula. The Pennar rises in the Chenna Kasava hill of the Nandidurg range, in Chikkaballapura district of Karnataka and flows towards east eventually draining into the Bay of Bengal. The total length of the river from origin to its outfall in the Bay of Bengal is 597 km. The principal tributaries of the river joining from left are the Jayamangali, the Kunderu and the Sagileru whereas the Chiravati, the Papagni and the Cheyyeru joins it from right. There are four (04) water quality stations at Chennur, Nagalamadike, Nellore and Tadipatri on river Pennar.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value. In this study area, all the Pennar River water quality stations data reported that Arsenic, Cadmium, Chromium, Copper Nickel, Zinc and Iron concentrations lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity of Arsenic, Cadmium, Chromium, Copper Nickel, Zinc and Iron in the river waters are observed during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Pennar River are 0.005-0.683 µg/L; 0.180-20.24 µg/L; 0.580-38.5 µg/L and 0.014-0.199 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 11% and 10% of samples are found above the permissible limit with respect to Nickel and Lead.

11.18 PALAR RIVER

The Palar Basin is an important basin among the 12 basins lying between the Pennar and the Cauvery basins. This basin is divided into three major topographical divisions namely, i) the hill ranges of Eastern Ghats ii) the plateau region and iii) the coastal plains. Though most of the drainage area lies in Tamil Nadu, its drainage area extends to cover the South-East and South-Western parts of Karnataka and Andhra Pradesh respectively. The shape of the basin is rhombus and finds its outlet in to Bay of Bengal. Central Water Commission is operating three (03) water quality monitoring stations at Avarankuppam, Arcot and Chengalpet on this river.
**Observations/Findings:**

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except Lead at Arcot in both the seasons. In this study area, all the Palar River water quality stations data reported that all the trace and toxic metal (Arsenic, Cadmium, Chromium, Copper, Nickel, Zinc and Iron) concentrations excluding Lead lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity in the river waters are observed for aforementioned trace & toxic metals excluding lead during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Palar River are 0.010-0.136 μg/L; 0.970-10.14 μg/L; 0.020-51.52 μg/L and 0.003-0.212 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 14% of samples are found above the permissible limit with respect to Lead.

**11.19 GOMTI RIVER**

The Gomti River originates near Mainkot, about 3 km east of the Pilibhit town in Uttar Pradesh, at an elevation of 200 m. The river drains the area between Ramganga and Ghaghra systems. The total length of the river is about 940 km and it flows entirely in the State of Uttar Pradesh. The total drainage area of the river is 30,437 sq. km. The river flows through Sahajahanpur, Kheri, Lucknow, Barabanki, Sultanpur, Faizabad, Jaunpur, Varanasi and Ghazipur districts before merging into the Ganga in Audihar in Jaunpur. Lucknow, the capital city of Uttar Pradesh, is situated on the banks of the Gomti River. The main tributaries of the Gomti River are the Gachai, the Sai, the Jomkai, the Barna, the Chuha and the Sarayu. There are five (05) water quality stations at Neemsar, Lucknow, Sultanpur, Maighat and Jaunpur on river Gomti.
Observations/Findings:

From the above graphs it is observed that, during the study period in monsoon and non-monsoon seasons almost all the parameters observed below the threshold value except Iron from Sultanpur to Maighat river stretch in monsoon season. In this study area, all the Gomti River water quality stations data reported that Arsenic, Cadmium, Chromium, Copper, Nickel and Zinc concentrations lies within the acceptable and permissible limits of Bureau of Indian Standards (BIS) and no toxicity in the river waters are observed for Arsenic, Cadmium, Chromium, Copper, Nickel and Zinc metals during the study period. The concentration of the cadmium, chromium, lead and iron varies in the Gomti River are 0.037-1.414 µg/L; 0.190-45.340 µg/L; 0.140-23.440 µg/L and 0.009-0.782 mg/L respectively during the May, 2014 and August 2017. During the study period approximately 16% and 28% of samples are found above the permissible limit with respect to Lead and Iron.
12. INDEX VALUE CALCULATION:

Index Value = Average of Normalised Values of all parameters.

Parameters considered for Index Value calculations:
(a) Cadmium (Cd)  (b) Chromium (Cr)  (c) Copper (Cu)
(d) Nickel (Ni)    (e) Lead (Pb)       (f) Iron (Fe)

Threshold value = 1 (One)

Index Value Trends along the Rivers during the study period:
13. CONCLUSION

A comprehensive study of the results reveals that out of 414 River water quality stations monitored, water samples collected at 136 water quality stations are found within the permissible limit for all purposes. While 57 stations were obtained beyond the permissible limit due to presence of two or more toxic metals. There are 168 numbers of stations where water was considered unfit for drinking purpose due to presence of Iron concentration beyond permissible limit. Similarly water is found unfit for drinking purpose at nineteen stations due to presence of cadmium, at four stations due to presence of copper, at seven stations due to presence of Chromium, at seventeen stations due to presence of nickel and sixty three stations due to presence of lead contamination. Nevertheless, it was concluded that Arsenic and Zinc concentrations are found within the acceptable limits as per Bureau of Indian Standards (BIS) and no toxicity of Arsenic and Zinc in the River waters is observed during the study period.

Furthermore, it is evident from the Annexure-4 that few water quality stations and stretches which are located on the major rivers were found contamination with more than two toxic metals where it is necessary to take immediate attention to remediate the river waters as far as drinking purpose concern. The details thereof is an under,

- Dibrugarh WQ Station has contaminated with respect to Pb and Fe, Tezpur WQ Station was contaminated with respect to Cu, Cr and Fe which are located on Brahmaputra River.
- Chenimari and Margherita WQ Stations located on Buridehing River have been contaminated with respect to Pb and Fe.
- Bihabar WQ Station with respect to Cr, Cu and Fe, Sivasagar WQ Station with respect to Pb and Fe got contaminations which are located on Buridehing River.
- Locations on Ganga River like Ankinghat WQ Station has contaminated with respect to Pb and Fe, Bhitaura, Fatehgarh and Kanpur WQ stations have been contaminated with respect to Cr, Pb and Fe, WQ Station at Kachlabridge has been contaminated with Cr, Cu, Ni, Pb and Fe.
- WQ Stations located on Ghagra River such As Elginbridge and Turtipar have been contaminated with respect to Cr, Pb and Fe.
- Huvenhedgi WQ Station situated on Krishna River having pollution with respect to Ni and Pb.
- Gopalkheda WQ Station was contaminated with respect to Pb, Cu and Fe, Mahuwa WQ Station has contaminated with respect to Cr and Fe which are located on Purna River.
- WQ Stations located on Ramaganga River such as Dabri contaminated with respect to Pb and Fe, Moradabad WQ station contaminated with respect to Cr, Pb and Fe.
- Locations situated on Rapti River like Balrampur, Birdghat, Regauli WQ Stations contaminated with respect to Cr, Pb and Fe, Bansi WQ Station contaminated with respect to Cd, Cr, Pb and Fe.
- Vautha WQ Station located on Sabarmathi River contaminated with respect to Cd, Ni, Pb and Fe.
- Ghatsila and Jamsolghat WQ Stations located on Subarnarekha River have been contaminated with respect to Cu and Fe.
• Bawapuram and Mantralayam WQ Stations located on Thungabhadra River have been contaminated with respect to Cd, Ni and Pb.

And it is worth noting that during the study period, Lowara WQ Station located on Shturni River was found 3 times above acceptable limit out of 9 times sampling, Mathura and Mohana WQ Stations situated on Yamuna River were found 2 times above acceptable limit out of 9 times sampling with respect to Cd, with respect to Cr concentration stations like Balrampur, Bansi and Birdghat on Rapti River were found 3 times out of 8 times sampling, 3 times out of 7 times sampling and 3 times out of 8 times sampling respectively its contamination above acceptable limit. Lead contamination was found at Birdghat on Rapti River 3 times out of 8 times sampling and at Durvesh on Vaitarna River found 4 times out of 7 times sampling, at Motinaroli on Kim River was found 3 times out of 8 times sampling, at Neemsar on Gomti River was found 3 times out of 7 times sampling, at Regauli on Rapti River found 3 times out of 8 times of sampling, at Vautha on Sabarmati River found 3 times out of 9 times of sampling.

The global metal consumption rate is increasing rapidly in accordance with the exponential population growth and the advancement of production technologies. Metal contamination owing to anthropogenic sources is a persistent global issue, having environmental, political and medical implications (Blackman and Baumol 2008; Rees and Wackernagel 2008). Heavy metals are toxic and carcinogenic and have shown to cause serious health effects on humans and the flora & fauna. As a consequence, various treatment methods have been developed for the treatment of metal contaminated waste streams and some processes can also recover the metals. Among the commonly used physico-chemical and biological technologies for heavy metal removal and recovery, cost effectiveness, technical feasibility, plant simplicity and longevity of the process are the factors that govern the selection of an appropriate technology (S.Janyasuthiwong, 2017; Rene, 2017).

The effluent of industries or other sources containing high levels of heavy metals needs to be treated before it’s discharged into the receiving river water streams because heavy metals are toxic, carcinogenic and bio-accumulative in organisms (Needleman 2004). There are various wastewater treatment technologies available for treating heavy metals contaminated water prior to ultimate discharge in natural water bodies, for example chemical precipitation, evaporative recovery, oxidation/reduction, filtration, ion exchange, membrane technologies and electrochemical treatment technologies are commonly used for practical applications (Fu and Wang 2011; Liang et al. 2010).

Adsorption is a method well known for its cost effectiveness in metal removal. It is widely used in many countries, especially in developing and transition countries, where expensive, advanced technologies cannot be afforded. Adsorption is an effective physico-chemical process for removing heavy metals from wastewater, especially for treating wastewaters with a low metal concentration. This process is very effective and relatively cheap if low cost adsorbents are used. There are many adsorbents available, varying from natural materials (clay balls) to agricultural waste and waste materials (sludges). The advantage of using agricultural waste as heavy metal adsorbent is the reduction of the solid waste problems and an increase in economic value and incentive of several by-products from agricultural materials. Rice husk, coconut shell, banana peel, sawdust, orange peel and groundnut shell are some examples of adsorbents from agricultural materials.
which have been studied over the past years (Demirbas 2008; Janyasuthiwong et al. 2015; Mohan and Singh 2002; Sud et al. 2008; S. Janyasuthiwong, 2017).

Phytoremediation is one of the biological technologies used for the treatment of pollutants present in wastewater, including heavy metals. This technology not only offers advantages during wastewater treatment, but also provides other advantages in terms of ecology, green area, reduced carbon footprint and aesthetics. Phytoremediation is the method in which selected plant species that are used to mitigate the environmental problems or pollutants (metals, pesticides, solvents, crude oils and theirs derivatives) from soil, air, or water. There are many plant species that are commonly used in this field: Vetiveria sp., Typha sp. and Cyperus sp. are examples of those plants. Maine et al. (2006) reported that the constructed wetlands which were planted with several plant species for example Pistia stratiotes, Cyperus alternifolius and Typha domingensis, showed a high percentage of Cr and Ni removals and the Zn concentration was below 50 μg/L (S.Janyasuthiwong, 2017).

Iron is an essential element in human nutrition. In this regard, it may be mentioned that the presence of higher concentration of iron in drinking water makes its taste unpleasant; however, living organism can tolerate higher concentration of iron without any serious damage to their system. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status, and iron bioavailability and range from about 10 to 50 mg/day (FAO/WHO, 1988). Although iron is essential element to humans and are relatively non-toxic, ions of these elements in water often cause mild to severe aesthetic problems, such as discoloured water, precipitation, scaling, staining and metallic water taste. Metallic taste and staining in laundry and toilet staining occur at iron concentration above 0.3 mg/L. The BIS has set the drinking water maximum contaminant levels (MCL) of 0.3mg/L for iron. Iron is not considered mutagenic or carcinogenic in the forms typically found in the aquatic environment and drinking water. Because of their ubiquitous presence in conventional drinking water sources, removal of iron is one of the most common water treatment practices. A two-step process with chemical oxidation followed by filtration is often employed for the removal of dissolved iron from water. The oxidants used include oxygen in air, chlorine, permanganate and ozone. Sand, anthracite, greensand and other synthetic manganese dioxide media are used as granular filter media to remove oxidized iron. Ion-exchange softening may also be used, but only on smaller scales. Other treatment methods that may be used for iron and manganese removal include water reverse osmosis and nanofiltration (Sharma, 2014; Ikehata, et al., 2014)
14. RECOMMENDATIONS

Based on the evaluation of the results obtained from the analysis of River water samples of 414 water quality station spanning all over India, it is recommended that the trace and toxic metals in the river water samples may be monitored at least four times during the water year. It was concluded that water quality of the Indian rivers particularly in some identified polluted stretches have been affected adversely by manmade activities by overcrowding accompanied by inadequate treatment or non-existent sanitation and also by unregulated enormous discharge of untreated industrial waste waters into riverine system. This might be caused by the population growth and also due to the compulsory growth in agricultural & industrial activities. The effluent discharge from the industry in localized areas due to this water pollution is creating situations which are dangerous to health of human and aquatic life.

1. All the toxic metallic elements like chromium and its other associated heavy metals coming from the tanneries, mining & other industries should be treated chemically and biologically before such wastes are founds its way to River.

2. Promotion of effective and efficient implementation of water pollution control laws and regulations.

3. There is an urgent need for stringent Government policy and monitoring for effluents discharged from agriculture and industries into the several Indian rivers such as Ganga, Gagra, Rapti, Ramganga, Subernarekha, and Thungabhadra etc.

4. Speciation of the toxic metals e.g. Chromium (Cr\textsuperscript{+3} & Cr\textsuperscript{+6}) and Arsenic (As\textsuperscript{+3} & As\textsuperscript{+5}) in Indian rivers need to study.

5. The metal fractionation study should be carried out in the river sediments to identify the inorganic load (Metal Load).

Special studies for particular stretches of the rivers may also be undertaken suitably by the concerned basin organization. The number of parameters and frequencies of sampling can be increased for better observations, interpretation & modeling purposes, for other important parameters also such as biological parameters.
15. Reference


ER Rene, E Sahinkaya, A Lewis, PNL Lens (2017), Sustainable Heavy Metal Remediation: Volume 1: Principles and Processes, Springer International Publishing AG 2017


Sharma P.D. (2005), Environmental Biology and Toxicology. Rastogi Publications.


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<td>Ganga/Ghagbra/Rapti</td>
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<td>Mahanadi</td>
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<td>51</td>
<td>Bawapuram</td>
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<td>52</td>
<td>Behalpur</td>
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<td>73°35'42&quot;</td>
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<td>57</td>
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<td>Cauvery/Suvarnavathi</td>
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<td>Longitude</td>
<td>District</td>
<td>State</td>
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<td>64</td>
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<td>68</td>
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<td>88°25’21”</td>
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<td>Pennar</td>
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<td>Site Name</td>
<td>River Name/Tributary/ SubTributary</td>
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<td>District</td>
<td>State</td>
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<td>92°01’07”</td>
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<td>River Name/Tributary/ SubTributary</td>
<td>Latitude</td>
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<td>District</td>
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<td>Ganga</td>
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<td>Farakka/(HR)</td>
<td>Bhagirathi/Feeder Canal</td>
<td>24°48'08''</td>
<td>87°55'18''</td>
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<tr>
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<td>Fatehgarh</td>
<td>Ganga</td>
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<tr>
<td>S. No.</td>
<td>Site Name</td>
<td>River Name/Tributary/ SubTributary</td>
<td>Latitude</td>
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<td>District</td>
<td>State</td>
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<td>24°47'19&quot;</td>
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<td>123</td>
<td>Gadarwara</td>
<td>Narmada/Sakkar</td>
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<td>78°47'27&quot;</td>
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<td>124</td>
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<td>125</td>
<td>Gajaldoba</td>
<td>Brahmaputra / Teesta</td>
<td>26°45'09&quot;</td>
<td>88°35'14&quot;</td>
<td>Jalpaiguri</td>
<td>West Bengal</td>
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<tr>
<td>126</td>
<td>Galeta</td>
<td>Ganga/Yamuna/Hindon</td>
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<td>77°27'45&quot;</td>
<td>Meerut</td>
<td>Uttar Pradesh</td>
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<tr>
<td>127</td>
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<td>Bhadar</td>
<td>21°39'52&quot;</td>
<td>70°10'52&quot;</td>
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<td>128</td>
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<td>Ganga</td>
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<td>78°08'30&quot;</td>
<td>Gaziabad</td>
<td>Uttar Pradesh</td>
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<td>129</td>
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<td>25°04'00&quot;</td>
<td>79°20'00&quot;</td>
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<td>130</td>
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<td>Gujarat</td>
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<td>131</td>
<td>Gaya</td>
<td>Ganga/Kiul/Harohar/Phalgu</td>
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<td>85°00'48&quot;</td>
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<td>Bihar</td>
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<td>132</td>
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<td>Brahmaputra/Dhansiri(South)/Doyang</td>
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<td>93°58'39&quot;</td>
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<td>Assam</td>
</tr>
<tr>
<td>133</td>
<td>Ghat</td>
<td>Ganga/Ghaghra/Sharda/Sarju</td>
<td>29°30'00&quot;</td>
<td>80°07'40&quot;</td>
<td>Pithoragarh</td>
<td>Uttarakhand</td>
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<td>134</td>
<td>Ghatora</td>
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<td>Chhattisgarh</td>
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<td>135</td>
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<td>Purba Singhbhum</td>
<td>Jharkhand</td>
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<td>136</td>
<td>Ghish</td>
<td>Brahmaputra / Teesta / Ghish</td>
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<td>137</td>
<td>Ghugumari</td>
<td>Brahmaputra/ Torsa</td>
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<td>89°27'39&quot;</td>
<td>Cooch Behar</td>
<td>West Bengal</td>
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<tr>
<td>138</td>
<td>Gokak</td>
<td>Krishna/Ghataprabha</td>
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<td>74.50'04&quot;</td>
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<td>Jammu &amp; Kashmir</td>
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<td>139</td>
<td>Golaghat</td>
<td>Brahmaputra/Dhansari(South)</td>
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<td>93°57'07&quot;</td>
<td>Golaghat</td>
<td>Assam</td>
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<td>140</td>
<td>Golokganj</td>
<td>Brahmaputra/Sonkosh</td>
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<td>89°49'10&quot;</td>
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<td>Assam</td>
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<tr>
<td>141</td>
<td>Gomlai</td>
<td>Brahmani</td>
<td>21°50'16&quot;</td>
<td>84°56'33&quot;</td>
<td>Sundergarh</td>
<td>Odisha</td>
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<tr>
<td>142</td>
<td>Gopalkheda</td>
<td>Tapi/Purna</td>
<td>20°52'27&quot;</td>
<td>76°59'23&quot;</td>
<td>Akola</td>
<td>Maharashtra</td>
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<tr>
<td>S. No.</td>
<td>Site Name</td>
<td>River Name/Tributary/ SubTributary</td>
<td>Latitude</td>
<td>Longitude</td>
<td>District</td>
<td>State</td>
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<td>Burhabalang</td>
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<td>86°55'05&quot;</td>
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<td>144</td>
<td>Gummanur</td>
<td>Ponnaiyur</td>
<td>12°33'18&quot;</td>
<td>78°08'18&quot;</td>
<td>Krishnagiri</td>
<td>Tamilnadu</td>
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<td>145</td>
<td>Gumrabazar</td>
<td>Meghna/Surma/Gumra</td>
<td>25°00'41&quot;</td>
<td>92°30'35&quot;</td>
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<td>Assam</td>
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<tr>
<td>146</td>
<td>Gunupur</td>
<td>Vamsadhara</td>
<td>22.20'00&quot;</td>
<td>84.30'15&quot;</td>
<td>Simdega</td>
<td>Jharkhand</td>
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<td>147</td>
<td>Haladi</td>
<td>Haladi</td>
<td>13°34'52&quot;</td>
<td>74°51'26&quot;</td>
<td>Udipi</td>
<td>Karnataka</td>
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<td>148</td>
<td>Halia</td>
<td>Krishna/Halla</td>
<td>16°47'24&quot;</td>
<td>79°20'19&quot;</td>
<td>Nalgonda</td>
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<td>149</td>
<td>Hamirpur</td>
<td>Ganga/Yamuna</td>
<td>25°57'39&quot;</td>
<td>80°09'16&quot;</td>
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<td>Narmada</td>
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<td>76°58'33&quot;</td>
<td>Harda</td>
<td>Madhya Pradesh</td>
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<td>151</td>
<td>Hanskhali</td>
<td>Bhagirathi/Churni</td>
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<td>88°36'31&quot;</td>
<td>Nadia</td>
<td>West Bengal</td>
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<td>152</td>
<td>Haridwar</td>
<td>Ganga</td>
<td>13.58'34&quot;</td>
<td>75.41'07&quot;</td>
<td>Shimoga</td>
<td>Karnataka</td>
</tr>
<tr>
<td>153</td>
<td>Harlahalli</td>
<td>Krishna/Tungabhadra</td>
<td>14°49'50&quot;</td>
<td>75°40'28&quot;</td>
<td>Haveri</td>
<td>Karnataka</td>
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<tr>
<td>154</td>
<td>Hassimara</td>
<td>Brahmaputra/Torsa</td>
<td>26°43'52&quot;</td>
<td>89°21'28&quot;</td>
<td>Jalpaiguri</td>
<td>West Bengal</td>
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<td>155</td>
<td>Hathidah</td>
<td>Ganga</td>
<td>25°23'06&quot;</td>
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<td>Patna</td>
<td>Bihar</td>
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<td>156</td>
<td>Hayaghat</td>
<td>Ganga/Kosi/Bagmati</td>
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<td>85°51'57&quot;</td>
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<tr>
<td>157</td>
<td>Hivra</td>
<td>Godavari/Pranhipatra/Wardha</td>
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<td>78°19'29&quot;</td>
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<td>158</td>
<td>Holehonur</td>
<td>Krishna/Tungabhadra/Bhadra</td>
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<td>75°41'07&quot;</td>
<td>Shimoga</td>
<td>Karnataka</td>
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<td>159</td>
<td>Honnali</td>
<td>Krishna/Tungabhadra</td>
<td>14°14'18&quot;</td>
<td>75°39'27&quot;</td>
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<td>Narmada</td>
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<td>161</td>
<td>Huvenhedigi</td>
<td>Krishna</td>
<td>12.20'46&quot;</td>
<td>76.17'16&quot;</td>
<td>Mysore</td>
<td>Karnataka</td>
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<td>162</td>
<td>Jagdalpur</td>
<td>Godavari/Indravati</td>
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<td>82°02'26&quot;</td>
<td>Bastar</td>
<td>Chhattisgarh</td>
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<td>163</td>
<td>Jagibhakatgaon</td>
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<td>92°21'07&quot;</td>
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<tr>
<td>S. No.</td>
<td>Site Name</td>
<td>River Name/Tributary/ SubTributary</td>
<td>Latitude</td>
<td>Longitude</td>
<td>District</td>
<td>State</td>
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<td>164</td>
<td>Jai Nagar</td>
<td>Ganga/Kosi/Kamla-Balan</td>
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<td>Bihar</td>
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<td>88°56'18&quot;</td>
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<td>West Bengal</td>
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<td>166</td>
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<td>Jammu and Kashmir</td>
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<td>167</td>
<td>Jamshedpur</td>
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<td>22°48'56&quot;</td>
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<td>Jharkhand</td>
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<tr>
<td>169</td>
<td>Japla</td>
<td>Ganga/Sone</td>
<td>24°34'05&quot;</td>
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<td>Odisha</td>
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<td>171</td>
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<td>Bihar</td>
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<td>92°52'44&quot;</td>
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<td>174</td>
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<td>Chhatisgarh</td>
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<td>Cauvery/Lakshmamirthra</td>
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<tr>
<td>180</td>
<td>Kalna (EBB)*</td>
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<td>West Bengal</td>
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<td>Site Name</td>
<td>River Name/Tributary/ SubTributary</td>
<td>Latitude</td>
<td>Longitude</td>
<td>District</td>
<td>State</td>
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<td>184</td>
<td>Kampur</td>
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<td>26°09′13″</td>
<td>92°39′23″</td>
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<td>Ganga</td>
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<td>83°43′20″</td>
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<td>Odisha</td>
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<td>Odisha</td>
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<td>190</td>
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<td>Bhagirathi</td>
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<td>88°08′52″</td>
<td>Burdwan</td>
<td>West Bengal</td>
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<td>77.05′27″</td>
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<td>88°30′10″</td>
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<td>Gujarat</td>
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<td>197</td>
<td>Kharkhana</td>
<td>Meghna/Myndu</td>
<td>25°09′30″</td>
<td>92°13′30″</td>
<td>Jaintia Hills</td>
<td>Meghalaya</td>
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<tr>
<td>198</td>
<td>Khatoli</td>
<td>Ganga/Yamuna/Chambal/Parwati</td>
<td>25°40′57″</td>
<td>76°28′58″</td>
<td>Kota</td>
<td>Rajasthan</td>
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<td>199</td>
<td>Kheronighat</td>
<td>Brahmaputra/ Kopili</td>
<td>25°50′54″</td>
<td>92°53′12″</td>
<td>Karbi Anglong</td>
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<td>200</td>
<td>Kidangoor</td>
<td>Meenachil</td>
<td>09°40′30″</td>
<td>76°36′10″</td>
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<td>201</td>
<td>Kodumudi</td>
<td>Cauvery</td>
<td>11°04′52″</td>
<td>77°53′25″</td>
<td>Erode</td>
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<td>202</td>
<td>Koelwar</td>
<td>Ganga/Sone</td>
<td>25°34′15″</td>
<td>84°47′59″</td>
<td>Arrah</td>
<td>Bihar</td>
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<td>203</td>
<td>Kogaon</td>
<td>Narmada/Kundi</td>
<td>22°06′18″</td>
<td>75°40′42″</td>
<td>Khargone</td>
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<td>204</td>
<td>Kokrajhar</td>
<td>Brahmaputra/Gaurang</td>
<td>26°23′49″</td>
<td>90°15′18″</td>
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<tr>
<td>S. No.</td>
<td>Site Name</td>
<td>River Name/Tributory/ SubTributory</td>
<td>Latitude</td>
<td>Longitude</td>
<td>District</td>
<td>State</td>
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<td>205</td>
<td>Kollegal</td>
<td>Cauvery</td>
<td>12°11′21″</td>
<td>77°06′00″</td>
<td>Chamarajanagar</td>
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<td>206</td>
<td>Konta</td>
<td>Godavari/Sabari</td>
<td>17°48′00″</td>
<td>81°23′34″</td>
<td>Dantewara</td>
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<td>207</td>
<td>Koperagaon</td>
<td>Godavari</td>
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<td>Jabalpur</td>
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<tr>
<td>208</td>
<td>Kora</td>
<td>Ganga/Yamuna/Rind</td>
<td>26°07′58″</td>
<td>80°27′15″</td>
<td>Fatehpur</td>
<td>Uttar Pradesh</td>
</tr>
<tr>
<td>209</td>
<td>Koteshwari</td>
<td>Ganga/Bhagirath</td>
<td>23.01′51″</td>
<td>79.00′56″</td>
<td>Narsinghpur</td>
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<td>210</td>
<td>Kudalaiyathur</td>
<td>Vellar</td>
<td>22.29′30″</td>
<td>76.59′37″</td>
<td>Harda</td>
<td>Madhya Pradesh</td>
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<td>211</td>
<td>Kudige</td>
<td>Cauvery</td>
<td>12°30′09″</td>
<td>75°57′40″</td>
<td>Coorg</td>
<td>Karnataka</td>
</tr>
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<td>212</td>
<td>Kudlur</td>
<td>Cauvery/Palar</td>
<td>11°50′26″</td>
<td>77°27′46″</td>
<td>Chamarajan-agara</td>
<td>Karnataka</td>
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<td>213</td>
<td>Kuldah Bridge</td>
<td>Ganga/Sone</td>
<td>24°24′45″</td>
<td>81°42′01″</td>
<td>Sidhi</td>
<td>Madhya Pradesh</td>
</tr>
<tr>
<td>214</td>
<td>Kulsi</td>
<td>Brahmaputra/Kulsi</td>
<td>25°58′45″</td>
<td>91°23′09″</td>
<td>Kamrup</td>
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<td>215</td>
<td>Kumbidi</td>
<td>Bharathapuzha</td>
<td>10°51′00″</td>
<td>76°01′18″</td>
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</tr>
<tr>
<td>216</td>
<td>Kumhari</td>
<td>Godavari / Pranhita / Wainganga</td>
<td>21°53′03″</td>
<td>80°10′30″</td>
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<td>Madhya Pradesh</td>
</tr>
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<td>217</td>
<td>Kuniyil</td>
<td>Chaliyar</td>
<td>11°14′26″</td>
<td>76°01′26″</td>
<td>Malappuram</td>
<td>Kerala</td>
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<tr>
<td>218</td>
<td>Kuppelur</td>
<td>Krishna/Tungabhadra/Kumudavathi</td>
<td>14°30′00″</td>
<td>75°38′02″</td>
<td>Haveri</td>
<td>Karnataka</td>
</tr>
<tr>
<td>219</td>
<td>Kurubhata</td>
<td>Mahanadi/Mand</td>
<td>21°59′11″</td>
<td>83°12′15″</td>
<td>Raigarh</td>
<td>Chhattisgarh</td>
</tr>
<tr>
<td>220</td>
<td>Kurundwad</td>
<td>Krishna</td>
<td>16°41′01″</td>
<td>74°36′11″</td>
<td>Kolhapur</td>
<td>Maharashtra</td>
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<td>221</td>
<td>Kuttyadi</td>
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<td>11°37′30″</td>
<td>75°47′04″</td>
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<td>222</td>
<td>Kuzhithurai</td>
<td>Thambraparni</td>
<td>08°18′08″</td>
<td>77°10′51″</td>
<td>Knayakumari</td>
<td>Tamilnadu</td>
</tr>
<tr>
<td>223</td>
<td>Labha</td>
<td>Ganga/Mahananda</td>
<td>25°26′10″</td>
<td>87°45′57″</td>
<td>Katihar</td>
<td>Bihar</td>
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<td>224</td>
<td>Lakhisarai</td>
<td>Ganga/Kiul</td>
<td>25°10′33″</td>
<td>86°05′58″</td>
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<td>Bihar</td>
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<td>225</td>
<td>Lalganj</td>
<td>Ganga/Gandak</td>
<td>25°50′05″</td>
<td>85°09′47″</td>
<td>Vaishali</td>
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<td>Site Name</td>
<td>River Name/Tributory/ SubTributory</td>
<td>Latitude</td>
<td>Longitude</td>
<td>District</td>
<td>State</td>
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<td>226</td>
<td>Lowara</td>
<td>Shetruni</td>
<td>21°26'36&quot;</td>
<td>71°33'42&quot;</td>
<td>Bhavnagar</td>
<td>Gujarat</td>
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<td>227</td>
<td>Lucknow</td>
<td>Ganga/Gomti</td>
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<td>80°56'47&quot;</td>
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</tr>
<tr>
<td>228</td>
<td>M.H. Halli</td>
<td>Cauvery/Hemavathi</td>
<td>12°49'08&quot;</td>
<td>76°08'00&quot;</td>
<td>Hassan</td>
<td>Karnataka</td>
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<td>229</td>
<td>Madhira</td>
<td>Krishna/Munneru/Wyra</td>
<td>25°10'44&quot;</td>
<td>77°41'13&quot;</td>
<td>Shivpuri</td>
<td>Madhya Pradesh</td>
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<td>230</td>
<td>Madla</td>
<td>Ganga/Yamuna/Ken</td>
<td>26°25'03&quot;</td>
<td>78°55'48&quot;</td>
<td>Datia</td>
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<tr>
<td>231</td>
<td>Mahidpur</td>
<td>Ganga/Yamuna/ Chambal/Shipra</td>
<td>23°28'50&quot;</td>
<td>75°38'11&quot;</td>
<td>Ujjain</td>
<td>Madhya Pradesh</td>
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<tr>
<td>232</td>
<td>Mahuwa</td>
<td>Purna</td>
<td>21°00'57&quot;</td>
<td>73°08'08&quot;</td>
<td>Surat</td>
<td>Gujarat</td>
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<td>233</td>
<td>Maighat</td>
<td>Ganga/Gomti</td>
<td>25°38'37&quot;</td>
<td>82°50'48&quot;</td>
<td>Jaunpur</td>
<td>Uttar Pradesh</td>
</tr>
<tr>
<td>234</td>
<td>Majhitar</td>
<td>Brahmaputra / Teesta / Rangit</td>
<td>27°06'28&quot;</td>
<td>88°19'18&quot;</td>
<td>South Sikkim</td>
<td>Sikkim</td>
</tr>
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<td>235</td>
<td>Malakkara</td>
<td>Pamba</td>
<td>09°19'57&quot;</td>
<td>76°39'47&quot;</td>
<td>Pothanamthitt</td>
<td>Kerala</td>
</tr>
<tr>
<td>236</td>
<td>Malkhed</td>
<td>Krishna/Bhima/Kagra</td>
<td>17°12'12&quot;</td>
<td>77°09'25&quot;</td>
<td>Gulbarga</td>
<td>Karnataka</td>
</tr>
<tr>
<td>237</td>
<td>Manas NH Crossing</td>
<td>Brahmaputra/Manas</td>
<td>26°27'51&quot;</td>
<td>90°44'59&quot;</td>
<td>Barpeta</td>
<td>Assam</td>
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<tr>
<td>238</td>
<td>Mancherial</td>
<td>Godavari</td>
<td>18°50'09&quot;</td>
<td>79°26'42&quot;</td>
<td>Adilabad</td>
<td>Andhra Pradesh</td>
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<td>239</td>
<td>Mandleeshwar</td>
<td>Narmada</td>
<td>22°10'06&quot;</td>
<td>75°39'36&quot;</td>
<td>Khargone</td>
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</tr>
<tr>
<td>240</td>
<td>Manendragarh</td>
<td>Mahanadi/Hasdeo</td>
<td>23°12'13&quot;</td>
<td>82°13'02&quot;</td>
<td>Koria</td>
<td>Chhatisgarh</td>
</tr>
<tr>
<td>241</td>
<td>Mangaon (Seasonal)</td>
<td>Savitri/kal</td>
<td>18°13'58&quot;</td>
<td>73°17'05&quot;</td>
<td>Raigarh</td>
<td>Maharastra</td>
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<td>242</td>
<td>Mankara</td>
<td>Bharathapuzha</td>
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<td>Kerala</td>
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<td>243</td>
<td>Manot</td>
<td>Narmada</td>
<td>22°44'08&quot;</td>
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<td>244</td>
<td>Mantralayam</td>
<td>Krishna/Thungabhadra</td>
<td>16.46'51&quot;</td>
<td>74.38'00&quot;</td>
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<td>Marella</td>
<td>Gundlakamma</td>
<td>15°52'58&quot;</td>
<td>79°54'37&quot;</td>
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<tr>
<td>246</td>
<td>Margherita</td>
<td>Brahmaputra/ Buridehing</td>
<td>27°17'01&quot;</td>
<td>95°39'46&quot;</td>
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</tr>
<tr>
<td>S. No.</td>
<td>Site Name</td>
<td>River Name/Tributary/ SubTributary</td>
<td>Latitude</td>
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<td>District</td>
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<td>247</td>
<td>Marol</td>
<td>Krishna/Tungabhadra/Varada</td>
<td>14°56'20&quot;</td>
<td>75°37'05&quot;</td>
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<td>Mathabhanga</td>
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<td>89°14'08&quot;</td>
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<td>Mathanguri</td>
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<td>90°57'22&quot;</td>
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<td>Assam</td>
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<td>251</td>
<td>Mathura</td>
<td>Ganga/Yamuna</td>
<td>27°26'30&quot;</td>
<td>77°42'54&quot;</td>
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<td>252</td>
<td>Matigara</td>
<td>Ganga/Mahananda/Balson</td>
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<td>88°22'37&quot;</td>
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<td>253</td>
<td>Matijuri</td>
<td>Barak/Katakhal</td>
<td>24°38'53&quot;</td>
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<td>Assam</td>
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<td>254</td>
<td>Matunga</td>
<td>Brahmaputra / Palgadiya / Kalanadi</td>
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<td>91°32'07&quot;</td>
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<td>Assam</td>
</tr>
<tr>
<td>255</td>
<td>Mawi</td>
<td>Ganga/Yamuna</td>
<td>29°23'07&quot;</td>
<td>77°09'16&quot;</td>
<td>Muzaffar Nagar</td>
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<td>Meja Road</td>
<td>Ganga/Tons</td>
<td>25°14'00&quot;</td>
<td>82°02'16&quot;</td>
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<td>257</td>
<td>Mekhliganj</td>
<td>Brahmaputra / Teesta</td>
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<td>258</td>
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<td>Brahmaputra/Noa-dehing</td>
<td>27°29'57&quot;</td>
<td>96°12'35&quot;</td>
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<td>Mizoram</td>
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<td>Ganga</td>
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<td>Narmada/Burhner</td>
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<td>80°37'26&quot;</td>
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<td>264</td>
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<td>21°24'16&quot;</td>
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<td>Gujarat</td>
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<td>08°42'52&quot;</td>
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<td>Subarnarekha</td>
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<td>Jharkhand</td>
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<td>Brahmaputra / Jaldhaka / Murti</td>
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<td>88°49'42&quot;</td>
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<td>S. No.</td>
<td>Site Name</td>
<td>River Name/Tributory/ SubTributory</td>
<td>Latitude</td>
<td>Longitude</td>
<td>District</td>
<td>State</td>
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<td>Cauvery</td>
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<td>Nallathur</td>
<td>Cauvery/Nandalar</td>
<td>22.03'57&quot;</td>
<td>85.40'24&quot;</td>
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<td>Odisha</td>
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<tr>
<td>275</td>
<td>Namsai</td>
<td>Brahmaputra/Noa-dehing</td>
<td>27°37'28&quot;</td>
<td>95°53'44&quot;</td>
<td>Lohit</td>
<td>Mizoram</td>
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<tr>
<td>276</td>
<td>Nandgaon</td>
<td>Godavari/Pranhita/Wunna</td>
<td>20°32'04&quot;</td>
<td>78°48'04&quot;</td>
<td>Wardha</td>
<td>Maharastra</td>
</tr>
<tr>
<td>277</td>
<td>Nandipalli</td>
<td>Pennar/Sagaileru</td>
<td>14°42'51&quot;</td>
<td>79°01'21&quot;</td>
<td>Kadapa</td>
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<tr>
<td>278</td>
<td>Nanglamoraghat</td>
<td>Brahmaputra/Desang</td>
<td>27°00'00&quot;</td>
<td>94°49'05&quot;</td>
<td>Sivasagar</td>
<td>Assam</td>
</tr>
<tr>
<td>279</td>
<td>Neamatighat</td>
<td>Brahmaputra</td>
<td>26°52'12&quot;</td>
<td>94°15'08&quot;</td>
<td>Jorhat</td>
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</tr>
<tr>
<td>280</td>
<td>Neeleswaram</td>
<td>Periyar</td>
<td>10°11'00&quot;</td>
<td>76°29'46&quot;</td>
<td>Emakulam</td>
<td>Kerala</td>
</tr>
<tr>
<td>281</td>
<td>Neemsar</td>
<td>Ganga/Gomti</td>
<td>27°20'46&quot;</td>
<td>80°28'40&quot;</td>
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<tr>
<td>282</td>
<td>Nellthurai</td>
<td>Cauvery/Bhavani</td>
<td>11°17'16&quot;</td>
<td>76°53'28&quot;</td>
<td>Coimbatore</td>
<td>Tamilnadu</td>
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<td>283</td>
<td>Nellore</td>
<td>Pennar</td>
<td>14°28'13&quot;</td>
<td>79°59'20&quot;</td>
<td>Nellore</td>
<td>Andhra Pradesh</td>
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<tr>
<td>284</td>
<td>Neora</td>
<td>Brahmaputra / Teesta / Neora</td>
<td>26°52'43&quot;</td>
<td>88°46'18&quot;</td>
<td>Jalpaiguri</td>
<td>West Bengal</td>
</tr>
<tr>
<td>285</td>
<td>Nowrangpur</td>
<td>Godavari/Indravati</td>
<td>19°11'51&quot;</td>
<td>82°30'43&quot;</td>
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<td>Odisha</td>
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<td>286</td>
<td>Numaligarh</td>
<td>Brahmaputra/Dhansiri(South)</td>
<td>26°38'02&quot;</td>
<td>93°43'48&quot;</td>
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<td>287</td>
<td>P.G.Bridge</td>
<td>Godavari/Pranhita/Penganga</td>
<td>19°49'02&quot;</td>
<td>78°34'39&quot;</td>
<td>Yeotmal</td>
<td>Maharastra</td>
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<td>288</td>
<td>Pachauli</td>
<td>Ganga/Yamuna/Sind</td>
<td>25°10'44&quot;</td>
<td>77°41'13&quot;</td>
<td>Shivpuri</td>
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<td>S. No.</td>
<td>Site Name</td>
<td>River Name/Tributary/SubTributary</td>
<td>Latitude</td>
<td>Longitude</td>
<td>District</td>
<td>State</td>
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<td>289</td>
<td>Pachegaon</td>
<td>Godavari/Pravara</td>
<td>19°32'04&quot;</td>
<td>74°50'02&quot;</td>
<td>Ahmednagar</td>
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<td>290</td>
<td>Paderdibadi</td>
<td>Mahi</td>
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<td>Dungarpur</td>
<td>Rajasthan</td>
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<td>291</td>
<td>Pagladiya N.T. Road</td>
<td>Brahmaputra / PagladiYa</td>
<td>26°26'58&quot;</td>
<td>91°27'36&quot;</td>
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<td>Assam</td>
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<td>292</td>
<td>Paleru Bridge</td>
<td>Krishna/Paleru</td>
<td>16°57'08&quot;</td>
<td>80°02'56&quot;</td>
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<td>Andhra Pradesh</td>
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<td>293</td>
<td>Paliakalan</td>
<td>Ganga/Ghaghr/Harda</td>
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<td>80°33'09&quot;</td>
<td>Lakhimpur Khiri</td>
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<tr>
<td>294</td>
<td>Palla</td>
<td>Ganga/Yamuna</td>
<td>28°49'46&quot;</td>
<td>77°13'27&quot;</td>
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<td>295</td>
<td>Panbari</td>
<td>Brahmaputra / Burisuti</td>
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<td>90°49'44&quot;</td>
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<td>Assam</td>
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<td>296</td>
<td>Pancharatna</td>
<td>Brahmaputra</td>
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<td>90°34'38&quot;</td>
<td>Goalpara</td>
<td>Assam</td>
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<tr>
<td>297</td>
<td>Pandu</td>
<td>Brahmaputra</td>
<td>26°10'15&quot;</td>
<td>91°40'18&quot;</td>
<td>Kamrup</td>
<td>Assam</td>
</tr>
<tr>
<td>298</td>
<td>Panposh</td>
<td>Brahmani</td>
<td>22°13'33&quot;</td>
<td>84°48'01&quot;</td>
<td>Sundergarh</td>
<td>Odisha</td>
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<tr>
<td>299</td>
<td>Passighat</td>
<td>Brahmaputra/Siang</td>
<td>28°04'23&quot;</td>
<td>95°20'25&quot;</td>
<td>East Siang</td>
<td>Mizoram</td>
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<td>300</td>
<td>Patan</td>
<td>Narmada/Hiran</td>
<td>23°18'42&quot;</td>
<td>79°39'46&quot;</td>
<td>Jabalpur</td>
<td>Madhya Pradesh</td>
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<tr>
<td>301</td>
<td>Pathagudem</td>
<td>Godavari/Indravati</td>
<td>18°49'39&quot;</td>
<td>80°20'21&quot;</td>
<td>Bhopalur</td>
<td>Chhattisgarh</td>
</tr>
<tr>
<td>302</td>
<td>Pathardihi</td>
<td>Mahanadi/Seonath/Kharun</td>
<td>21°20'28&quot;</td>
<td>81°35'38&quot;</td>
<td>Raipur</td>
<td>Chhattisgarh</td>
</tr>
<tr>
<td>303</td>
<td>Pati</td>
<td>Narmada/Goi</td>
<td>21°56'36&quot;</td>
<td>74°44'41&quot;</td>
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<td>304</td>
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<td>Ganga</td>
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<td>Patna</td>
<td>Bihar</td>
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<td>305</td>
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<td>Kallada</td>
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<td>76°45'40&quot;</td>
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<td>Kerala</td>
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<td>306</td>
<td>Pauni</td>
<td>Godavari/Pranhtita/Wainganga</td>
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<td>79°38'46&quot;</td>
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<td>307</td>
<td>Peralam</td>
<td>Cauvery/Vanjiyar</td>
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<td>79°39'50&quot;</td>
<td>Thiruvanur</td>
<td>Tamilnadu</td>
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<td>308</td>
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<td>Valapattam</td>
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<td>Site Name</td>
<td>River Name/Tributary/SubTributary</td>
<td>Latitude</td>
<td>Longitude</td>
<td>District</td>
<td>State</td>
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<td>309</td>
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<td>Godavari</td>
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<td>Khammam</td>
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<tr>
<td>310</td>
<td>Phulgaon (Seasonal)</td>
<td>Krishna/Bhima</td>
<td>18°40'00&quot;</td>
<td>74°00'07&quot;</td>
<td>Pune</td>
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<td>311</td>
<td>Pingalwada</td>
<td>Dhadher</td>
<td>22°06'39&quot;</td>
<td>73°04'43&quot;</td>
<td>Vadodara</td>
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</tr>
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<td>312</td>
<td>Polavaram</td>
<td>Godavari</td>
<td>17°14'45&quot;</td>
<td>81°39'35&quot;</td>
<td>West Godavari</td>
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<tr>
<td>313</td>
<td>Pratapgarh</td>
<td>Ganga/Gomti/Sai</td>
<td>25°56'05&quot;</td>
<td>82°00'07&quot;</td>
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<td>314</td>
<td>Pratappur</td>
<td>Ganga/Yamuna</td>
<td>25°21'17&quot;</td>
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<td>315</td>
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<td>Chenab</td>
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<td>75°39'04&quot;</td>
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<td>Jammu and Kashmir</td>
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<td>316</td>
<td>Pudur</td>
<td>Bharathapuzha</td>
<td>10°46'48&quot;</td>
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<td>Pulamanthole</td>
<td>Bharathapuzha</td>
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<td>318</td>
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<td>Godavari/Purna</td>
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<td>76.56'46&quot;</td>
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<td>Rushikulya</td>
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<td>320</td>
<td>Puthimari D.R.F.</td>
<td>Brahmaputra / Puthimari</td>
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<td>91°42'01&quot;</td>
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<td>Assam</td>
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<td>Rajegaon</td>
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<td>Mahanadi</td>
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<td>327</td>
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<td>S. No.</td>
<td>Site Name</td>
<td>River Name/Tributory/ SubTributory</td>
<td>Latitude</td>
<td>Longitude</td>
<td>District</td>
<td>State</td>
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<tr>
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<td>74°50’04”</td>
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<td>Ranganadi NT-Road Crossing</td>
<td>Brahmaputra/</td>
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<td>Mahi/som</td>
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<td>74°13’25”</td>
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<td>334</td>
<td>Reguali</td>
<td>Ganga/Ghagbra/Rapti</td>
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<td>20°59’00”</td>
<td>83°32’09”</td>
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<td>Odisha</td>
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<td>341</td>
<td>Samdoli (Seasonal)</td>
<td>Krishna/Varna</td>
<td>16°51’18”</td>
<td>74°29’48”</td>
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<td>22°54’57”</td>
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<td>Jhelum</td>
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<td>75°03’58”</td>
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<td>Ganga/Yamuna/ Chambal/Parwan</td>
<td>24°58’09”</td>
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<td>Brahmaputra/Sankosh</td>
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<td>Latitude</td>
<td>Longitude</td>
<td>District</td>
<td>State</td>
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<td>Tapi</td>
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<td>75°34'37&quot;</td>
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<td>398</td>
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Details of Indian rivers and their sites where the water was found fit for use in terms of toxic metal contamination during the study period.

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<td>A.P.Ghat</td>
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**Total Water Quality Station Fit**: 136
Details of WQ Monitoring stations where the water was found unfit for use due to the presence of only one parameter (Iron or Copper or Cadmium or Nickel or Lead) above the acceptable limits during the study period

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### STATUS OF TRACE AND TOXIC METALS IN INDIAN RIVERS, 2018

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# Status of Trace and Toxic Metals in Indian Rivers, 2018

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Details of WQ Monitoring stations where the water was found unfit for use due to presence of more than two toxic metals above acceptable limits during the study period.

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<td>Name of the Water Quality Sites</td>
<td>Toxic metals due to which Unfit</td>
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Details of water quality sites, Rivers and the level of toxic metal concentration found above the acceptable limit as prescribed by BIS during the study period.

1. CADMIUM (Cd in μg/L)

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### 2. CHROMIUM (Cr in µg/L)

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3. COPPER (Cu in µg/L)

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## STATUS OF TRACE AND TOXIC METALS IN INDIAN RIVERS, 2018

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### 5. NICKEL (Ni in µg/L)

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### Annexure-6

Seasonal average values of Trace and Toxic metals with total no of water quality samples found above / below the acceptable limit as prescribed by BIS 10500: 2012

| ARSENIC |
|------------------|------------------|------------------|------------------|------------------|
| **S. No.** | **Water Quality Site** | **Arsenic (in µg/L) Average** | **BIS: 10500: 2012** |
| | | **Total** | **Non-Monsoon** | **Monsoon** | **Min** | **Max** | **No. of Stations** |
| | | | | | | | **Above 10 µg/L** | **Below 10 µg/L** |
| 1 A B Road Xing | 0.896 | 0.728 | 0.980 | 0.090 | 1.870 | 0 | 3 |
| 2 A.P. Puram | 0.320 | 0.320 | - | 0.020 | 0.620 | 0 | 2 |
| 3 A.P. Ghat | 3.424 | 3.740 | 2.950 | 1.430 | 7.420 | 0 | 5 |
| 4 Aauriya | 4.964 | 6.017 | 3.385 | 3.330 | 8.560 | 0 | 5 |
| 5 Abu Road | 1.637 | 1.815 | 1.280 | 1.280 | 2.000 | 0 | 3 |
| 6 Addoor | 2.860 | - | 2.860 | 2.860 | 0 | 1 |
| 7 Adityapur | 3.228 | 3.940 | 1.090 | 1.090 | 5.490 | 0 | 4 |
| 8 Agra | 3.632 | 1.630 | 6.635 | 1.380 | 8.160 | 0 | 5 |
| 9 Aie NH Crossing | 1.730 | 1.730 | - | 1.730 | 1.730 | 0 | 1 |
| 10 Akabarpur | 3.038 | 3.483 | 2.370 | 0.220 | 7.500 | 0 | 5 |
| 11 Akhnoor | 2.030 | 1.910 | 2.390 | 0.550 | 3.310 | 0 | 4 |
| 12 Akkihebbal | 1.740 | 1.830 | 1.380 | 0.110 | 3.580 | 0 | 5 |
| 13 Aklera | 2.120 | 1.929 | 2.310 | 0.548 | 3.960 | 0 | 4 |
| 14 Alladupalli | 3.172 | 3.963 | 1.590 | 0.350 | 8.960 | 0 | 6 |
| 15 Allahabad | 3.140 | 3.342 | 2.635 | 1.190 | 5.540 | 0 | 7 |
| 16 Alutama | 1.270 | 1.297 | 1.190 | 0.270 | 2.120 | 0 | 4 |
| 17 Ambarampalayam | 3.277 | 2.218 | 5.395 | 0.100 | 7.960 | 0 | 6 |
| 18 Ambasamudram | - | - | - | 0.000 | 0.000 | 0 | 0 |
| 19 Anandpur | 1.200 | 1.110 | 1.470 | 0.620 | 2.070 | 0 | 4 |
| 20 Andhiyar Kore | 5.210 | 5.210 | - | 5.210 | 5.210 | 0 | 1 |
| 21 Ankinghat | 4.618 | 5.910 | 2.035 | 0.120 | 8.400 | 0 | 6 |
| 22 Annavasal | - | - | - | 0.000 | 0.000 | 0 | 0 |
| 23 Arangaly | 5.577 | 4.895 | 6.940 | 2.040 | 7.750 | 0 | 3 |
| 24 Arcot | 0.660 | - | 0.660 | 0.660 | 0.660 | 0 | 1 |
| 25 Arjunwad | 2.540 | - | 2.540 | 2.540 | 2.540 | 0 | 1 |
| 26 Ashramam | 3.663 | 4.130 | 2.730 | 2.730 | 4.490 | 0 | 3 |
| 27 Ashti | 2.044 | 2.448 | 1.035 | 0.580 | 6.070 | 0 | 7 |
| 28 Avershe | 0.715 | 1.070 | 0.360 | 0.360 | 1.070 | 0 | 2 |
| 29 Ayilam | 5.517 | 3.840 | 8.870 | 0.080 | 8.870 | 0 | 3 |
| 30 Ayodhya | 1.415 | 1.390 | 1.465 | 0.030 | 3.660 | 0 | 6 |
| 31 Azmabad | 3.521 | 4.716 | 0.535 | 0.170 | 6.470 | 0 | 7 |
| 32 B.P. Ghat | 2.808 | 2.923 | 2.580 | 0.710 | 7.410 | 0 | 6 |
| 33 Badatighat | 3.631 | 4.592 | 1.230 | 0.260 | 8.550 | 0 | 7 |
| 34 Badlapur | 3.177 | 3.240 | 3.050 | 3.040 | 3.440 | 0 | 3 |
| 35 Balrampur | 1.977 | 2.420 | 1.090 | 0.290 | 4.830 | 0 | 6 |
| 36 Baltara | 2.474 | 3.026 | 1.095 | 0.260 | 6.130 | 0 | 7 |
| 37 Bamni (Banjar) | 1.143 | 1.143 | 1.145 | 0.100 | 2.190 | 0 | 6 |
### STATUS OF TRACE AND TOXIC METALS IN INDIAN RIVERS, 2018

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### Water Quality Site | Arsenic (in µg/L) | BIS: 10500: 2012
|-----------------|-----------------|-----------------
<p>|                 | Average         | No. of Stations |
|                 | Total | Non-Monsoon | Monsoon | Min | Max | Above 10 µg/L | Below 10 µg/L |
| 258 Miao        | 1.784 | 1.728       | 1.925    | 0.240 | 3.690 | 0 | 7 |
| 259 Mirzapur    | 2.706 | 3.150       | 1.595    | 0.770 | 6.080 | 0 | 7 |
| 260 Mohana (Betwa) | 1.930 | 2.347       | 1.305    | 0.540 | 4.090 | 0 | 5 |
| 261 Mohana (Yamuna) | 2.721 | 3.302       | 0.685    | 0.120 | 7.040 | 0 | 9 |
| 262 Mohgaon     | 1.623 | 1.742       | 1.325    | 0.370 | 4.720 | 0 | 7 |
| 263 Moradabad   | 2.963 | 3.285       | 2.320    | 1.300 | 4.370 | 0 | 6 |
| 264 Motinarioli | 1.980 | 2.090       | 1.760    | 0.040 | 5.620 | 0 | 6 |
| 265 Murappanadu | 3.388 | 1.977       | 7.620    | 0.580 | 7.620 | 0 | 4 |
| 266 Muri        | 3.830 | 4.553       | 1.660    | 1.660 | 6.740 | 0 | 4 |
| 267 Murti       | 3.810 | 3.810       | -        | 3.810 | 3.810 | 0 | 1 |
| 268 Musiri      | 2.137 | 2.137       | -        | 0.850 | 3.340 | 0 | 3 |
| 269 Muthankera  | 4.697 | 2.870       | 8.350    | 1.670 | 8.350 | 0 | 3 |
| 270 Nagrakata   | 3.400 | 3.400       | -        | 3.400 | 3.400 | 0 | 1 |
| 271 Naharkatia  | 1.801 | 2.084       | 1.095    | 1.090 | 3.730 | 0 | 7 |
| 272 Naidupet    | -     | -           | -        | 0.000 | 0.000 | 0 | 0 |
| 273 Nallammaranpatty | 2.100 | -           | 2.100    | 2.100 | 2.100 | 0 | 1 |
| 274 Nallathur   | 2.910 | 2.910       | -        | 2.780 | 3.040 | 0 | 2 |
| 275 Namsai      | 1.466 | 1.250       | 2.005    | 0.280 | 3.300 | 0 | 7 |
| 276 Nandgaon    | 2.856 | 2.167       | 3.890    | 0.100 | 7.680 | 0 | 5 |
| 277 Nandipalli  | 3.667 | 6.500       | 2.250    | 1.580 | 6.500 | 0 | 3 |
| 278 Naglamoraghat | 3.211 | 3.862       | 1.585    | 0.360 | 7.100 | 0 | 7 |
| 279 Neamatighat | 2.949 | 3.132       | 2.490    | 0.590 | 5.550 | 0 | 7 |
| 280 Neeleswaram | 4.040 | 4.390       | 3.340    | 1.350 | 7.430 | 0 | 3 |
| 281 Neemar      | 3.852 | 5.557       | 1.295    | 0.170 | 8.100 | 0 | 5 |
| 282 Nellithurai | 3.615 | 3.615       | -        | 0.660 | 6.570 | 0 | 2 |
| 283 Nellore     | 2.075 | 2.075       | -        | 1.700 | 2.450 | 0 | 2 |
| 284 Neora       | 5.710 | 5.710       | -        | 5.710 | 5.710 | 0 | 1 |
| 285 Nowrangpur  | 1.727 | 2.455       | 0.270    | 0.270 | 3.150 | 0 | 3 |
| 286 Numaligarh  | 2.909 | 3.440       | 1.580    | 0.300 | 8.430 | 0 | 7 |
| 287 P.G.Bridge  | 2.773 | 2.260       | 3.800    | 0.640 | 6.940 | 0 | 6 |
| 288 Pachauli    | 0.710 | -           | 0.710    | 0.710 | 0.710 | 0 | 1 |
| 289 Pachegaon   | 0.950 | -           | 0.950    | 0.950 | 0.950 | 0 | 1 |
| 290 Paderibadi  | 2.001 | 2.586       | 0.540    | 0.270 | 5.780 | 0 | 7 |
| 291 Pagladiya N.T.Road | 1.476 | 1.588       | 1.195    | 0.070 | 4.090 | 0 | 7 |
| 292 Paleru Bridge | 0.645 | 1.210       | 0.080    | 0.080 | 1.210 | 0 | 2 |
| 293 Paliakalan  | 2.858 | 2.813       | 2.950    | 0.630 | 7.400 | 0 | 6 |
| 294 Palla       | 2.044 | 2.484       | 0.505    | 0.400 | 6.810 | 0 | 9 |
| 295 Panbari     | 4.380 | 4.380       | -        | 4.380 | 4.380 | 0 | 1 |
| 296 Pancharatna | 1.113 | 1.224       | 0.835    | 0.090 | 3.190 | 0 | 7 |
| 297 Pandu       | 1.689 | 1.890       | 1.185    | 0.400 | 5.170 | 0 | 7 |
| 298 Panposh     | 2.130 | 2.213       | 1.880    | 1.170 | 3.100 | 0 | 4 |
| 299 Passighat   | 3.203 | 3.203       | -        | 0.670 | 5.950 | 0 | 3 |
| 300 Patan       | 3.253 | 3.092       | 3.655    | 0.290 | 8.710 | 0 | 7 |
| 301 Pathagudem  | 2.013 | 2.875       | 0.290    | 0.290 | 3.740 | 0 | 3 |</p>
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## STATUS OF TRACE AND TOXIC METALS IN INDIAN RIVERS, 2018

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## STATUS OF TRACE AND TOXIC METALS IN INDIAN RIVERS, 2018

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### STATUS OF TRACE AND TOXIC METALS IN INDIAN RIVERS, 2018

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## STATUS OF TRACE AND TOXIC METALS IN INDIAN RIVERS, 2018

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## Status of Trace and Toxic Metals in Indian Rivers, 2018

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## Status of Trace and Toxic Metals in Indian Rivers, 2018

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## STATUS OF TRACE AND TOXIC METALS IN INDIAN RIVERS, 2018

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CENTRAL WATER COMMISSION
Ministry of Water Resources, River Development and Ganga Rejuvenation
New Delhi