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**GOVERNMENT OF INDIA**
**Ministry of Jal Shakti**
**Department of Water Resources**
**River Development and Ganga Rejuvenation**

# STATUS OF TRACE AND TOXIC METALS IN RIVERS OF INDIA

**(January to December 2022)**


## Central Water Commission

**August, 2024**


**Shri Kushvinder Vohra**

**Chairman**
**Central Water Commission**
**Department of WR, RD, & GR**
**Ministry of Jal Shakti**


Water is an essential resource for both ecosystems and human societies. However, human activities on land and water have significantly affected the availability and quality of water. Providing enough safe water is perhaps the most crucial issue we face today. To achieve sustainable development, it is imperative to ensure water security worldwide, which requires responsible and sustainable management of freshwater resources. Therefore, regular monitoring of the quantity and quality of water resources is essential. In India, rivers are the primary surface water resources, and the Central Water Commission has developed expertise in water resources management through hydro-meteorological observation sites across the country. As of January 2023, CWC is monitoring 782 water quality stations across the country.

River water is currently being reported as contaminated with trace and toxic metals, both due to human activity and natural resources. Their presence above the established limits in water can pose significant threats to flora and fauna due to their non-biodegradable nature. The Central Water Commission (CWC) is conducting an analysis of nine trace and toxic metals, namely: Arsenic, Cadmium, Copper, Chromium, Iron, Lead, Mercury, Nickel, and Zinc. The present study, the 6th edition of the “Status of Trace and Toxic Metals in Indian Rivers," involves the analysis of the aforementioned metals for the period of January-December 2022, in relation to 328 stations across various parts of India. The previous editions of this study were published in May 2014, April 2018, August 2019, and December 2021.

I hope that this publication proves to be useful for all stakeholders and agencies involved in taking remedial measures to conserve the quality of river water. The information presented here can also be used for the purposes of protection, management, planning, and policy-making. Additionally, it may prove useful for conducting assessments related to climate change and water security, as well as academic and scientific research.

**Shri P. Manroi Scott**

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Water is an essential resource for sustaining life and plays a crucial role in various aspects of human civilization, including agriculture, industry, and public health. The availability of good quality water is of paramount importance. However, human intervention and climate change have posed significant challenges to the water sector, making water scarce, unpredictable, polluted, or all of the above. The effects of human activities on land and water are now extensive and profound. The availability of sufficient quantities of safe water may be the most crucial issue we face for the next generation.

To ensure a successful and sustainable rejuvenation effort, it is imperative to consider long-term measures that encompass hydrology, water quality, ecology, social dynamics, and economic aspects. This necessitates adopting holistic strategies that include infrastructure projects, fostering innovation, co-creation, and meaningful engagement of all stakeholders towards a common goal. Geographically, rivers are the lowest line in an area and ultimately disposal of waste from various sectors reach them, thereby polluting the river water beyond the permissible limits. At some places, the river water quality parameters are beyond limit even for irrigation purposes. Thus, it has become very essential to evaluate the environmental impacts of water resources to minimize the progressive deterioration in the quality of water.

Central Water Commission (CWC) has been monitoring the water quality of rivers in India since 1963. They have a network of 782 water quality stations as of January 2023, and a 3-tier laboratory system consisting of 427 Level-I, 18 Level-II, and 5 Level-III laboratories across the country. The Level-III laboratories analyze 9 trace and toxic metals, including arsenic, cadmium, copper, chromium, iron, lead, mercury, nickel, and zinc.

I would like to express my appreciation for the initiative taken by Davendra Pratap Mathuria, Chief Engineer (P&DO), and the work carried out by Shri Pankaj Kumar Sharma, Director of RDC-II Directorate, as well as the dedicated efforts of all officers of RDC-II Directorate and the scientific officers of all CWC laboratories in compiling and preparing this report. I hope that this document will be useful for all CWC offices, central/state agencies, and other stakeholders in the field of water quality.

**Shri Davendra Pratap Mathuria**

**Chief Engineer (P&DO)**
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Water quality is influenced by various physical, chemical, and biological factors and their effects on the water's beneficial uses. People evaluate water quality based on its physical, chemical, and biological characteristics. For example, people require their drinking water to be pure, wholesome, and potable to maintain good health.

The Central Water Commission (CWC) plays a vital role in the water quality monitoring process. As part of its integrated hydrological investigation, the CWC collects water samples from various river basins in the country. Initially, the CWC only monitored water quality for irrigation and other related purposes. However, as the amount of pollution discharged into rivers increased, it became necessary to monitor biological, trace & toxic metals, and pesticide-related parameters as well.

This publication compiles the analysis results of 9 trace & toxic metals in river water samples collected from 328 water quality monitoring stations of CWC from January to December 2022. As there are no specific standards for river water quality, the analysis results are compared with the acceptable limits prescribed by BIS: 10500-2012 as a benchmark only. The report identifies locations where the concentration of these metals exceeded the acceptable limits.

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## DATA CHECKING AND ITS VALIDATION:

**All Scientific Staff & Officers of concerned divisional laboratories of Central Water Commission. Data and results were shared vide email and presented during Technical discussion on 08 February, 2024 with all the staff/ officers of regional CWC offices /labs.**

## Index

## List of Figures

# List of Tables

## ABBREVIATION

| | |
|---|---|
| µg/L | Microgram per Litre |
| mg/L | Milligram per Litre |
| AAS | Atomic Absorption Spectrophotometer |
| APHA | American Public Health Association |
| As | Arsenic |
| BCM | Billion Cubic meter |
| BIS | Bureau of Indian Standards |
| CDS | Centers for Disease Control and Prevention |
| Cd | Cadmium |
| Cr | Chromium |
| Cu | Copper |
| EFR | East Flowing Rivers |
| Fe | Iron |
| Hg | Mercury |
| ICMR | Indian Council of Medical Research |
| ICP-MS | Inductively Coupled Plasma Mass Spectrometer |
| IUPAC | International Union of Pure and Applied Chemistry |
| kms | kilo meters |
| M. ha | Million hectres |
| MCL | Maximum Contaminant Level |
| mm | milli meter |
| MSL | Mean Sea Level |
| Ni | Nickel |
| NRWQL | National River Water Quality Laboratory |
| Pb | Lead |
| ppb | Parts Per Billion |
| ppm | Parts Per Million |
| TEL | Tetra Ethyl Lead |
| UMGWQL | Upper Middle Ganga Water Quality Laboratory |
| USEPA | United States Environmental Protection Agency |
| WFR | West Flowing Rivers |
| WHO | World Health Organisation |
| WQ | Water Quality |
| Zn | Zinc |

## EXECUTIVE SUMMARY

River water is nowadays reported to be contaminated with trace & toxic metals due to anthropogenic sources as well as natural resources. Their presence above limit in water will cause serious threats to flora and fauna because of their non-biodegradability. CWC is involved in the analysis of 9 trace & toxic metals namely: Arsenic, Cadmium, Copper, Chromium, Iron, Lead, Mercury, Nickel, and Zinc. The present study involves the data analysis of 5980 samples collected during January, 2022 to December, 2022 from 10 river basins of India for the above-mentioned 9 trace & toxic metals. These samples were analyzed at 2 water quality laboratories of CWC namely: National River Water Quality Laboratory, Upper Yamuna Division, New Delhi and Upper and Middle Ganga Water Quality Laboratory, Middle Ganga Division-3, Varanasi. In absence of any river water-specific standards, the analysis results are compared with the prescribed limits of BIS: 10500-2012 as a benchmark only.

The parameter-wise summary of the analysis results is given below:

### Arsenic (As)

BIS (Bureau of Indian Standards) 10500:2012 has recommended an acceptable limit of 10 µg/L of arsenic in drinking water. Out of 5942 river water samples, 48 samples from 30 water quality stations were found to have arsenic concentrations beyond the acceptable limit. The arsenic concentration varies from 0.000 to 19.47 µg/L. Maximum arsenic concentration (19.47 µg/L) was observed at Kora water quality monitoring station on Rind River (a tributary of Yamuna) on 12.06.2022.

| As Acceptable Limit as BIS 10500: 2012 | 10 µg/L |
|---|---|
| **No. of Samples Tested** | 5942 |
| **No. of samples where metal found above acceptable limit** | 48 |
| **No. of Stations where metal found above acceptable limit** | 30 |
| **No. of Basin / Rivers where metal found above acceptable limit** | 1/14 |

### Cadmium (Cd)

BIS (Bureau of Indian Standards) 10500:2012 has recommended an acceptable limit of 3 µg/L of cadmium in drinking water. Out of total 5942 river water samples analysed, 5 samples from 4 water quality stations were found to have cadmium concentrations beyond the acceptable limit. The cadmium concentration varies from 0.000 to 5.542 µg/L. Maximum cadmium concentration (5.542 µg/L) was observed at Lucknow water quality monitoring station on Gomti River on 21.01.2022.

| Cd Acceptable Limit as BIS 10500: 2012 | 3 µg/L |
|---|---|
| **No. of Samples Tested** | 5942 |
| **No. of samples where metal found above acceptable limit** | 5 |
| **No. of Stations where metal found above acceptable limit** | 4 |
| **No. of Basins / Rivers where metal found above acceptable limit** | 3/3 |

## Chromium (Cr)

BIS (Bureau of Indian Standards 10500:2012) has recommended an acceptable limit of 50 µg/L of chromium in drinking water. Out of total 5939 river water samples analysed, 17 samples from 16 water quality stations were found to have chromium concentrations beyond the acceptable limit. The chromium concentration varies from 0.000 to 87.575 µg/L. Maximum chromium concentration (87.575 µg/L) was observed at Udaipur water quality monitoring station on Brahmaputra River on 21.12.2022.

| Cr Acceptable Limit as BIS 10500: 2012 | 50 µg/L |
|---|---|
| **No. of Samples Tested** | 5939 |
| **No. of samples where metal found above acceptable limit** | 17 |
| **No. of Stations where metal found above acceptable limit** | 16 |
| **No. of Basins / Rivers where metal found above acceptable limit** | 6/16 |

## Copper (Cu)

BIS (Bureau of Indian Standards) 10500:2012) has recommended an acceptable limit of 50 µg/L of copper in drinking water. Out of total 5941 river water samples analysed, 5 samples from 5 water quality stations were found to have copper concentrations beyond the acceptable limit. The copper concentration varies from 0.000 to 98.097 µg/L. Maximum copper concentration (98.097 µg/L) was observed at Avarankuppam water quality monitoring station on Palar River on 01.11.2022.

| Cu Acceptable Limit as BIS 10500: 2012 | 50 µg/L |
|---|---|
| **No. of Samples Tested** | 5941 |
| **No. of samples where metal found above acceptable limit** | 5 |
| **No. of Stations where metal found above acceptable limit** | 5 |
| **No. of Rivers where metal found above acceptable limit** | 3/5 |

## Iron (Fe)

BIS has recommended the acceptable limit of 1.0 mg/L (1000 µg/L) for Iron. Out of total 5980 river water samples analysed, 113 samples from 74 water quality stations were found to have iron concentrations beyond the acceptable limit. The iron concentration varies from 0.000 to 11.387 mg/L. Maximum iron concentration (11.387 mg/L) was observed at Kirtinagar D/S water quality monitoring station on Alakananda River on 11.05.2022.

| Fe Acceptable Limit as BIS 10500: 2012 | 1000 µg/L |
|---|---|
| **No. of Samples Tested** | 5980 |
| **No. of samples where metal found above acceptable limit** | 113 |
| **No. of Stations where metal found above acceptable limit** | 74 |
| **No. of Basins / Rivers where metal found above acceptable limit** | 7/51 |

## Lead (Pb)

Bureau of Indian Standards (10500:2012) has recommended that the acceptable limit for lead is 0.01 mg/L or 10 µg/L in drinking water. Out of total 5942 river water samples analysed, 37 samples from 30 water quality stations were found to have lead concentrations beyond the acceptable limit. The lead concentration varies from 0.000 to 63.483 µg/L. Maximum lead concentration (63.483 µg/L) was observed at Avershe water quality monitoring station on Seetha River on 01.07.2022

| Pb Acceptable Limit as BIS 10500: 2012 | 10 µg/L |
|---|---|
| No. of Samples Tested | 5942 |
| No. of samples where metal found above acceptable limit | 37 |
| No. of Stations where metal found above acceptable limit | 30 |
| No. of Basins / Rivers where metal found above acceptable limit | 6/25 |

## Mercury (Hg)

BIS (Bureau of Indian Standards) 10500:2012) has recommended an acceptable limit of 1 µg/L of mercury in drinking water. Out of total 5941 river water samples analysed, 18 samples from 18 water quality stations were found to have mercury concentrations beyond the acceptable limit. The mercury concentration varies from 0.000 to 8.903 µg/L. Maximum mercury concentration (8.903 µg/L) was observed at Palla U/S Delhi water quality monitoring station on Yamuna River on 01.05.2022.

| Hg Acceptable Limit as BIS 10500: 2012 | 1 µg/L |
|---|---|
| No. of Samples Tested | 5941 |
| No. of samples where metal found above acceptable limit | 18 |
| No. of Stations where metal found above acceptable limit | 18 |
| No. of Rivers where metal found above acceptable limit | 5/11 |

## Nickel (Ni)

BIS (Bureau of Indian Standards) 10500:2012) has recommended an acceptable limit of 20 µg/L of nickel in drinking water. Out of total 5942 river water samples analysed, 11 samples from 11 water quality stations were found to have nickel concentrations beyond the acceptable limit.The nickel concentration varies from 0.000 to 69.01 µg/L. Maximum nickel concentration (69.01 µg/L) was observed at Madamon water quality monitoring station on Pamba River on 23.08.2022.

| Ni Acceptable Limit as BIS 10500: 2012 | 20 µg/L |
|---|---|
| No. of Samples Tested | 5942 |
| No. of samples where metal found above acceptable limit | 11 |
| No. of Stations where metal found above acceptable limit | 11 |
| No. of Basins / Rivers where metal found above acceptable limit | 4/9 |

## Zinc (Zn)

BIS (Bureau of Indian Standards) 10500:2012 has recommended acceptable limit of 5 mg/L (5000 µg/L) of Zinc in drinking water. Out of total 5940 river water samples analysed, no sample is found to have zinc concentration beyond the acceptable limit. The zinc concentration varies from 0.000 to 950.535 µg/L. Maximum zinc concentration (950.535 µg/L) was observed at Haridwar water quality monitoring station on Ganga River on 01.05.2022.

| Zn Acceptable Limit as BIS 10500: 2012 | 5000 µg/L |
|---|---|
| No. of Samples Tested | 5940 |
| No. of samples where metal found above acceptable limit | 0 |
| No. of Stations where metal found above acceptable limit | 0 |
| No. of Basins / Rivers where metal found above acceptable limit | 0/0 |

The analysis results of 328 water quality monitoring stations spread over 10 river basins of CWC were considered for the study. All metals are found to be within the acceptable limits at 187 out of 328 monitored stations while at 141 stations studied, at least one metal was found to be beyond the limit.

The overall summary of the results is as under:

| Sl. No. | Trace & Toxic Metal | Acceptable limit as per BIS:10500, 2012 (in µg/L) | Total No. of samples analysed | No. of samples where metal found within acceptable limit | No. of samples where metal found above acceptable limit | % of samples where metal found above acceptable limit |
|---|---|---|---|---|---|---|
| 1 | Arsenic (As) | 10 | 5942 | 5894 | 48 | 0.81 |
| 2 | Cadmium (Cd) | 3 | 5942 | 5937 | 5 | 0.08 |
| 3 | Chromium (Cr) | 50 | 5939 | 5922 | 17 | 0.29 |
| 4 | Copper (Cu) | 50 | 5941 | 5936 | 5 | 0.08 |
| 5 | Iron (Fe) | 1000 | 5980 | 5867 | 113 | 1.89 |
| 6 | Lead (Pb) | 10 | 5942 | 5905 | 37 | 0.62 |
| 7 | Mercury (Hg) | 1 | 5941 | 5923 | 18 | 0.30 |
| 8 | Nickel (Ni) | 20 | 5942 | 5931 | 11 | 0.19 |
| 9 | Zinc (Zn) | 5000 | 5940 | 5940 | 0 | 0.00 |

# 1. INTRODUCTION

Environmental pollution is a pervasive issue caused by a wide array of pollutants present in water, air, and soil. Of particular concern within this complex web of pollutants are "Heavy Metals," a category encompassing metallic and metalloid elements with densities ranging from 3.5 to 7 g/cm³. In modern parlance, the term 'heavy metal' has come to signify metallic chemical elements and metalloids that exert toxicity on both the environment and human health. Notably, some metalloids and even lighter metals, such as selenium, arsenic and aluminum, are classified as heavy metals due to their toxic properties, while certain heavy metals, such as gold, are typically non-toxic.

Heavy metals represent a prevalent source of pollution in both water and soil, and the increasing concentration of these metals in the environment has raised significant public concern due to their well-documented toxicity. While defining heavy metals can vary in the literature, they are generally characterized by a high atomic number, atomic weight, and a density exceeding 5.0 g/cm³. In a broader context, metals are intrinsic components of the Earth's crust, and some, such as copper, selenium, and zinc, are essential trace elements necessary to maintain human metabolism. However, when present in higher concentrations, they can exhibit toxic effects. On the other hand, certain metals like mercury, cadmium, and lead have direct toxic impacts on human health.

The roster of common toxic 'heavy metals' includes Beryllium (Be), aluminum (Al), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), selenium (Se), molybdenum (Mo), silver (Ag), cadmium (Cd), tin (Sn), antimony (Sb), barium (Ba), mercury (Hg), thallium (Tl), and lead (Pb). These metals have been identified as subjects of substantial public health concern by the World Health Organization (WHO).

Over the course of the last few decades, there has been a notable surge in the concentration of these heavy metals within river water and sediments. This escalating presence has the potential to exert adverse effects on crops, including grains and vegetables, grown in soil and water tainted with these heavy metals. Consequently, this situation poses a significant threat to both human health and the environment due to the inherent toxicity, non-biodegradability, and propensity for bioaccumulation associated with heavy metals.

## 1.1 Sources of Metal Pollution

Heavy metals are naturally occurring elements found in the Earth's crust since the planet's formation. Various natural processes can contribute to heavy metal pollution, including volcanic activity, metal corrosion, metal evaporation from soil and water, sediment re-suspension, soil erosion, and geological weathering. However, the substantial increase in the use of heavy metals has led to a significant upsurge in these metallic substances in both terrestrial and aquatic environments. The proliferation of heavy metal pollution is primarily attributed to human activities, such as metal mining, smelting, foundries, and other metal-based industries. Additionally, heavy metals are introduced into the environment through agricultural practices, including leaching from sources like landfills, waste dumps, livestock and chicken manure, runoff from automobiles, and roadwork.

Due to their chemical properties, metals often persist in the environment, undergoing chemical transformations while accumulating in the food chain. These pollutants find their way into the environment through various human activities, including mining, refining, and electroplating industries. The effluents produced by these industries contain an array of heavy metals, including cadmium, copper, chromium, nickel, lead, and zinc. The subsequent release of these effluents into water bodies significantly contributes to the increasing presence of toxic heavy metals in aquatic environments. Heavy metals, with their high-water solubility, are readily absorbed by living organisms. Their mobility within natural water ecosystems and their toxicity to living organisms have led to their classification as major inorganic contaminants in surface and ground waters. Even when present in low, almost undetectable quantities, their resistance to degradation implies that, through natural processes such as bio-magnification, their concentration may elevate to levels that trigger toxic effects.

## 1.2 Metal Pollution from Mining and Processing Ores

The activities involved in mining, including excavation, ore extraction, and mineral processing, can, at times, result in environmental damage. For instance, mining operations have the potential to harm the environment by destroying habitats, farmland, and homes, causing soil erosion, and contaminating waterways with toxic discharge. Smelting processes, such as those that emit toxic materials like arsenic (As), selenium (Se), lead (Pb), cadmium (Cd), and sulfur oxides, can lead to significant air pollution.

Surface mining, while producing about eight times more waste compared to underground mining, can still present environmental challenges. Deep mining, on the other hand, may exacerbate issues, including seismic activity. When underground mines collapse, it not only poses risks to miners' lives but also results in surface subsidence, potentially causing infrastructure, such as roads and houses, to collapse. As easily accessible minerals become depleted, miners are forced to dig deeper to access these resources. A study by the National Academy of Science projected that copper (Cu) mining operations in the year 2000 would generate three times more waste per ton of copper output compared to similar activities in 1978.

The exposure of pyrite (FeS) and other sulfide minerals to atmospheric oxygen and moisture leads to their oxidation and the formation of acid-mine drainage water. The release of acid-mine drainage from active and abandoned mines, especially coal mines, is widely recognized for its negative impact on water quality. This drainage dissolves toxic elements from tailings and soils, carrying them into water bodies and even groundwater. Water quality issues often involve elevated 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 result in the deposition of substantial quantities of trace metals, including lead (Pb), zinc (Zn), copper (Cu), arsenic (As), and silver (Ag), into drainage basins or their direct discharge into aquatic environments.

### 1.3 Metal Pollution from Domestic Wastewater Effluents

Domestic wastewater effluents typically contain substantial quantities of trace metals derived from metabolic waste byproducts, the corrosion of water pipes - copper (Cu), lead (Pb), zinc (Zn), and cadmium (Cd), and household products, including detergents - iron (Fe), manganese (Mn), chromium (Cr), nickel (Ni), cobalt (Co), zinc (Zn), boron (B), and arsenic (As). In general, wastewater treatment processes remove less than 50% of the metal content from the influent, resulting in effluents with significant metal loads. Moreover, the sludge produced as a byproduct of wastewater treatment is also enriched with metals. In essence, domestic wastewater and the disposal of both domestic and industrial sludge constitute the primary anthropogenic sources of cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), and mercury (Hg) pollution.

### 1.4 Metal Pollution from Stormwater Runoff

Stormwater drainage from developed urban regions is a notable contributor to the introduction of metal pollutants into the receiving bodies of water. The specific makeup of metals present in urban runoff is contingent upon numerous variables, encompassing urban layout, vehicular traffic patterns, road construction materials, land usage, and the topographical and climatic attributes of the surrounding watershed.

### 1.5 Metal Pollution from Industrial Wastes and Discharges

In most cases, the levels of heavy metals in industrial effluents far exceed the allowable limits set for discharges into aquatic environments. Therefore, it is imperative to implement effective treatment measures for effluents containing these metals before releasing them into water bodies. The types of metals and their concentrations in industrial wastewater vary significantly based on the specific industry's activities and processes.

**Table 1: Anthropogenic sources of heavy metals in the environment**

| Sl. No. | Pollutant | Major sources |
|---|---|---|
| **1.** | **Arsenic** | Arsenic containing fungicides, pesticides and herbicides, metal smelters, byproducts of mining activities, chemical wastes |
| **2** | **Cadmium** | Cadmium producing industries, electroplating, welding. By-products from refining of Pb, Zn and Cu, fertilizer industry, pesticide manufacturers, cadmium–nickel batteries, nuclear fission plants. |

| Sl. No. | Pollutant | Major sources |
|---|---|---|
| 3 | **Chromium** | Metallurgical and chemical industries, processes using chromate compounds, cement and asbestos units |
| 4 | **Copper** | 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 |
| 5 | **Iron** | Cast Iron, Wrought Iron, steel, alloys, construction, transportation, machine manufacturing |
| 6 | **Lead** | Automobile emissions, lead smelters, burning of coal and oil, lead arsenate pesticides, smoking, mining and plumbing |
| 7 | **Mercury** | Mining and refining of mercury, organic mercurials used in pesticides, laboratories using mercury |
| 8 | **Nickel** | 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 |
| 9 | **Zinc** | Zinc refineries, galvanizing processes, brass manufacture, metal plating, plumbing |

### 1.6 Sanitary Landfills

Sanitary landfills, where waste is carefully disposed of, can still contribute to environmental issues. The metal content and average concentrations in leachates from these landfills are notable. Specifically, you will find copper (Cu) at an average concentration of 5 parts per million (ppm), zinc (Zn) at 50 ppm, lead (Pb) at 0.3 ppm, and mercury (Hg) at 60 parts per billion (ppb). These metals can leach into the surrounding soil and potentially contaminate groundwater, posing a concern for the quality of local water sources.

### 1.7 Agricultural Runoff

Agricultural runoff, which occurs when water flows over cultivated fields, can carry a range of metals into the environment. These metals often originate in the sediment and soils that have absorbed residues from plants and animals, as well as various agricultural inputs. This can include the presence of copper (Cu), zinc (Zn), and other metals stemming from fertilizers, herbicides, and fungicides. Additionally, the use of sewage and sludge as fertilizers can introduce metals like copper and zinc into the agricultural ecosystem. It's crucial to manage agricultural runoff to mitigate the impact of these metals on water quality and surrounding ecosystems.

### 1.8Fossil Fuel Combustion

Fossil fuel combustion, a prevalent source of energy, can have significant consequences for water quality. When fossil fuels like coal, oil, and natural gas are burned for energy, they release various metals into the atmosphere. These metals can later deposit into natural waters, including lakes and rivers. This contamination can have harmful effects on aquatic ecosystems and human health. It is essential to monitor and mitigate the release of these airborne metals to safeguard the quality of natural waters and the well-being of the environment and communities.

## 2. TOXICITY OF TRACE & TOXIC METALS

Heavy metals may enter the human body through various routes, including food, water, and air, or they can be absorbed through the skin when individuals come into contact with them in agriculture and various settings, including manufacturing, pharmaceutical, industrial, or residential settings. Despite the long-standing awareness of the adverse health effects of heavy metals, exposure to these substances continues and, in some parts of the world, is even increasing. Consequently, the management of heavy metal contamination and the removal of toxic heavy metals from water have become pressing challenges for the twenty-first century.

Out of the 35 metals recognized as hazardous to human health, 23 are categorized 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. Nevertheless, the most severe health risks associated with heavy metals are linked to exposure to lead, cadmium, mercury, and arsenic (classified as a metalloid but often considered a heavy metal). Substantial quantities of any of these metals can result in acute or chronic toxicity, leading to damage or impairment of mental and central nervous functions, alterations in blood composition, lung, kidney, liver damage, and damage to other vital organs. Prolonged exposure to these heavy metals can lead to slowly progressing physical, muscular, and neurological degenerative processes that mimic diseases such as Alzheimer's, Parkinson's, muscular dystrophy, and multiple sclerosis. Allergies are not uncommon, and repeated long-term contact with certain metals or their compounds may even lead to cancer.

The toxicity of heavy metals depends on a multitude of factors, including the specific metal present, its chemical properties, its biological role, the organism exposed, and the stage of the organism's life during exposure. When one organism is affected, it can disrupt the entire food chain. Given that humans typically occupy the top of the food chain, we are particularly vulnerable as we can accumulate higher levels of heavy metals due to their concentration increasing up the food chain. Both industrial and domestic waste is commonly discharged into sewage systems, which often contain high concentrations of heavy metals. These heavy metals are not readily broken-down during sewage treatment. Instead, they are either removed in the final effluent or retained in the sludge produced during the treatment process. The characteristics and pollutants in the sewage that enters water bodies depend on the level of sewage treatment in place. In response to the problems arising from the untreated release of sewage into rivers and seas, various regulations and improved technologies have been implemented. To mitigate the discharge of pollutants into our waters, it is imperative to establish stringent regulations and adopt advanced technologies.

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

## 2.1 Toxicity of Arsenic

Arsenic is a widely distributed element, ranking 20th in natural abundance, constituting approximately 0.00005% of the Earth's crust, 14th in seawater, and 12th in the human body (Mandal and Suzuki, 2002). Arsenic is found in various environmental compartments, including rocks, soil, water, air, and biota.

Arsenic occurs in the environment in various oxidation states, such as As(V), As (III), As (0), and As(-III). The chemical forms and oxidation states of arsenic are of particular significance in terms of toxicity. Inorganic forms are generally more toxic and mobile than organo-arsenic species, with arsenite (As(III)) considered to be more toxic than arsenate (As(V)). Research has indicated 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 observed that As (III) is 10 times more toxic than As(V) and 70 times more toxic than Mono Methyl Arsonate (MMA(V)) and Di Methyl Arsinate (DMA(V)). However, trivalent methylated arsenic species, such as MMA(III) and DMA(III), have been found to be more toxic than inorganic arsenic because they are more effective at causing DNA damage (Styblo et al. 2000; Dopp et al. 2004). Arsenic can enter the human body through ingestion, inhalation, or skin absorption. Most ingested and inhaled arsenic is readily absorbed through the gastrointestinal tract and lungs into the bloodstream.

Individuals who consume arsenic-contaminated water often display arsenical skin lesions, which are a late manifestation of arsenic toxicity. Prolonged exposure to arsenic-contaminated water can lead to various diseases, including conjunctivitis, hyperkeratosis, hyperpigmentation, cardiovascular diseases, disturbances in the peripheral vascular and nervous systems, skin cancer, gangrene, leucomelanosis, non-pitting swelling, hepatomegaly, and splenomegaly (Kiping, 1977; WHO, 2001; Pershagen, 1983). Chronic symptoms resulting from long-term arsenic exposure are nonspecific, such as weight loss and chronic weakness. Prolonged exposure can lead to arsenicosis, cardiovascular diseases, skin lesions, and other organ function disorders (Bissen and Frimmel 2003). Arsenicosis is a chronic illness that arises from prolonged consumption of water with high arsenic levels over an extended period (Kapaj et al. 2006). Advanced stages of arsenic toxicity can manifest in effects on the lungs, uterus, genitourinary tract, and other parts of the body. Additionally, elevated concentrations of arsenic in drinking water have been linked to an increase in stillbirths and spontaneous abortions (Csanady and Straub, 1995).

## 2.2 Toxicity of Cadmium

Cadmium is a naturally occurring element in the Earth's crust, distributed uniformly at an estimated average concentration of between 0.10 and 0.50 µg/L. In nature, cadmium is found in various inorganic compounds and as complexes with naturally occurring chelating agents. Organo-cadmium compounds are highly unstable and have not been observed in the natural environment. Cadmium is produced during the extraction of zinc and finds applications in the plating industry, pigments, the manufacturing of plastic materials, batteries, and alloys. The contamination of water with cadmium results from industrial discharges and leaching from landfilled areas. Drinking water can also become contaminated when it passes through galvanized iron pipes or plated plumbing fittings used in water distribution.

Cadmium is considered highly toxic, ranking just below mercury in terms of its toxicity. Exposure to low levels of cadmium typically does not produce immediate health effects but can lead to severe health problems over extended periods. The gastrointestinal tract is the primary route of cadmium uptake in both humans and animals. Cadmium is toxic to humans, animals, microorganisms, and plants. However, only a small portion of cadmium intake is absorbed by the body, mainly accumulating in bones, the liver, and, in cases of chronic exposure, the kidneys. Recent evidence suggests that relatively low cadmium exposure may lead to skeletal damage, resulting in low bone mineral density (osteoporosis) and fractures. The toxicity of cadmium lies in its accumulation in soft tissues. Animal studies have indicated 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, abdominal pain, anemia, kidney failure, and diarrhea. Inhalation of cadmium dust or smoke may lead to dryness of the throat, headache, chest pain, coughing, increased discomfort, and bronchial complications (Lu et al., 2007). Adverse health effects resulting from the ingestion or inhalation of cadmium include renal tubular dysfunction due to high urinary cadmium excretion, high blood pressure, lung damage, and lung cancer.

Furthermore, cadmium accumulates in the bodies of animals and humans throughout their lifespans. The liver and kidneys are the primary stations of cadmium accumulation. After inhalation or absorption through the gastrointestinal tract, cadmium is concentrated in the kidneys, where its half-life can exceed 10 to 20 years. One of the well-documented toxic effects of cadmium poisoning is nephrotoxicity. Adverse renal effects are more commonly observed with exposure to low levels of cadmium. These effects are manifested by the excretion of low-molecular-weight plasma proteins, such as β2-microglobulin and retinol-binding protein (RBP).

A widely reported case of cadmium poisoning, known as “itai-itai byo”, occurred in Japan after World War II. Cadmium pollution from mining and refinery factories contaminated the Jinzo River water, which was used for irrigation. Rice grown in these cadmium-affected fields absorbed the metal, and people consumed it through water and the food chain, leading to osteomalacia and skeletal deformations. Severe pain in the body and joints prompted people to cry out "ITAI-ITAI" (it hurts-it hurts).

## 2.3 Toxicity of Chromium

Chromium can exist in various valence states, ranging from -2 to +6, but it is predominantly found in the environment in either the trivalent (Cr [III]) or hexavalent

(Cr [VI]) state. Trivalent chromium (Cr [III]) is the most common naturally occurring state. Small amounts of chromic oxide ($Cr_2O_3$) are typically present in most soils and rocks. In contrast, hexavalent chromium (Cr [VI]) is frequently found in nature as chromates ($CrO_4^{2-}$) and dichromates ($Cr_2O_7^{2-}$). These hexavalent forms are often a result of industrial and domestic emissions.

Chromium is unique as it is considered both an essential nutrient and a potential health hazard, primarily because it can exist in different oxidation states. Specifically, chromium in the +6 oxidation state, denoted as Cr(VI), is regarded as harmful, even in small quantities. In contrast, chromium in the +3 oxidation state, written as Cr (III), is considered essential for maintaining good health when consumed in moderate amounts. Chromium (III) is recognized as an essential nutrient for humans. Shortages of this form of chromium can lead to various health issues, including heart conditions, metabolic disruptions, and diabetes. Chromium (III) plays a crucial role in fat synthesis from glucose and the oxidation of fat to carbon dioxide. However, excessive intake of chromium (III) can also result in health effects, such as skin rashes.

Individuals who smoke tobacco are at an elevated risk of exposure to chromium. Chromium (VI) is recognized for its capacity to induce various health issues. When encountered in compounds used in leather products, it can trigger allergic reactions, leading to skin rashes. Inhalation of chromium (VI) can result in irritations of the nose, often leading to nosebleeds. Other health concerns associated with chromium (VI) exposure include:

- Skin rashes
- Discomfort in the stomach and the development of ulcers
- Respiratory complications
- Weakening of the immune system
- Damage to the kidneys and liver
- Genetic material alterations
- Increased risk of lung cancer
- Mortality

The extent of health risks stemming from chromium exposure is contingent upon its specific oxidation state. The metallic form of chromium, as found in particular products, generally poses low toxicity, whereas the hexavalent form is considered toxic. Adverse effects of hexavalent chromium on the skin may manifest as ulcerations, dermatitis, and allergic skin reactions. Inhalation of hexavalent chromium compounds can lead to ulceration and perforation of the mucous membranes within the nasal septum, irritation of the pharynx and larynx, asthmatic bronchitis, bronchospasms, and edema. Respiratory symptoms may include coughing, wheezing, shortness of breath, and nasal irritation.

Hexavalent chromium is also detrimental to plant and animal life, inducing symptoms such as the yellowing of leaves in crops like wheat and paddy. The World

Health Organization (WHO) has recommended a maximum permissible limit of 0.05 mg/L for chromium in drinking water to safeguard public health and ensure safe drinking water sources.

### 2.4 Toxicity of Copper

Copper stands as an essential micronutrient, as recognized in studies by Underwood (1977) and Goyer (1991). The Food and Nutrition Board (FNB) recommends an adult dietary copper intake of 1.53 mg/day (NRC, 1989). Copper exhibits three significant valence states: copper metal Cu(0), Cu(I), and Cu(II). In the natural world, copper manifests both as the pure metal and within minerals, with notable occurrences in cuprite ($Cu_2O$) and malachite ($Cu_2CO_3(OH)_2$). Predominantly, copper is present in ores, encompassing sulphides, oxides, and carbonates.

Copper serves a dual role, being both essential and potentially toxic to living organisms. In its essential role, copper is vital for processes like proper growth, cardiovascular health, lung flexibility, neuroendocrine functions, neovascularization, and iron metabolism. On average, an adult human consumes approximately 1 mg of copper daily through their diet, with roughly half of that amount being absorbed (Harris 1997). Copper is obligatory for enzymes that partake in aerobic metabolism, including cytochrome oxidase in mitochondria, lysyl oxidase in connective tissue, dopamine mono-oxygenase in the brain, and ceruloplasmin. Acting as a co-factor for apo-copper-zinc superoxide dismutase (apoCuZnSOD), copper offers protection against free-radical damage to proteins, cell membrane lipids, and nucleic acids in a broad range of cells and organs.

While severe copper deficiencies are relatively rare in humans, they can lead to a spectrum of health issues, encompassing mental retardation, anemia, hypothermia, neutropenia, diarrhea, cardiac hypertrophy, bone fragility, impaired immune function, weakened connective tissue, compromised central-nervous-system (CNS) functions, peripheral neuropathy, and alterations in skin, fur (in animals), or hair color (Linder and Goode 1991; Uauy et al. 1998; Cordano 1998; Percival 1998).

Long-term exposure to elevated copper levels can induce irritations of the nose, mouth, and eyes, causing symptoms such as headaches, stomachaches, dizziness, vomiting, and diarrhea. Intentional high copper intake may lead to liver and kidney damage and, in extreme cases, fatal outcomes. The carcinogenic potential of copper remains undetermined, but there are scientific reports suggesting a correlation between long-term exposure to high copper concentrations and a decline in intelligence among young adolescents, a subject warranting further investigation. Industrial exposure to copper fumes, dust, or mists may lead to a condition known as metal fume fever, characterized by atrophic changes in nasal mucous membranes. Chronic copper poisoning can result in Wilson's disease, marked by hepatic cirrhosis, brain damage, demyelination, renal complications, and copper deposition in the cornea.

Moreover, excessive amounts of copper sulfate can negatively impact the botanical environment. In its ionic form, copper is highly toxic to the photosynthesis of green algae such as Chlorella pyrenoidosa and diatoms like Nitzchiz palea, even at concentrations typically found in natural waters. Soils in regions where copper fungicides are repetitively employed, notably in vineyards and orchards, may accumulate copper over time. This underlines the dual nature of copper: essential for life and health but also capable of causing adverse effects when in deficiency or excess.

## 2.5 Toxicity of Mercury

Mercury (Hg) is the only common metal that is liquid at room temperature. Mercury occurs naturally in the earth's crust. Although it may be found in air, water and soil, mercury is mostly present in the atmosphere as a gaseous element. Mercury's major natural source results from the degassing of the earth's crust, emissions from volcanoes and evaporation from natural bodies of water. Mining of metals also causes indirect mercury discharges to the atmosphere. Due to its long lifetime of approximately of 1 year in the atmosphere, mercury's dispersion, transport and deposition in the environment will cause harmful effects on ecosystems and human health. Mercury may be present in the environment in several forms: elemental or metallic mercury, inorganic mercury compounds and organic mercury compounds. Pure mercury is a volatile liquid metal. It has traditionally been used in products like thermometers, switches, barometers and instruments for measuring blood pressure. Mercury is naturally present in many rocks including coal. When coal is burned, mercury is released into the environment. For this reason, coal-burning power plants are one of the largest anthropogenic sources of mercury emissions to the air, in addition to all domestic human-caused mercury emissions. Burning hazardous wastes, producing chlorine, breaking mercury products, and spilling mercury, as well as the improper treatment and disposal of products or wastes containing mercury, can also contribute to its release into the environment (EPA, 2009). Mercury compounds are produced in small quantities for chemical and pharmaceutical applications. In ancient Greece mercury was used as a cosmetic to lighten the skin (Jarup, 2003): in some sub-Saharan African countries the use of cosmetic products to bleach or to lighten the skin is still frequent. The long term use of some pharmacologic compounds (hydroquinone, glucocorticoids and mercury) can cause severe health adverse effects (Jarup, 2003). Large quantities of mercury compounds are still used for amalgamation in illegal gold mining, in some developing countries. Anthropogenic sources of mercury and its compounds may result basically from the same sources as enunciated for Cadmium. In addition, underground mining, mining quarrying, opencast and, production of phytopharmaceutical products and biocides, pharmaceutical industry, landfills, urban waste treatment plants, industrial waste-water treatment plants, etc. (E-PRTR, 2010) also add to the list of sources of mercury.

Exposure to mercury may mainly occur as a consequence of the deposition from air into water or into soil. By natural biological processes certain microorganisms can change mercury into methyl mercury, a highly toxic and stable form that builds up in fish, shellfish and animals that eat fish, accumulating in the food chain. General population is exposed to methyl mercury through the food chain; fish and shellfish are the main source of exposure through the ingestion pathway (EPA, 2009). Breathing mercury vapor is another possible exposure pathway. This can occur when elemental mercury or products that contain elemental mercury break and release mercury into air, in especial in indoor spaces without enough ventilation. Nevertheless, the main exposure pathway is through food chain and not by inhalation (EPA, 2009). High level of mercury can cause harmful effects, such as nerve, brain and kidney damage, lung irritation, eye irritation, skin rashes, vomiting and diarrhea. Mercury has a number of effects on humans that can be simplified into the following main effects:

- Disruption of the nervous system
- Damage to brain functions
- DNA damage and chromosomal damage
- Allergic reactions, resulting in skin rashes, tiredness and headaches
- Negative reproductive effects, such as sperm damage, birth defects and miscar-riages

Damaged brain functions can cause degradation of learning abilities, personality changes, tremors, vision changes, deafness, muscle in coordination and memory loss. High levels of methylmercury in the bloodstream of little children may affect nervous system, affecting the normal thinking and learning (EPA, 2009). Chromosomal damage is known to cause mongolism. In Japan, human illness and death occurred in the 1950's among fishermen who ingested fish, crabs and shellfish contaminated with a simple alkali mercury compound from Japanese coastal industries. This mercury poisoning produced a crippling and often fatal disease known as "Minamata" disease. In minamata episode, crabs contained as much as 24 ppm, while kidney's from human victims contained 144 ppm. Chloro-alkali plants and primary mercury processing plants are known to emit mercury into the atmosphere in sufficient quantities to create a public health problem. Poisoning of mercury may cause anxiety, insomnia, muscular tremor and other psychological disturbances. Research work with plants has shown that mercury can produce genetic and chromosomal changes (Liptak, 1974).

## 2.6 Toxicity of Iron

Iron is essential for the well-being of nearly all life forms, ranging from micro-organisms to humans. As the fourth most abundant element in the Earth's crust, and the most prevalent heavy metal, iron mainly exists in the environment as either Fe (II) or Fe (III). In surface waters, iron typically takes the form of Fe (III) when the pH level exceeds 7, with most of these salts being insoluble. They settle out or are adsorbed onto surfaces, resulting in relatively low iron concentrations in well-aerated waters. However, under reducing conditions found in groundwater, certain lakes, reservoirs, and environments devoid of sulfides and carbonates, higher concentrations of soluble Fe(II) may emerge. The presence of iron in natural waters is attributed to processes such as rock and mineral weathering, acidic mine water drainage, landfill leachates, sewage effluents, and iron-related industries.

Iron is an indispensable component of human nutrition, playing a vital role in cytochromes, porphyrins, and metalloenzymes. Dietary iron needs vary by age and sex, with older infants, children, and menstruating women being particularly susceptible to iron deficiency. In the plant kingdom, iron is essential for metabolic processes. It is crucial for the synthesis of chlorophyll in green plants, although it is not part of the chlorophyll molecules. Most iron in plants exists within organic compounds, enzymes, and plays key roles in cellular metabolism, encompassing catalase, peroxidase, and cytochromes. Iron deficiencies in plants result in chlorosis, and it's known for its immobility within plant tissues.

Iron exists in the human body in both ionic (loosely bound, inorganic iron) and nonionic (tightly bound, organic form) states. Notably, it is a constituent of the hemoglobin molecule. Iron deficiency is linked to an increased susceptibility to lead poisoning, particularly among children. A deficiency in iron, along with other trace elements, can lead to pica, characterized by cravings for unusual or non-nutritive substances such as clay, chalk, ashes, or bricks, and it's commonly seen in individuals with hysteria, during pregnancy, or in cases of chlorosis. Iron deficiency can also affect the transport of lead within the body.
According to Dr. Ronald Hoffman, daily iron requirements vary by age, sex, and body weight, with recommendations as follows:

- Infants up to 6 months: 6 mg/day.
- Children from 6 months to 1 year: 10 mg/day.
- Children aged 1 to 10 years: 10 mg/day.
- Males aged 11 to 18 years: 12 mg/day.
- Males aged 19 to 51+ years: 10 mg/day.
- Females aged 11 to 50 years: 15 mg/day.
- Females over 51 years: 10 mg/day.
- Pregnant women: 30 mg/day.
- Lactating women: 15 mg/day.

While iron is essential in normal quantities, excessive iron intake can adversely affect the human system and may lead to conditions like hemochromatosis. Iron absorption is enhanced by factors like heme, ascorbic acid, and amino acids but is inhibited by tannins, calcium, phosphate, phytic acid, and dietary fibers.

In the human body, iron is central to life processes, with over half of it present in the form of hemoglobin, while the rest is stored mainly in the liver. Nutritional anemia, particularly iron-deficiency anemia, is a widespread deficiency condition worldwide. This condition often results from insufficient iron intake, and it is a significant public health concern in countries like India, affecting more than half of ever-married women. Addressing this issue is of utmost importance.

Natural water often contains iron in ferric and ferrous forms, with the ferric form predominating in most cases. The form of iron can change due to oxidation or reduction resulting from bacterial growth during water storage. Iron in water can be present in true solution, a colloidal state, or as relatively large suspended particles. Determining iron levels is crucial for evaluating the extent of corrosion and assisting in finding solutions to these problems. Research on corrosion and corrosion control involves various tests to assess metal loss, with iron determination being one of the most important (Sawyer, 1978). In drinking water, the highest desirable limit for iron is 1.0 mg/L.

## 2.7 Toxicity of Lead

Lead is among the most common heavy elements, with various stable isotopes found in nature. Notably, 208Pb is the most prevalent. Lead is primarily utilized in the production of lead-acid batteries, solder, and various alloys. Organo-lead compounds, such as tetraethyl and tetramethyl lead, were historically used as antiknock and lubricating agents in petrol, although many countries are phasing out their use for these purposes. With the diminishing use of lead-containing additives in petrol and lead-containing solder in the food processing industry, airborne and dietary lead concentrations are decreasing. As a result, the intake of lead from drinking water has become a more significant contributor to overall exposure.

Lead's toxic properties have been recognized for over two thousand years. The early Greeks used lead as a glazing material for ceramic pottery and discovered its harmful effects when it came into contact with acidic foods. There is evidence to suggest that some Roman emperors suffered illness and even death due to lead poisoning resulting from the consumption of wines contaminated with high levels of lead.

Lead is present in all human tissues and organs but is not required for nutritional purposes. It is considered a systemic poison because once it enters the bloodstream, it distributes throughout the body, affecting various organs and tissues. Lead inhibits hematopoiesis (the formation of blood or blood cells) by interfering with heme synthesis, potentially leading to anemia. It also impacts the kidneys by inducing renal tubular dysfunction, which can result in secondary complications. Gastrointestinal effects of lead poisoning include nausea, anorexia, and severe abdominal cramps (known as lead colic), often associated with constipation. Lead poisoning can also manifest as muscle and joint pain, lung damage, breathing difficulties, and conditions such as asthma, bronchitis, and pneumonia. Additionally, lead exposure can harm the immune system, impeding cell maturation and skeletal growth. Lead can cross the placental barrier and reach the fetus, increasing the risk of miscarriage, abortions, and stillbirths.

According to the CDC, lead poisoning is the most common and severe environmental health issue affecting young children. Children are more vulnerable to lead exposure than adults due to their rapid growth rate and higher metabolism. Children absorb more lead from the gastrointestinal tract (25% vs. 8% in adults), with ingested lead distributed to a smaller tissue mass. Children are also more likely to play and breathe closer to the ground, where lead dust accumulates. A significant problem arises from children ingesting lead-based paint flakes, accounting for up to 90% of childhood lead poisoning cases. The primary health concern in children exposed to lead is intellectual and brain damage, and high-level exposure can even be fatal. Plants grown in lead mining areas are known to accumulate high lead levels. Vegetation near highways can accumulate atmospheric dust containing lead as foliar deposits, originating from petrol combustion and absorption from soil.

## 2.8 Toxicity of Nickel

Nickel, the 24th most abundant element, accounting for approximately 0.008% of the Earth's crust, is a natural constituent of soil and water (Alloway 1995; Hostynek and Maibach 2002; Hedfi et al. 2007). It ranks as the 5th most abundant element in the biosphere and was initially discovered through the extraction of other metals. Principal nickel ores include nickelite (NiAs), millerite (NiS), and pentlandite ([Ni, Fe]S).

Nickel enters the environment from a range of natural and anthropogenic sources. Among industrial contributors, a significant portion of environmental nickel arises from the combustion of coal, oil, and other fossil fuels. Additional industrial sources of nickel emissions encompass mining and refining processes, nickel alloy production (steel), electroplating, and municipal waste incineration (Sharma 2005; Ensink et al. 2007). Wastewater discharged from municipal sewage treatment plants further adds to the accumulation of environmental nickel (van der Hoek et al. 2002).

While nickel is essential in small quantities, excessive uptake poses health risks to humans. Exposure to nickel can occur through air inhalation, water consumption, food intake, or smoking. Skin contact with nickel-contaminated soil or water can also lead to nickel exposure. One of the most prevalent modes of nickel exposure for the general public is through direct skin contact with nickel-plated materials. Notably, $Ni(CO)_4$ gas stands out as the most toxic compound among nickel compounds, with documented cases of fatalities in refineries. Initial symptoms include headaches, nausea, weakness, dizziness, vomiting, and epigastric pain, with a latency period of 1 to 5 days. Subsequent symptoms encompass chest constriction, chills, sweating, shortness of breath, coughing, muscle pains, fatigue, gastrointestinal discomfort, and in severe cases, convulsions and delirium.

Nickel fumes are known respiratory irritants and can lead to pneumonitis. Exposure to nickel and its compounds may result in the development of dermatitis referred to as "nickel itch" in sensitized individuals. Typically, itching appears up to 7 days before the onset of skin eruptions. Primary skin eruptions are erythematous or follicular and may progress to skin ulceration. Once acquired, nickel sensitivity appears to persist indefinitely. High-level occupational exposure has been associated with renal problems, vertigo, and dyspnoea (Commission of European Communities, 1976). Nickel, along with certain nickel compounds, has been classified by the National Toxicology Program (NTP) as having potential carcinogenic effects. The International Agency for Research on Cancer (IARC) categorizes nickel compounds within group 1 (indicating sufficient evidence of carcinogenicity in humans) and nickel within group 2B (representing agents that are possibly carcinogenic to humans).

## 2.9 Toxicity of Zinc

Zinc, the twenty-fifth most abundant element, constitutes approximately 0.02% of the Earth's crust by weight (Budavari, 1989). In its natural state, zinc typically appears dull grey due to its coating with oxide or basic carbonate, making it rare to find free zinc metal in nature (Beliles, 1994). Sphalerite, smithsonite, hemimorphite, and franklinite serve as the primary sources of zinc, with erosion being the largest natural contributor to zinc emissions in water. Zinc naturally enters the air mainly through igneous emissions and forest fires. Anthropogenic and natural sources contribute to zinc emissions to a similar extent, with key human-made sources including mining, zinc production facilities, iron and steel production, corrosion of galvanized structures, coal and fuel combustion, waste disposal and incineration, as well as the use of zinc-containing fertilizers and pesticides.

Zinc is an essential element for both animals and humans, playing a vital role in various enzyme systems. Reports of nutritional zinc deficiency in humans have emerged from various countries, with Egypt documenting an endemic zinc deficiency syndrome among young men (Prasad, et al., 1961; Halsted et al., 1972). This syndrome is characterized by stunted growth, signs of immaturity, and anemia, which are likely due to reduced intestinal zinc absorption. The condition was observed to be fully treatable with the administration of substantial doses of zinc sulfate.

Acute zinc toxicity can occur when excessive amounts of zinc salts are ingested, either accidentally or deliberately, such as through the use of zinc-containing emetics or dietary supplements. Vomiting is likely to ensue after the consumption of more than 500 mg of zinc sulfate. Instances of mass poisoning have been reported when acidic beverages were stored in galvanized containers, with symptoms including fever, nausea, vomiting, stomach cramps, and diarrhea occurring 3–12 hours after ingestion. Food poisoning attributed to the use of galvanized zinc containers in food preparation has also been documented. Symptoms in such cases arose within 24 hours and included nausea, vomiting, and diarrhea, occasionally accompanied by bleeding and abdominal cramps.

Symptoms of zinc toxicity in humans encompass vomiting, dehydration, electrolyte imbalances, abdominal pain, nausea, lethargy, dizziness, and impaired muscular coordination (Prasad and Oberleas, 1976). Reports of acute renal failure resulting from zinc chloride ingestion have also been documented (Csata, 1968). Unlike substances such as mercury (Hg), lead (Pb), or cadmium (Cd), zinc is an essential trace element for organisms, playing a crucial role in various physiological and metabolic processes. However, at high concentrations, zinc can become toxic to organisms.

Zinc is an essential trace element for both plants and animals, including humans, playing vital roles in various metabolic processes. Common effects of zinc poisoning in humans include non-fatal 'metal fume' fever from inhaling zinc oxide fumes and illnesses resulting from the consumption of acidic foods prepared in zinc galvanized containers. Specifically, zinc chloride in zinc salts can cause dermatitis upon skin contact.

# 3. WATER QUALITY CRITERIA

It is widely acknowledged that accessible sources of water on our planet are finite, and any form of pollution in these sources further diminishes their availability. Polluted water poses inherent health risks and cannot be safely used for drinking. Water with elevated salt levels is unsuitable for agricultural purposes and most industrial applications. Water quality also has a profound impact on the aesthetic and economic aspects of water bodies, affecting marine and freshwater ecosystems. Nevertheless, water that may not meet the standards for irrigation can often be suitable for industrial cooling. Every application of water necessitates a minimum quality standard concerning the presence of dissolved and suspended materials, encompassing both chemical and biological constituents. Ensuring this desirable water quality standard is essential to prevent harm to end-users.

The need to uphold a minimum quality standard for various water uses has led to the development of water quality criteria and water quality standards. Water quality criteria represent specific requirements that serve as the basis for making decisions or judgments to support a particular use. These criteria for different uses are established based on experimental data and our current understanding of health, ecological, and other considerations, considering their overall economic impact. It's crucial to note that these criteria are not rigid, but rather subject to adjustment as scientific knowledge evolves and more data is collected. The term "standard" refers to a specific principle or guideline set by an authority to restrict the concentration of various constituents in water, ensuring the safe utilization of water and safeguarding the environment.

## 3.1 Drinking Water Standards

Considering that people directly use water for drinking, providing water for domestic use is the most important purpose, and ensuring safe drinking water is the top priority in the National Water Policy. In India, organizations like the Bureau of Indian Standards (BIS) and the Indian Council of Medical Research (ICMR) have created rules for what is safe to drink. The World Health Organization (WHO) has also set international rules for safe drinking water. Below, we list the rules for safe levels of certain metals in drinking water based on the BIS code 10500:2012, in Table 2.

**Table 2: Drinking Water Standards for Trace & Toxic metals (BIS-10500:2012)**

| S.No. | Toxic metal | Requirement (Acceptable Limit ) | | Permissible Limit in the Absence of Alternative Source | |
|---|---|---|---|---|---|
| | | (mg/L) | (µg/L) | (mg/L) | (µg/L) |
| 1 | Total arsenic as As | 0.01 | 10 | No Relaxation | |
| 2 | Cadmium as Cd | 0.003 | 3 | No relaxation | |
| 3 | Total Chromium as Cr | 0.05 | 50 | No relaxation | |
| 4 | Copper as Cu | 0.05 | 50 | 1.5 | 1500 |
| 5 | Iron as Fe | 1.0 | 1000 | No relaxation | |
| 6 | Lead as Pb | 0.01 | 10 | No relaxation | |
| 7 | Nickel as Ni | 0.02 | 20 | No relaxation | |
| 8 | Zinc as Zn | 5 | 5000 | 15 | 15000 |

## 3.2 Regulatory Limits of Heavy Metals US Environmental Protection Agency (US EPA)

Various toxic heavy metals often contaminate surface water sources, and the maximum levels allowed, as per WHO and US EPA standards, are detailed in Table 3. These limits are compulsory for all water supply systems. In many cases, naturally occurring water, whether from surface or groundwater sources, contains some of these heavy metals at concentrations that are 100 to 1000 times higher than the recommended MCL values. As these heavy metals have various industrial uses, it becomes more important to focus on their removal, recovery, and recycling.

**Table 3: Maximum acceptable limits of several toxic heavy metal ions based on WHO and US EPA regulations**

| Heavy Metal | Toxicity rank | WHO (µg/L) | USEPA (µg/L) |
|---|---|---|---|
| Arsenic | 1 | 10 | 10 |
| Lead | 2 | 10 | 15 |
| Mercury | 3 | 6 | 2 |
| Cadmium | 7 | 3 | 5 |
| Chromium | 78 | 50 | 100 |
| Nickel | 57 | 70 | 100 |
| Zinc | 74 | NGL | 5000 |
| Copper | 120 | 2000 | 1300 |
| Iron | - | - | 300 |
| Note: NGL = NO Guideline | | | |

Based on data from human clinical studies and a range of other research, including animal experiments, governmental authorities have established drinking water standards. A concise overview of these standards can be found in Table 4, compiled by Hattingh in 1977.

**Table 4: Drinking water quality criteria for trace metals which might affect public health**

| Parameter (unit-µg/L) | USPHS (1962) | Japan (1968) | USSR (1970) | WHO European (1970) | WHO Intern. (1971) | SABS (1971) | NAS (1972) | Australia (1973) | US EPA (1975) | FRG (1975) | | BIS 10500:2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Arsenic** | 10 | 50 | 50 | 50 | 50 | 50 | 100 | 50 | 50 | 40 | | 10 |
| **Barium** | 1,000 | - | 4,000 | 1,000 | - | - | 1,000 | 1,000 | 1,000 | - | | 700 |
| **Cadmium** | 10 | - | 10 | 10 | 10 | 50 | 10 | 10 | 10 | 6 | | 3 |
| **Chromium** | 50 | 50 | 100 | 50 | - | 50 | 50 | 50 | 50 | 50 | | 50 |
| **Copper** | 1,000 | 10,000 | 100 | 50 | 50 | 1,000 | 1,000 | 10,000 | - | - | | 50 |
| **Lead** | 50 | 100 | 100 | 100 | 100 | 50 | 50 | 50 | 50 | 40 | | 10 |
| **Mercury** | - | 1 | 5 | - | 1 | - | 2 | - | 2 | 4 | | 1 |
| **Selenium** | 10 | - | 1 | 10 | 10 | - | 10 | 10 | 10 | 8 | | 10 |
| **Silver** | 50 | - | - | - | - | - | - | 50 | 50 | - | | 100 |
| **Zinc** | 5,000 | 100 | 1,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | - | 2,000 | | 5000 |

*World Health Organisation (WHO)*
*US Public Health Service (USPHS)*
*South African Bureau of Standards (SABS)*
*Russisa (USSR)*
*USA National Academy of Sciences (NAS)*
*Australia, Japan and Environmental Protection Agency (EPA) of the USA*

It is important to mention that maximum permissible concentrations (USSR) and threshold limit values (US) have been defined for occupational hygiene (as indicated by Roschin and Timofeevskaya in 1975). These values are primarily related to regulating workplace exposure to airborne particles and are not directly relevant to our current discussion.

## 3.3 Quality Criteria for Livestock

A safe water supply is vital for maintaining healthy livestock. Contaminated water has the potential to adversely affect the growth, reproduction, and overall productivity of animals, as well as the safety of animal products intended for human consumption. Moreover, polluted water sources for livestock and poultry have the potential to contaminate human drinking water supplies. As a result, it is essential to safeguard farm water sources from contamination by harmful agents like bacteria, nitrates, sulfates, and pesticides. While the Environmental Protection Agency has established drinking water standards for human consumption, there are currently no specific standards in place for drinking water provided to livestock or poultry. However, The National Academy of Sciences has issued recommendations for maximum allowable levels of certain contaminants.

The acceptable daily intake of various substances greatly depends on their concentrations and the overall water quality consumed. Animals' daily water requirements can vary based on several factors, including temperature, humidity, the water content of their food, their level of physical activity, and the salinity of the water source. Consequently, the recommended concentration levels for specific substances are determined considering these typical usage conditions. Excessive salinity in the drinking water provided to livestock can disrupt the animals' water balance and may even lead to fatalities. Elevated levels of certain ions in the water can result in health issues and potentially be fatal for animals. The National Academy of Sciences has established upper limits for toxic substances present in water (see Table 5).

**Table 5: Recommendations for levels of toxic substances in drinking water for livestock**

| Sr. | Toxic metal | Upper Limit in mg/L | Sr. | Toxic metal | Upper Limit in mg/L |
|---|---|---|---|---|---|
| **1.** | Arsenic | 0.2 | 5. | Iron as Fe | - |
| **2.** | Cadmium as Cd | 0.05 | 6. | Mercury as Hg | 0.01 |
| **3.** | Chromium as Cr | 1.0 | 7. | Zinc as Zn | 24 |
| **4.** | Copper as Cu | 0.5 | | | |

Sources: Environmental Studies Board, Nat. Acad. Of Sci., Nat Acad of Eng., Water Quality Criteria, 1972
Ayers, R.S. and D.W. Wescot, Water Quality for Agriculture, Food and Agriculture Organization of the United Nations, Rome, 1976

## 3.4 Water Quality for Irrigation

Most water sources naturally contain dissolved salts and trace elements, with many of these substances originating from the Earth's surface weathering processes. Furthermore, water quality can be influenced by drainage from irrigated farmlands and the discharge of sewage and industrial wastewater from urban areas. In the context of irrigation, salinity levels are usually the primary concern, as high salt concentrations can have adverse effects on both soil structure and crop yields. Nevertheless, irrigation water can also contain various trace elements that may limit its suitability for agriculture.

The required quality of irrigation water can vary significantly based on factors such as salinity, soil permeability, toxicity, and other considerations like excessive nitrogen content or unusual water pH. Some elements in irrigation water can directly harm crops. Determining toxicity thresholds in water is a complex task due to chemical reactions that occur when the water interacts with the soil. When an element is introduced to the soil through irrigation, it can either be neutralized through chemical reactions or accumulate in the soil until it reaches harmful levels. If water contains a certain element at a specific concentration, it may cause immediate harm to crops through foliar effects, particularly when sprinkler irrigation is employed. Alternatively, in the case of furrow irrigation, it might take several years for the element to accumulate to toxic levels, or it could become immobilized in the soil, never reaching harmful concentrations. The recommended water quality standards for irrigation are outlined in Table 6.

**Table 6: Recommended limits for constituents in reclaimed water for irrigation**

| Constituent | Long-term use (mg/L) | Short-term use (mg/L) | Remarks |
|---|---|---|---|
| **Aluminum (Al)** | 5.00 | 20 | Can cause nonproductivity in acid soils, but soils at pH 5.5 to 8.0 will precipitate the ion and eliminate toxicity. |
| **Arsenic (As)** | 0.10 | 2.0 | Toxicity to plants varies widely, ranging from 12 mg/L for Sudan grass to less than 0.05 mg/L for rice. |
| **Beryllium (Be)** | 0.10 | 0.5 | Toxicity to plants varies widely, ranging from 5 mg/L for kale to 0.5 mg/L for bush beans. |
| **Boron (B)** | 0.75 | 2.0 | 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. |
| **Cadmium (Cd)** | 0.01 | 0.05 | Toxic to beans, beets, and turnips at concentrations as low as 0.1 mg/L in nutrient solution. Conservative limits recommended. |
| **Chromium (Cr)** | 0.1 | 1.0 | Not generally recognized as essential growth element. Conservative limits recommended due to lack of knowledge on toxicity to plants. |
| **Cobalt (Co)** | 0.05 | 5.0 | Toxic to tomato plants at 0.1 mg/L in nutrient solution. Tends to be inactivated by neutral and alkaline soils. |
| **Copper (Cu)** | 0.2 | 5.0 | Toxic to a number of plants at 0.1 to 1.0 mg/L in nutrient solution. |
| **Fluoride (F)** | 1.0 | 15.0 | Inactivated by neutral and alkaline soils. |
| **Iron (Fe)** | 5.0 | 20.0 | Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of essential phosphorus and molybdenum. |
| **Lead (Pb)** | 5.0 | 10.0 | Can inhibit plant cell growth at very high concentrations. |
| **Lithium (Li)** | 2.50 | 2.50 | 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. |
| **Manganese (Mg)** | 0.2 | 10.0 | Toxic to a number of crops at a few-tenths to a few mg/L in acid soils. |
| **Molybdenum (Mo)** | 0.01 | 0.05 | 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. |
| **Nickel (Ni)** | 0.2 | 2.0 | Toxic to a number of plants at 0.5 to 1.0 mg/L; reduced toxicity at neutral or alkaline pH. |
| **Selenium (Se)** | 0.02 | 0.02 | Toxic to plants at low concentrations and to livestock if forage is grown in soils with low levels of added selenium. |
| **Vanadium (V)** | 0.1 | 1.0 | Toxic to many plants at relatively low concentrations. |
| **Zinc (Zn)** | 2.0 | 10.0 | Toxic to many plants at widely varying concentrations; reduced at increased pH (6 or above) and in fine textured or organic soils. |

Source: Rowe and Abdel-Magid, 1995

# 4. WATER QUALITY MONITORING BY CWC

Central Water Commission (CWC) is playing an important role in the field of water quality monitoring of river water and is observing water quality at various rivers since 1960's. As on January, 2023, CWC is observing water quality at 782 key locations in different rivers across the country: 657 on Hydrological Observation network and 125 Water Quality Sampling Stations (WQSS). In addition, CWC has started monitoring of water quality of water bodies across India since 01.03.2023. Till date, 88 water bodies have been identified for water quality monitoring purpose across various states of the country. The GIS map of the above-mentioned water quality stations monitored by CWC is given as Figure 1.

The details of distribution of WQ stations among different states of India can be seen in Table 7 and Figure 2. Details of distribution of WQ stations among 14 organisations of CWC is represented in Table 8 and Figure 3; and distribution among 23 basins of CWC is represented in Table 9 and Figure 4.

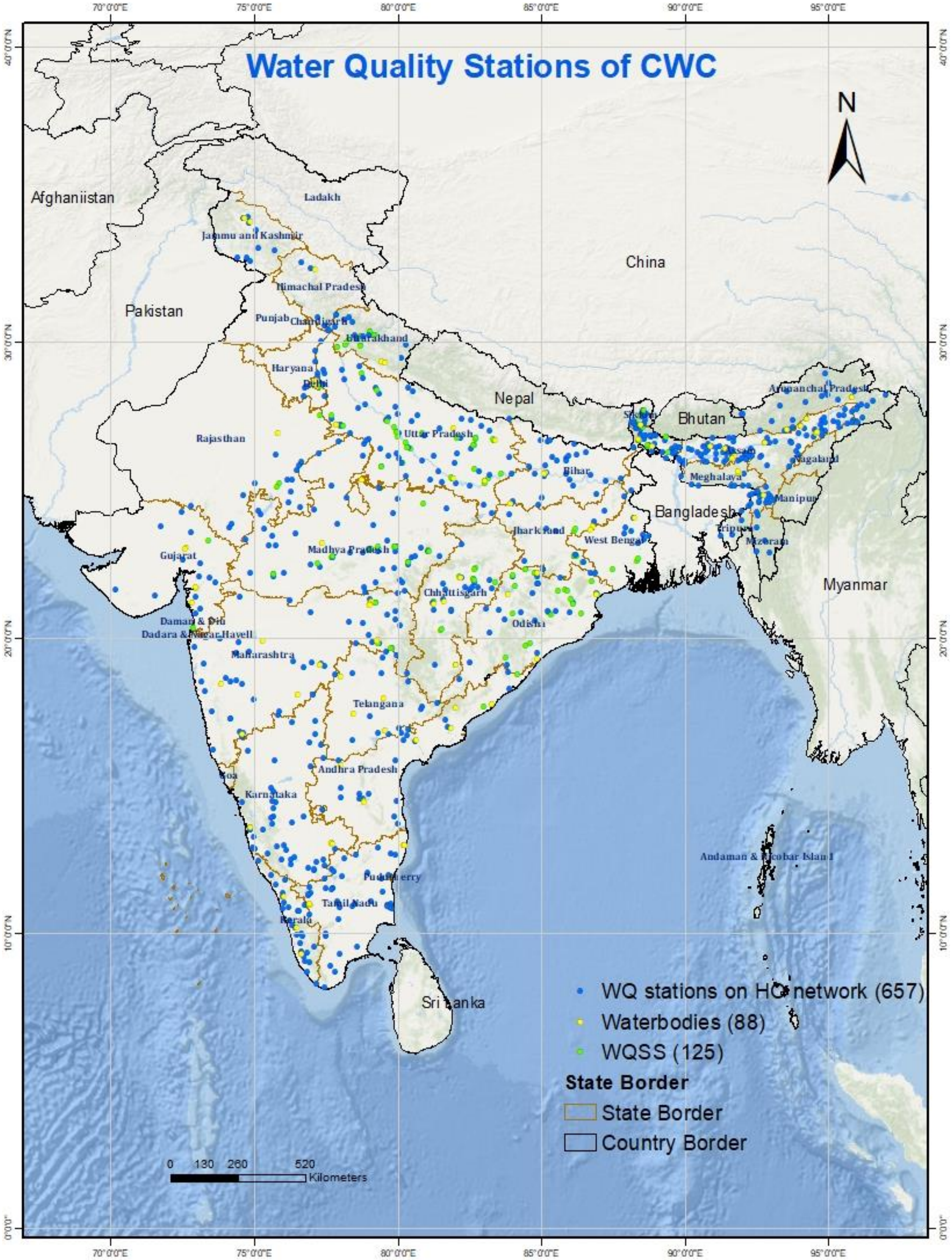


***Figure* 1: *Water quality network of CWC (as on 01.01.2023)***

**Table 7: State–wise distribution of Water Quality Stations of CWC**

| Sl. No. | State/UT | GDQ | GDSQ | GQ | WQSS | Water Bodies | Total |
|---|---|---|---|---|---|---|---|
| 1 | Andhra Pradesh | 4 | 14 | 1 | 2 | 7 | 28 |
| 2 | Arunachal Pradesh | 9 | 9 | 10 | - | 2 | 30 |
| 3 | Assam | 21 | 26 | 53 | - | 11 | 111 |
| 4 | Bihar | 6 | 22 | 1 | - | 2 | 31 |
| 5 | Chhattisgarh | 2 | 18 | - | 12 | 4 | 36 |
| 6 | Delhi | 1 | 2 | - | 3 | 3 | 9 |
| 7 | Gujarat | 4 | 9 | - | 2 | 6 | 21 |
| 8 | Haryana | 3 | 1 | - | - | - | 4 |
| 9 | Himachal Pradesh | - | 6 | - | - | 1 | 7 |
| 10 | Jammu & Kashmir | 3 | 6 | - | - | 2 | 11 |
| 11 | Jharkhand | 4 | 6 | 1 | 6 | 2 | 19 |
| 12 | Karnataka | 17 | 23 | 2 | - | 4 | 46 |
| 13 | Kerala | 2 | 24 | | - | 3 | 29 |
| 14 | Madhya Pradesh | 20 | 24 | 4 | 12 | 2 | 62 |
| 15 | Maharashtra | 17 | 25 | 4 | 6 | 10 | 62 |
| 16 | Manipur | - | - | 1 | - | - | 1 |
| 17 | Meghalaya | 5 | 3 | 1 | - | 2 | 11 |
| 18 | Mizoram | - | 5 | - | - | - | 5 |
| 19 | Odisha | 2 | 22 | 1 | 25 | 4 | 54 |
| 20 | Puducherry | 3 | - | - | - | - | 3 |
| 21 | Rajasthan | 8 | 8 | | 2 | 1 | 19 |
| 22 | Sikkim | - | 11 | 6 | 5 | 1 | 23 |
| 23 | Tamil Nadu | 21 | 21 | - | - | 5 | 47 |
| 24 | Telangana | 4 | 8 | 1 | - | 4 | 17 |
| 25 | Tripura | - | 3 | 2 | - | - | 5 |
| 26 | Uttar Pradesh | 14 | 47 | 4 | 28 | 6 | 99 |
| 27 | Uttarakhand | 5 | 9 | | 15 | 3 | 32 |
| 28 | West Bengal | 7 | 21 | 10 | 7 | 3 | 48 |
| | **Grand Total** | **182** | **373** | **102** | **125** | **88** | **870** |

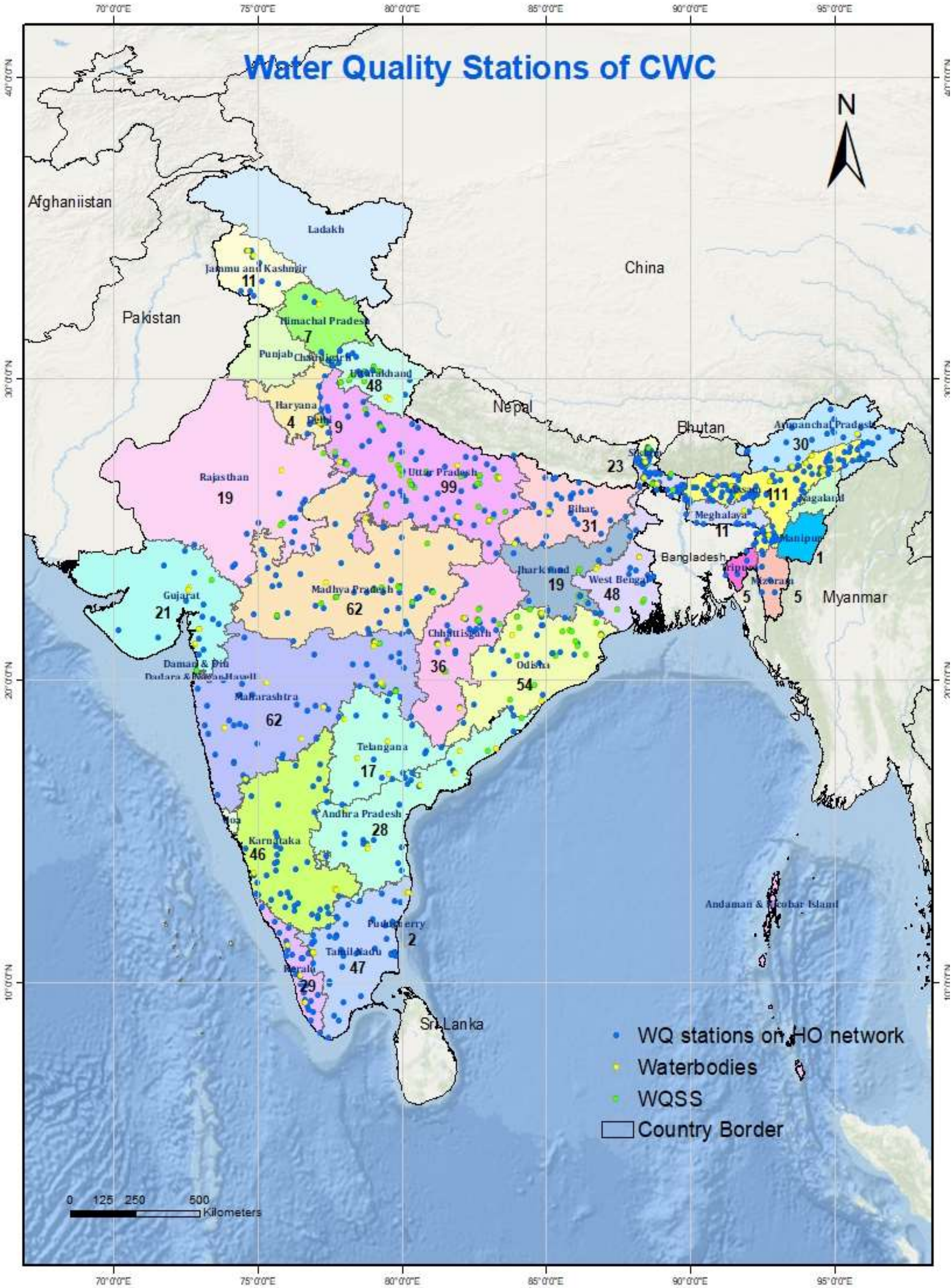


***Figure 2: State-wise distribution of Water Quality Stations monitored by CWC***

**Table 8: Organisation–wise distribution of Water Quality Stations of CWC**

| Sl. No. | Organisation | GDQ | GDSQ | GQ | WQSS | Water Bodies | Total |
|---|---|---|---|---|---|---|---|
| 1 | Barak and Other Basins Organisation, Shillong | 7 | 22 | 8 | - | 3 | 40 |
| 2 | Brahmaputra Basin Organisation, Guwahati | 27 | 24 | 58 | - | 12 | 121 |
| 3 | Cauvery & Southern Rivers Organisation, Coimbatore | 35 | 53 | - | - | 11 | 99 |
| 4 | Indus Basin Organisation, Chandigarh | 3 | 8 | - | - | 3 | 14 |
| 5 | Krishna & Godavari Basin Organisation, Hyderabad | 19 | 34 | 7 | - | 15 | 75 |
| 6 | Lower Ganga Basin Organisation, Patna | 9 | 33 | 1 | 6 | 5 | 54 |
| 7 | Mahanadi and Eastern Rivers Organisation, Bhubaneswar | 2 | 43 | 1 | 43 | 7 | 96 |
| 8 | Mahi & Tapi Basin Organisation, Gandhinagar | 6 | 15 | | 2 | 6 | 29 |
| 9 | Monitoring Central Organisation, Nagpur | 10 | 14 | 1 | 6 | 5 | 36 |
| 10 | Monitoring South Organisation, Bengaluru | 11 | 17 | - | - | 3 | 31 |
| 11 | Narmada Basin Organisation, Bhopal | 8 | 9 | 4 | 11 | 1 | 33 |
| 12 | Teesta & Bhagirathi Damodar Basin Organisation, Kolkata | 11 | 32 | 18 | 14 | 6 | 81 |
| 13 | Upper Ganga Basin Organisation, Lucknow | 6 | 32 | 1 | 33 | 5 | 77 |
| 14 | Yamuna Basin Organisation, New Delhi | 28 | 37 | 3 | 10 | 6 | 84 |
| | **Grand Total** | **182** | **373** | **102** | **125** | **88** | **870** |

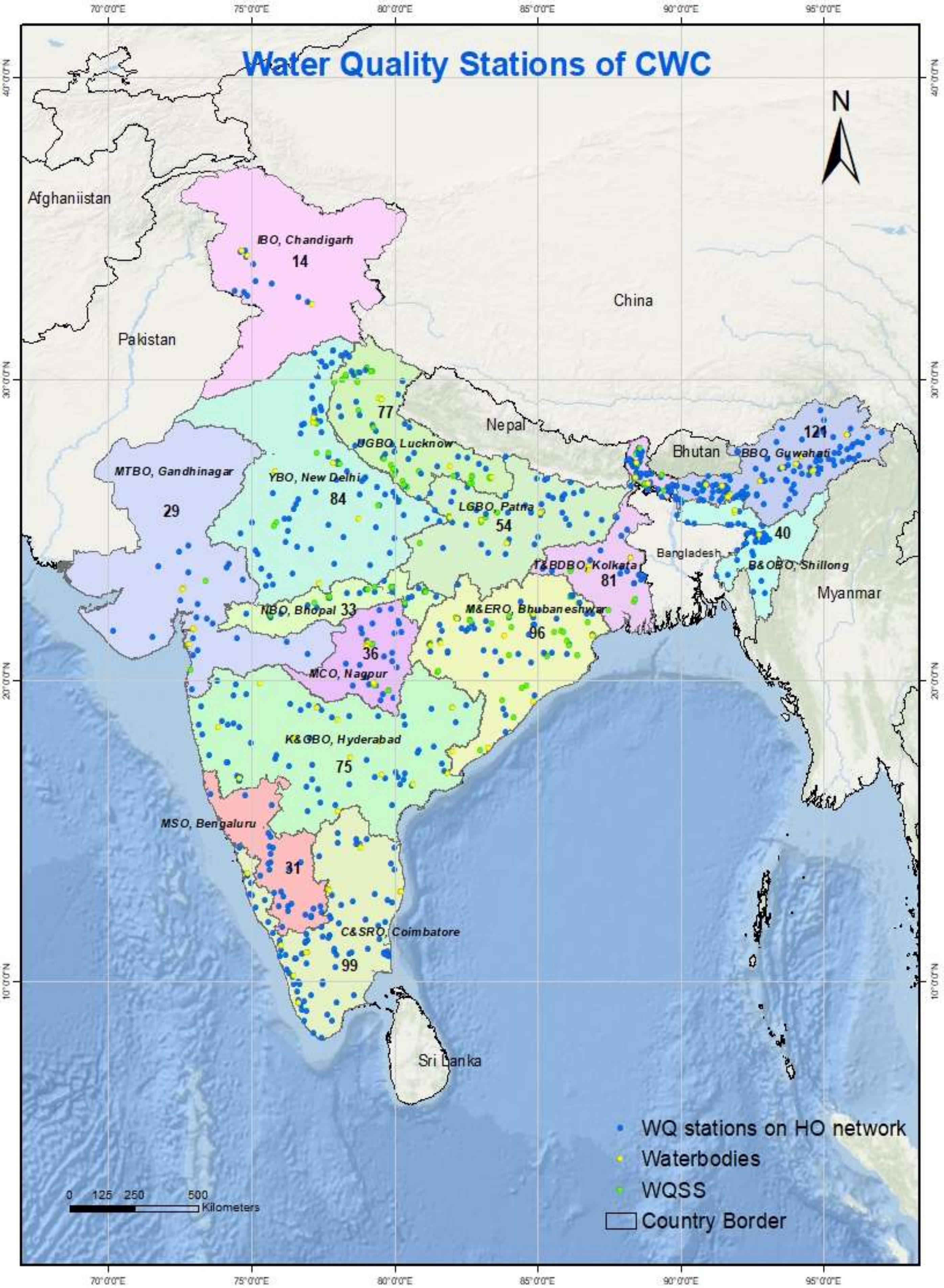


*Figure 3: Organisation-Wise Distribution of Water Quality Stations Monitored by CWC*

**Table 9: Basin-wise water-quality stations monitored by CWC**

| Sl. No. | Basin | GDQ | GDSQ | GQ | WQSS | Water Bodies | Total |
|---|---|---|---|---|---|---|---|
| 1 | Barak and Other Basins | 6 | 18 | 7 | - | 1 | 32 |
| 2 | Brahmani and Baitarni Basin | - | 11 | 1 | 15 | 1 | 28 |
| 3 | Brahmaputra Basin | 34 | 44 | 76 | 7 | 17 | 178 |
| 4 | Cauvery Basin | 17 | 24 | - | - | 3 | 44 |
| 5 | EFR between Pennar and Cauvery | 8 | 4 | - | - | 5 | 17 |
| 6 | EFR between Krishna and Pennar | - | 1 | - | - | - | 1 |
| 7 | EFR between Mahanadi and Godavari | - | 4 | - | 5 | 1 | 10 |
| 8 | EFR South of Cauvery | 2 | 4 | - | - | - | 6 |
| 9 | Ganga Basin | 48 | 115 | 6 | 56 | 19 | 244 |
| 10 | Godavari Basin | 19 | 26 | 4 | 6 | 14 | 69 |
| 11 | Indus (upto Indo-Pak Border) Basin | 3 | 8 | - | - | 3 | 14 |
| 12 | Krishna Basin | 14 | 27 | 3 | - | 6 | 50 |
| 13 | Mahanadi Basin | 1 | 22 | - | 15 | 4 | 42 |
| 14 | Mahi Basin | 2 | 3 | - | - | - | 5 |
| 15 | Narmada Basin | 8 | 11 | 4 | 11 | 3 | 37 |
| 16 | Pennar Basin | 4 | 4 | | - | 2 | 10 |
| 17 | River draining into Bangladesh Basin | - | 1 | - | - | - | 1 |
| 18 | River draining into Myanmar Basin | - | 2 | - | - | - | 2 |
| 19 | Sabarmati Basin | 1 | 1 | - | 1 | 2 | 5 |
| 20 | Subarnarekha Basin | 1 | 6 | - | 8 | 1 | 16 |
| 21 | Tapi Basin | 1 | 3 | - | - | 2 | 6 |
| 22 | WFR of Kutch and Saurashtra including Luni Basin | 2 | 3 | - | - | - | 5 |
| 23 | WFR South of Tapi | 11 | 31 | 1 | 1 | 4 | 48 |
| | **Grand Total** | **182** | **373** | **102** | **125** | **88** | **870** |

* EFR: East Flowing Rivers
WFR: West Flowing Rivers

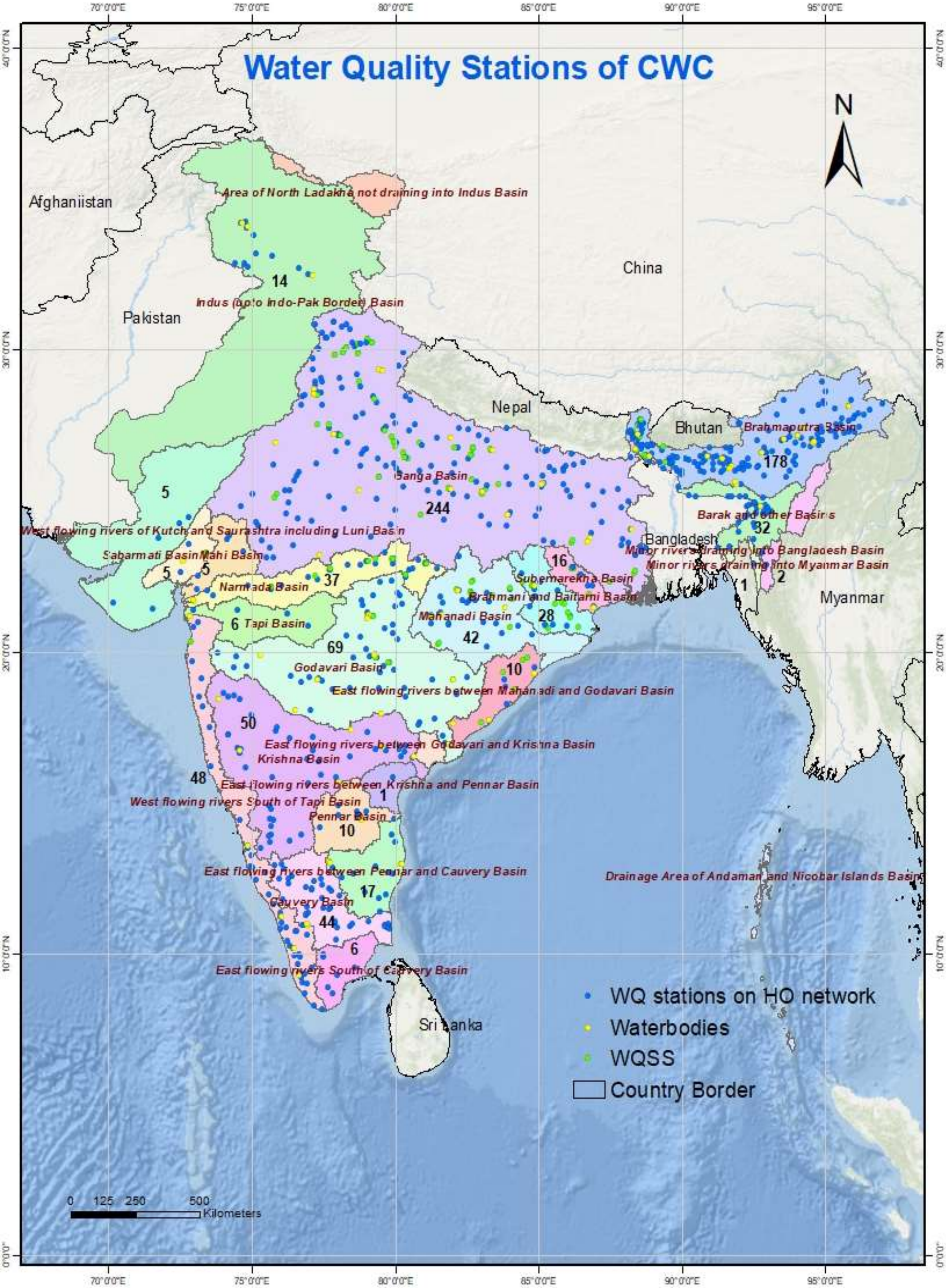


***Figure 4*: Basin-wise distribution of water quality Stations monitored by CWC**

The water quality samples collected at these stations are analysed at laboratories of CWC. At present, CWC follows a three-tier laboratory system which consists of Level I, II and III types of laboratories for providing analytical facilities for the analysis of river water samples collected from water quality monitoring stations covering all the important river basins of India.

The three-tier laboratory system consists of:

1. **Level-I Laboratories:** 427 level-I laboratories located at field water quality monitoring stations on various rivers of India for monitoring of 6 in-situ parameters: Colour, Odour, Temperature pH, Electrical Conductivity and Dissolved Oxygen (a map showing 427 Level-I labs can be seen at Figure 5).

2. **Level-II Laboratories:** 18 level-II laboratories located at division offices to analyse 25 physico-chemical and bacteriological parameters of river water.

3. **Level-III Laboratories:** 5 regional labs located at New Delhi, Varanasi, Hyderabad, Coimbatore and Guwahati for analysis of 41 parameters including trace & toxic metals and pesticides.

Out of 23 level-II/III laboratories of CWC, 22 laboratories are accredited by National Accreditation Board for Testing and Calibration Laboratories (NABL) in the field of testing in accordance with Standard ISO/IEC 17025:2017. A map showing level-II/III labs can be seen at Figure 6. The details of monitoring parameters in each level labs are depicted in Table 10.

**Table 10: List of Water Quality Parameters monitored by CWC**

| Sl. No. | Level-I | Level-II | Level-III |
|---|---|---|---|
| 1 | Temperature | Temperature | Temperature |
| 2 | Colour | pH | pH |
| 3 | Odour | Electrical Conductivity | Electrical Conductivity |
| 4 | pH | Dissolved Oxygen (DO) | Dissolved Oxygen (DO) |
| 5 | Electrical Conductivity | Turbidity | Turbidity |
| 6 | Dissolved Oxygen (DO) | Biochemical Oxygen Demand (BOD) | Biochemical Oxygen Demand (BOD) |
| 7 | | Chemical Oxygen Demand (COD) | Chemical Oxygen Demand (COD) |
| 8 | | Total Dissolved Solids (TDS) | Total Dissolved Solids (TDS) |
| 9 | | Sodium | Sodium |
| 10 | | Calcium | Calcium |
| 11 | | Magnesium | Magnesium |
| 12 | | Potassium | Potassium |
| 13 | | Carbonate | Carbonate |
| 14 | | Bicarbonate | Bicarbonate |
| 15 | | Chloride | Chloride |
| 16 | | Sulphate | Sulphate |
| 17 | | Fluoride | Fluoride |
| 18 | | Boron | Boron |
| 19 | | Ammoniacal Nitrogen | Ammoniacal Nitrogen |
| 20 | | Nitrate | Nitrate |
| 21 | | Nitrite | Nitrite |
| 22 | | Phosphate | Phosphate |
| 23 | | Silicate | Silicate |
| 24 | | Total Coliform | Total Coliform |
| 25 | | Fecal Coliform | Fecal Coliform |
| 26 | | | Arsenic |
| 27 | | | Cadmium |
| 28 | | | Chromium |
| 29 | | | Copper |
| 30 | | | Iron |
| 31 | | | Lead |
| 32 | | | Nickel |
| 33 | | | Mercury |
| 34 | | | Zinc |
| 35 | | | Alpha Benzenehexachloride (BHC), Beta BHC, Gama BHC (Lindane) |
| 36 | | | OP-Dichlorodiphenyltrichloroethane (OP DDT), PP-DDT |
| 37 | | | Alpha Endosulphan, Beta Endosulphan |
| 38 | | | Aldrin, Dieldrin |
| 39 | | | Carbaryl (Carbamate) |
| 40 | | | Malathion, Methyl Parathion |
| 41 | | | Anilophos, Chloropyriphos |

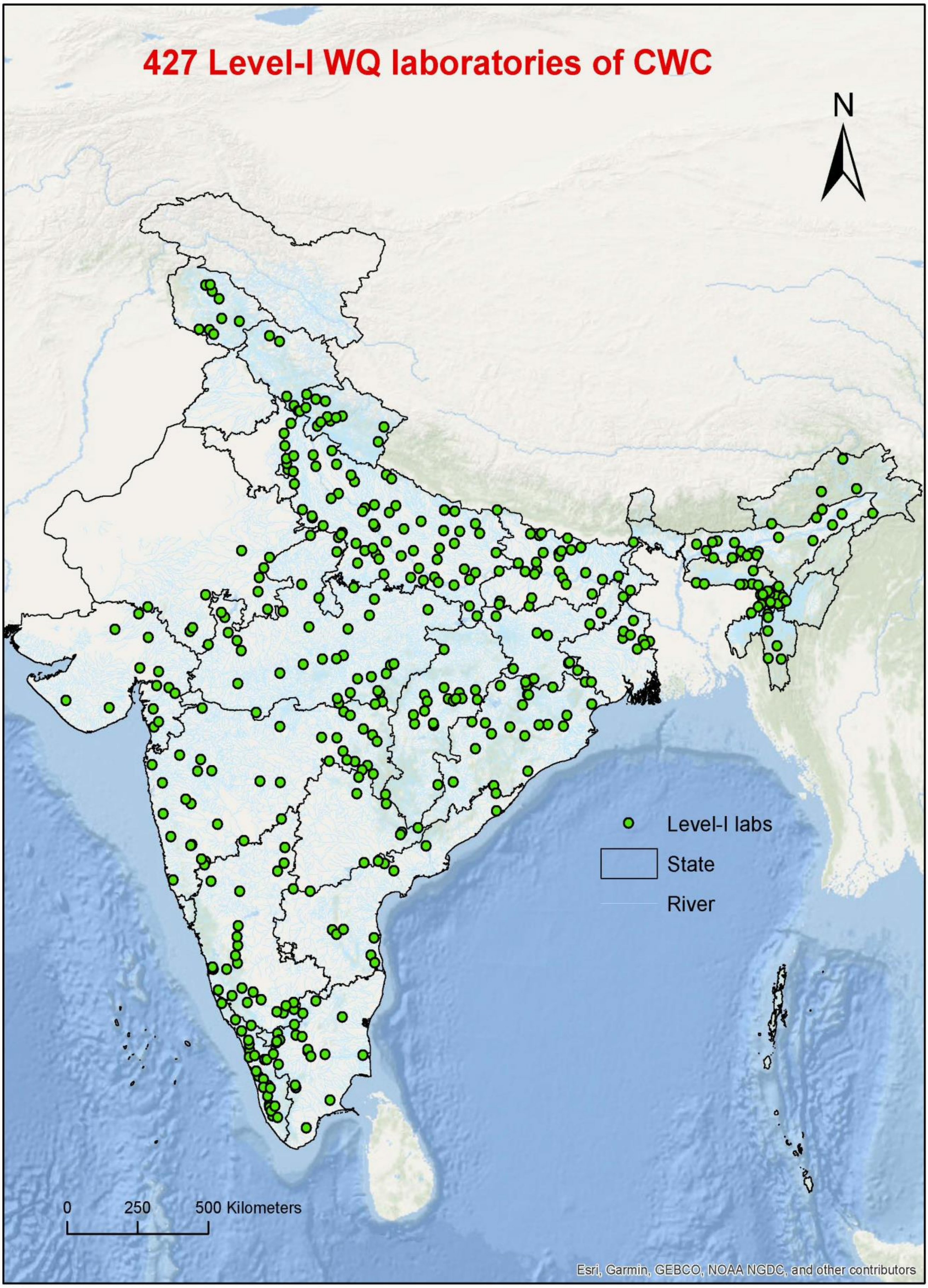


*Figure 5: Level-I Water quality laboratories of CWC*

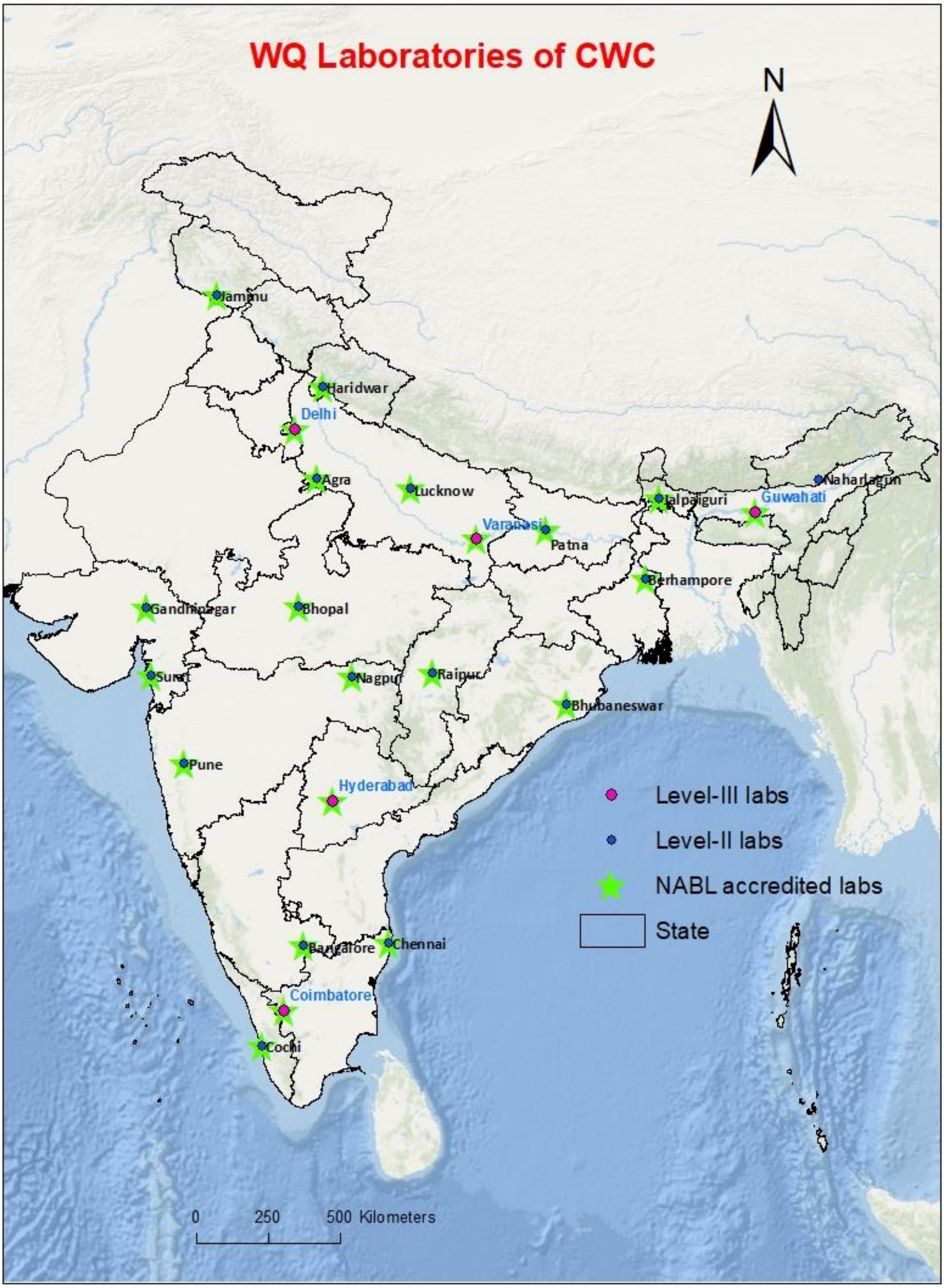


***Figure 6: Level-II/III Water quality laboratories of CWC***

# 5. STUDY AREA

The analysis results of 9 trace & toxic metals of water samples from 328 water quality monitoring stations of CWC are considered for the study (Figure 7). This involves the data analysis of 5980 samples collected during January, 2022 to December, 2022 from 10 river basins of India.

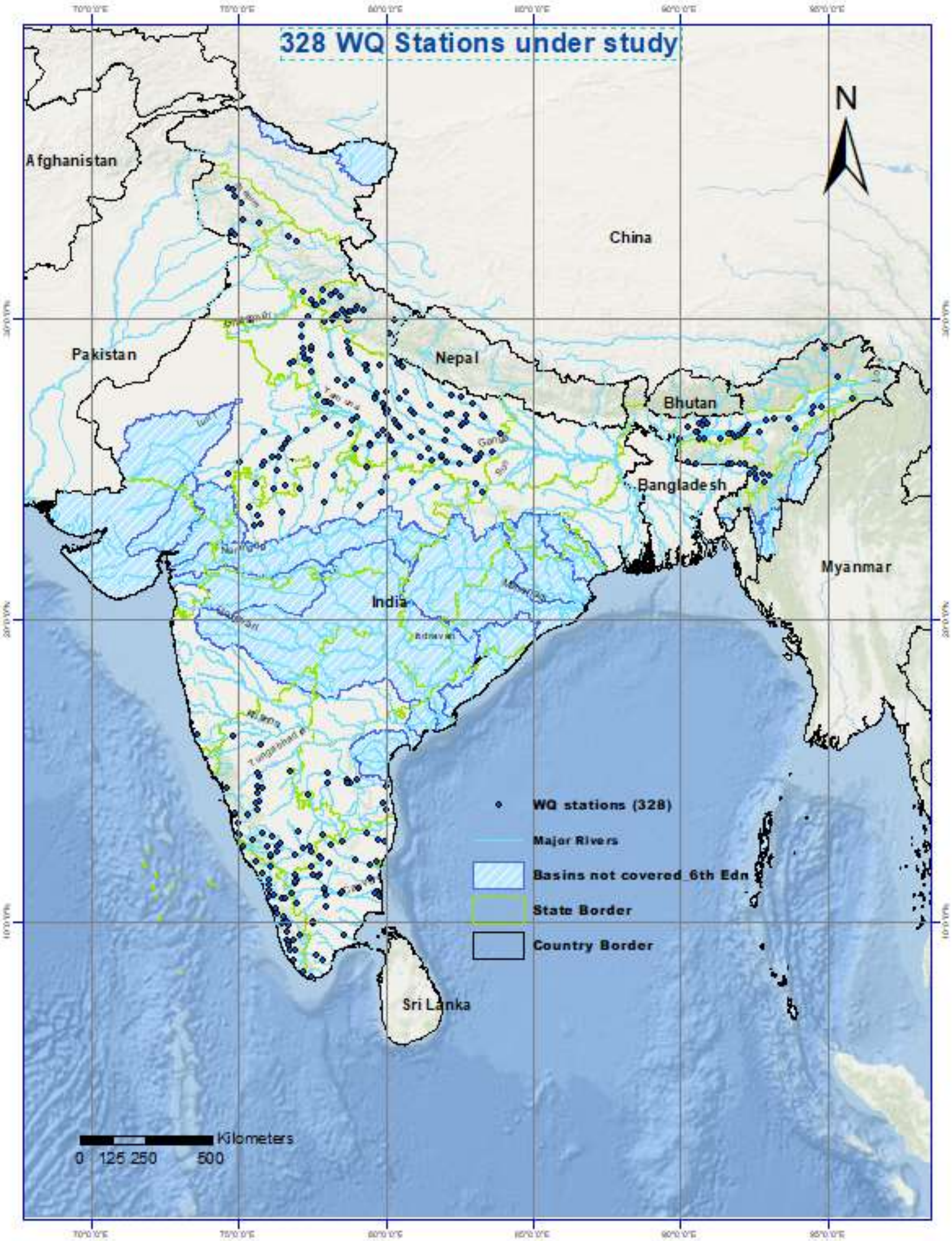


*Figure 7: 328 Water quality stations monitored*

The details of the 328 monitoring are enclosed as Annexure-I. The details of 10 basins considered for the study has been given below.

### *1. __Brahmaputra Basin:__*

The Brahmaputra River originates from the Mansarovar lake region near Mount Kailash, northern part of the Himalayas in Tibet. It fows through Tibet, India and Bangladesh. Brahmaputra basin inIndia stretches across the states of Arunachal Pradesh, Assam, West Bengal, Meghalaya, Nagaland and Sikkim. The basin lies between 88°11′ - 96°57′ E longitudes and 24°44′ - 30°3′ N latitudes. After flowing through Tibet, it enters India through Arunachal Pradesh, where the river is called Siang. It is joined by two mountain streams namely the Lohit and the Dibang near Sadiya town to form the mighty Brahmaputra River. As the river follows its course through the valley, it receives a number of tributaries at its north and south banks. The principal tributaries of the river are Lohit, Dibang, Subansiri, Jiabharali, Dhansiri(North), Manas, Torsa, Sankosh, Teesta, Burhidihing, Desang, Dikhow, Dhansiri(South) Raidak-I, Raidak-II and Kopili. Torsa and Jaldhaka rivers flowing through the northern West Bengal also join the main stream of Brahmaputra but, in the plains of Bangladesh.

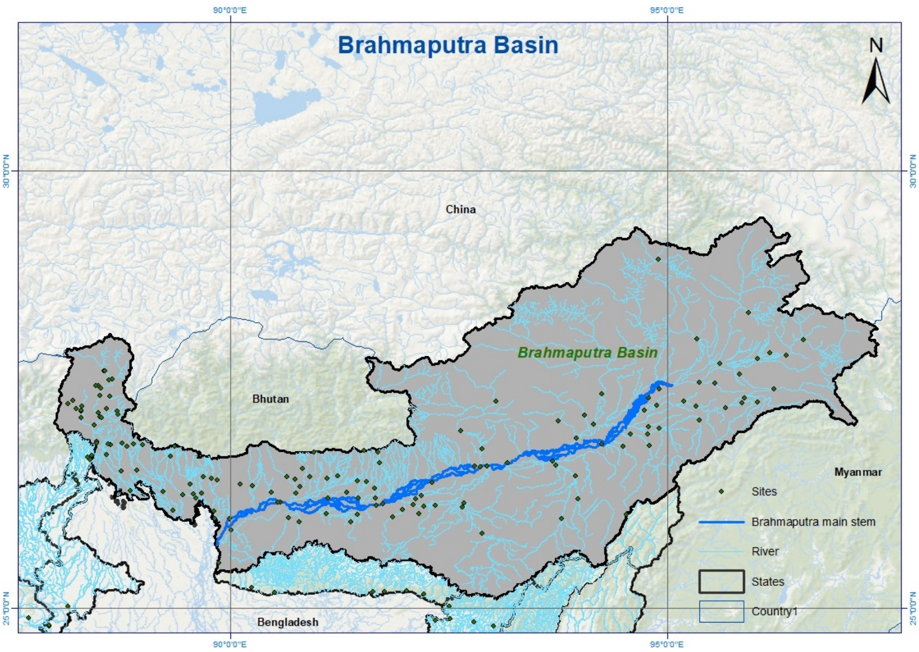


*Figure 8: Brahmaputra Basin*

Brahmaputra catchment is the heaviest rainfall region in the world. Brahmaputra basin, particularly the portions in Assam, is prone to annual floods and river bank erosions. Water quality samples collected from 30 water quality stations are being considered for the study.

### ***__Barak and Other Basins:__***

Barak is an important river system in North East India. The Barak basin has a catchment spread over the states of Meghalaya, Manipur, Mizoram, Assam, Tripura and Nagaland as well in the neighbouring country of Myanmar. Upto Indo-Bangladesh border in Karimganj district of Assam, the catchment area of the Barak River is 26,193 sq.km.

All the other rivers draining directly into the Meghna River system are small compared to the Barak River. The Barak also has numerous tributaries within Assam and Manipur. The principal right bank tributaries are Makru, Jiri, Chiri, Madhura, Jatinga, Gumra, Harang and Badri. The principal left bank tributaries are Irang, Tuivai, Sonai, Katakhal, Singla and Longai. At the international border with Bangladesh, Barak splits into two branches: Surma in the north and Kushiyara in the south. The river Surma flows in the northern part of Sylhet district of Bangladesh before joining the Meghna River system. The south flowing rivers of the Khasi and Jaintia hills of Meghalaya drain into Surma valley. The Kushiyara River flows in the southern portion of the Sylhet district before joining the Meghna River. A few west flowing rivers from Assam and Tripura join the Kushiyara after entering Bangladesh.

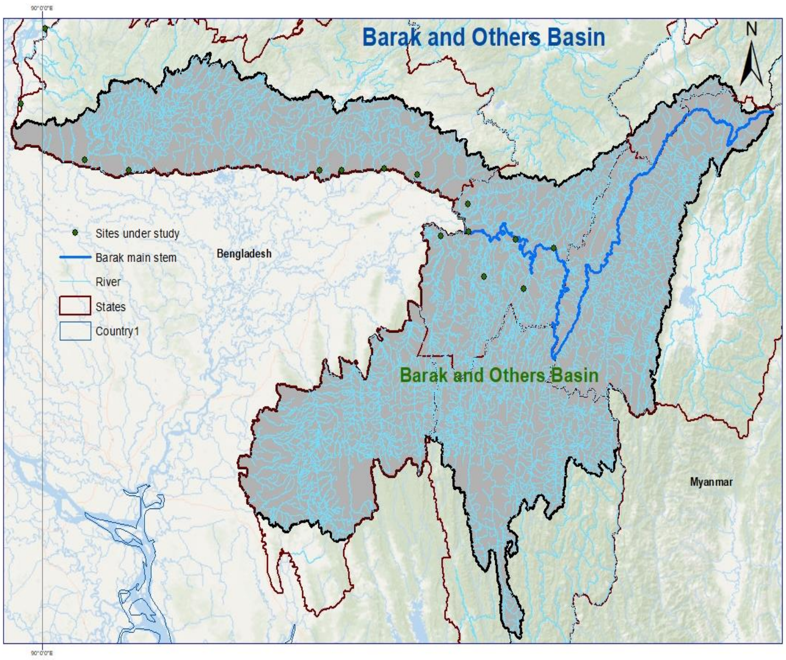


*Figure 9: Barak and Other Basins*

Water quality samples collected from 13 water quality stations are being considered for the study.

2. ***Cauvery Basin:***

River Cauvery is the third largest perennial river flowing in Southern India. It originates at Talakaveri on the Brahmagiri range of Hills in Kodagu District of Karnataka amidst Western Ghats at an elevation of 1,341 m above MSL and drains a total area of 81,155 Sq. kms. It flows in south-eastern direction across the Plateau of Mysore and joins the Bay of Bengal in Nagapattinam District of Tamil Nadu. The river basin lies between 75°30' – 79°45'E longitudes and 10°05'N – 13°30'N latitudes. Cauvery Basin covers the states of Karnataka, Tamil Nadu, Puducherry and some parts of Kerala. The Cauvery basin is fan shaped in Karnataka

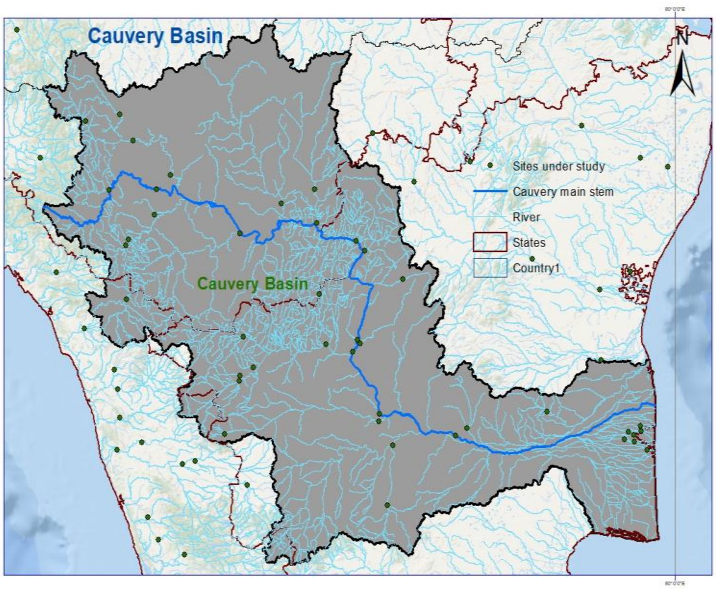


*Figure 10: Cauvery Basin*

and leaf shaped in Tamil Nadu. The major tributaries are Harangi, Hemavati, Kabini, Bhavani, Lakshmanthirtha, Noyyal, and Arkavati.

Water quality samples collected from 41 water quality stations are being considered for the study.

### 3. ***East Flowing Rivers between Pennar and Cauvery Basin and East Flowing Rivers South of Cauvery Basin:***

The East Flowing Rivers (South of river Krishna excluding Cauvery and Pennar Basins) cover large areas in the states of Andhra Pradesh, Tamil Nadu and some parts of Karnataka and Union territory of Puducherry.
The basin of East flowing rivers consists of several independent river basins of peninsular India lying to the South of Krishna basin, except Cauvery basin. The East flowing rivers are draining into the Bay of Bengal. There are eleven river basins of which Palar and Ponnaiyar are more important. Other river basins are Gundlakamma, Paleru, Swarnamukhi, Kalingi, Varahanadi, Vellar, Vaigai, Vaippar and Tambraparani.

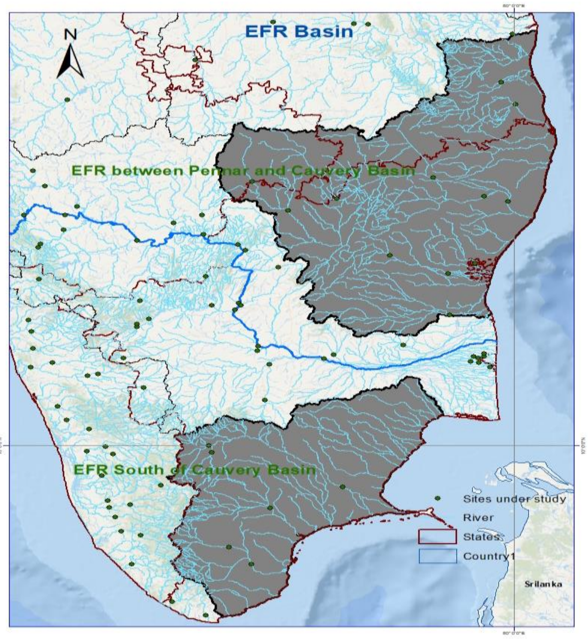


*Figure 11: EFR Basin*

Water quality samples collected from 17 water quality stations are being considered for the study.

### 4. ***Ganga Basin***

The Ganga River originates from the southern great Himalayas in Uttarakhand on the Indian side of the border with Tibet. It is formed by five headstreams, namely Bhagirathi, Alaknanda, Mandkini, Dhauliganga and Pindar. Of those, the two major headstreams are the Alaknanda and the Bhagirathi, which receives both monsoon as well as glacial melt water from the Himalayan glaciers known as Gangotri. The major tributaries of Ganga are also originating from the Himalaya excluding Sone

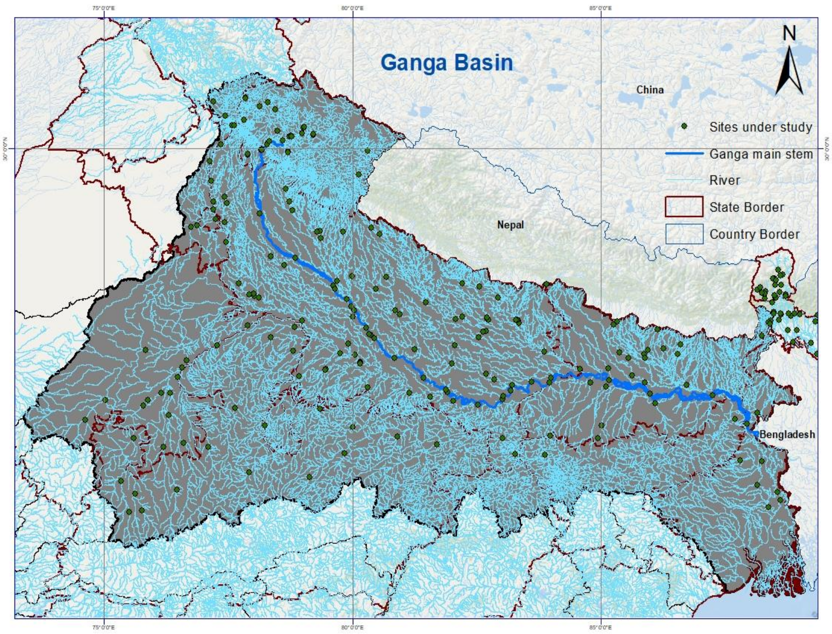


*Figure 12: Ganga Basin*

and Damodar rivers originating from the Amarkantak hills of Maikal range and Khamar-pat hill on Chotanagpur Plateau, respectively.

Alakananda and Bhagirathi Rivers join at Devprayag in Uttarakhand to form the river Ganga which acts as a single stream. At Prayagraj, river Ganga receives its biggest tributary, the river Yamuna, from right. The delta of the river Ganga can be said to start from Farakka in West Bengal. From the origin after traversing about 2500 km it empties into the Bay of Bengal at Ganga Sagar Island. The mainstream of river Ganga falls in the States of Uttrakhand, Uttar Pradesh, Bihar, Jharkhand and West Bengal. Rishikesh, Haridwar and Varanasi are important cities in the banks of the river Ganga. The main tributaries are Yamuna, Gomti, Ghaghra, Son, Gandak, Ramganga, Kosi etc. Water quality samples collected from 161 water quality stations are being considered for the study.

5. ***Indus(upto Indo-Pak Border) Basin***

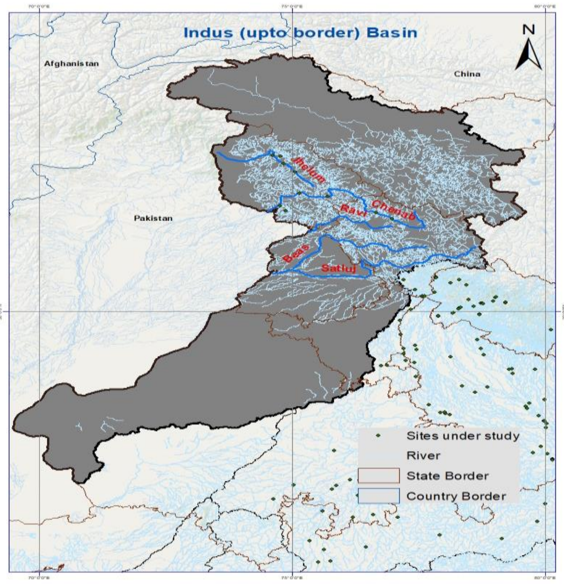


*Figure 13: Indus Basin*

The Indian part of Indus basin spreads over the states of Jammu & Kashmir, Ladakh, Himachal Pradesh, Punjab and a part of Rajasthan, Haryana, and Union Territory of Chandigarh. Upper part of the basin consists of mountain ranges and narrow valleys lying in Jammu and Kashmir, Ladakh and Himachal Pradesh. In Punjab, Haryana and Rajasthan the basin consists of vast plains, which are the fertile granary of the country. It was the cradle of the great Indus Valley civilization of ancient world. The Indian part of the basin consists of five major tributaries: Sutlej, Ravi, Beas, Chenab, and Jhelum which are ultimately merging with river Indus in Pakistan.

Water quality samples collected from 10 water quality stations are being considered for the study.

6. ***Pennar Basin***

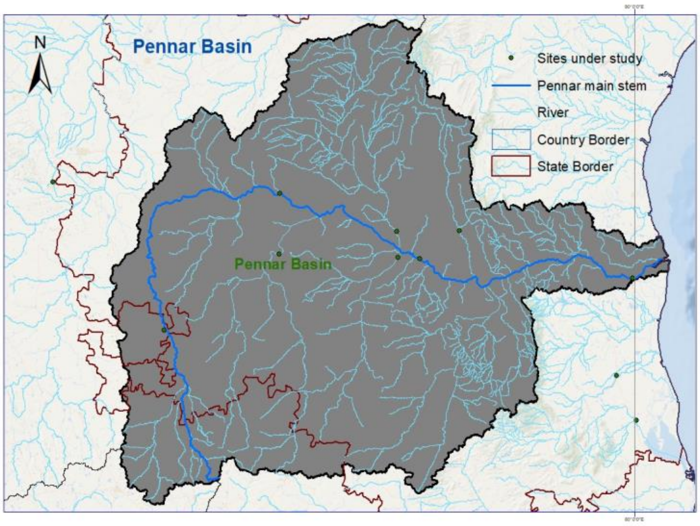


*Figure 14: Pennar Basin*

The Pennar River is one of the major East flowing rivers in Southern India. It rises in the Chennakesava hill of the Nandidurg range in Karnataka.

The Pennar drains an area of 55,213 Sq.kms in the states of Karnataka and Andhra Pradesh. The total length of Pennar River is 597 Km of which 61 Km runs in Karnataka and the rest in Andhra Pradesh. This river has six major tributaries viz., the Jayamangali, the Kunderu and the Sagileru joining from the left, the Chitravathi, the Papagni and the Cheyyeru joining on the right.

Water quality samples collected from 8 water quality stations are being considered for the study.

### *7. West Flowing Rivers South of Tapi Basin*

The West Flowing Rivers Basin consists of all the small independent river basins of peninsular India lying to the South of Krishna Basin (except Cauvery Basin) draining into the Arabian Sea. The basin is located in the South West corner of the peninsular India and covers the areas in the States of Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala. There are as many as 31 Nos of medium and minor river basins in this region viz., Ulhas, Bhogeshwari, Amba, Kal, Kajavi, Gad, Mandovi/Madei, Aghanashini, Haladi, Sita, Swarna, Gurupur, Netravathi, Payaswani, Valatapatnam, Kuttyadi, Chaliyar, Kadalundi, Bharathapuzha, Chalakudi, Periyar, Muvattupuzha, Meenachil, Pamba, Achankovil, Manimala, Kallada, Vamanapuram, Tambraparani and Pazhayar. All the rivers originate from the high mountains of the Western Ghats and exhibit similar characteristics. They have steep high banks which rarely overflow or cause floods.

*Figure 15: WFR South of Tapi Basin*

Water quality samples collected from 36 water quality stations are being considered for the study.

### *8. Krishna Basin*

The river Krishna is the second largest eastward draining interstate river in Peninsular India. The basin of Krishna is situated between East longitudes 73° 21′ to 81° 09′ and North latitudes 13° 07′ to 19° 25′ in the Deccan Plateau covering large areas in the States of Maharashtra, Karnataka, Telangana and Andhra Pradesh. The river Krishna rises in the Western Ghats at an altitude of 1337 m just North of Mahabaleswar, about 64 km from the Arabian Sea and flows from West to East through the States of Maharashtra, Karnataka, Telangana and Andhra Pradesh before it joins the Bay of Bengal at downstream of Vijayawada.

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

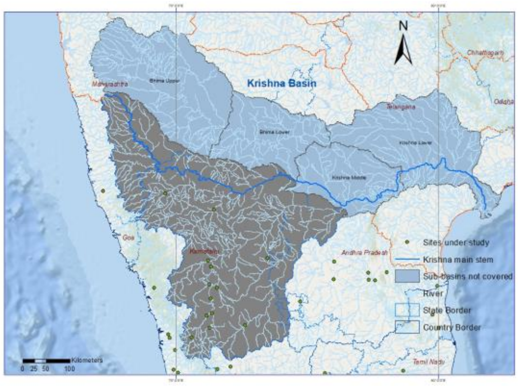


*Figure 16: Krishna Basin*

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

Water quality samples collected from 12 water quality stations are being considered for the study. Theses stations belong to Krishna Upper and Thungabhadra sub-basins.

# 6. METHODOLOGY

Living organisms require trace amounts of certain metals, including cobalt, copper, iron, manganese, molybdenum, vanadium, strontium, and zinc, for their proper functioning. However, excessive levels of these essential metals can be harmful to organisms. On the other hand, non-essential metals like cadmium, chromium, mercury, lead, arsenic, and antimony pose more significant concerns for surface water systems, as these metals can have adverse effects on human and animal life. Once these non-essential metals enter a system, they tend to persist for longer periods. Inorganic metals, once absorbed, have the potential to interact with various binding stations within the human body and possess a strong affinity for biological tissues. While natural water contains trace amounts of toxic metals, the issue of metal pollution has been exacerbated by industrial waste containing these metals. Major contributors to metal pollution in surface water include industries such as electroplating, metallurgy, galvanizing plants, tanneries, and thermal power stations. Metals can exist in various forms in surface water, including colloidal, particulate, and dissolved forms, with dissolved concentrations typically being low. The soluble forms are generally in the form of ions, unionized compounds, organo-metallic chelates, or complexes. The solubility of trace metals in surface water is primarily influenced by factors such as pH, the type and concentration of ligands to which the metal can bind, and the oxidation state of mineral components.

## 6.1 Metal Detection Techniques

Various analytical methods are commonly used to estimate heavy metals in water and wastewater. These methods include:

- **Inductively Coupled Plasma Analyser (ICP):** ICP techniques are widely used and applicable over a broad linear range. They are especially sensitive when analyzing refractory elements. However, the detection limits for ICP methods are generally higher than those for Atomic Absorption Spectrophotometry (AAS).
- **Atomic Absorption Spectrophotometry (AAS):** AAS is another widely used technique for detecting heavy metals. It is known for its sensitivity and is particularly useful for measuring specific elements.
- **Colorimetric Methods:** Colorimetric methods are applied when potential interferences are known to be within the limits of the particular method. These methods rely on color changes to indicate the presence and concentration of specific heavy metals.
- **Polarographic Estimation:** Polarography is an electroanalytical method that can be used to detect heavy metals in solution based on their electrochemical behavior.
- **Ion-Selective Electrodes (ISE):** Ion-selective electrodes are used to measure the concentration of specific ions, including heavy metal ions, in a solution. These electrodes are selective for particular ions and can provide precise measurements.

## 6.2 Chemicals and Reagents

Chemicals and reagents used during the chemical analyses were of analytical reagent grade. Standard solutions are prepared using certified reference materials. De-ionized water was consistently utilized in the study. To ensure the accuracy of the experiments, all glassware and containers were meticulously cleaned. This cleaning process involved soaking them in detergent, followed by immersion in 10% nitric acid for 48 hours. Subsequently, the glassware was thoroughly rinsed with de-ionized water multiple times before use.

## 6.3 Method

In the current study, water samples were collected and stored in polyethylene containers. These water samples were then meticulously prepared for the quantification of various heavy metals: arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc. At most of the stations, 3 samples were collected at an interval of 10 days in a month. A total of 5980 samples were collected during January, 2022 to December, 2022 from 10 river basins of India. 9 trace & toxic metals namely: arsenic, cadmium, copper, chromium, iron, lead, mercury, nickel, and zinc were analysed during this period. The collected samples are transported to Level-II/III laboratories and after sample preparation/preservation, sent to two Level-III laboratories of CWC: NRWQL, New Delhi and UMGWQL, Varanasi. These samples were analyzed at two Level-III laboratories of CWC: National River Water Quality Laboratory, Upper Yamuna Division, New Delhi and Upper and Middle Ganga Water Quality Laboratory, Middle Ganga Division-3, Varanasi using ICP-MS and APHA method.

*Figure 17: AAS*


*Figure 18: ICP-MS*

# 7. RESULTS AND DISCUSSION

CWC is involved in the analysis of 9 trace & toxic metals namely: arsenic, cadmium, copper, chromium, iron, lead, mercury, nickel, and zinc. The analysis results are compared with the prescribed limits of BIS: 10500-2012. The analysis results of 328 water quality monitoring stations spread over 10 river basins of CWC were considered for the study. All metals are found to be within the acceptable limits at 187 out of 328 monitored stations while at 141 stations under study, at least one metal was found to be beyond the limit.

The overall summary of the results is as under:

**Table 11: Overall summary**

| Sl. No. | Trace & Toxic Metal | Acceptable limit as per BIS:10500, 2012 (in µg/L) | Total No. of samples analysed | No. of samples where metal found within acceptable limit | No. of samples where metal found above acceptable limit | % of samples where metal found above acceptable limit |
|---|---|---|---|---|---|---|
| 1 | Arsenic (As) | 10 | 5942 | 5894 | 48 | 0.81 |
| 2 | Cadmium (Cd) | 3 | 5942 | 5937 | 5 | 0.08 |
| 3 | Chromium (Cr) | 50 | 5939 | 5922 | 17 | 0.29 |
| 4 | Copper (Cu) | 50 | 5941 | 5936 | 5 | 0.08 |
| 5 | Iron (Fe) | 1000 | 5980 | 5867 | 113 | 1.89 |
| 6 | Lead (Pb) | 10 | 5942 | 5905 | 37 | 0.62 |
| 7 | Mercury (Hg) | 1 | 5941 | 5923 | 18 | 0.30 |
| 8 | Nickel (Ni) | 20 | 5942 | 5931 | 11 | 0.19 |
| 9 | Zinc (Zn) | 5000 | 5940 | 5940 | 0 | 0.00 |

The details and overall status of stations under study is given at Annexure-I.
The parameter-wise discussion of the analysis results is given in the ensuing paragraphs.

## 7.1 Arsenic (As)

BIS (Bureau of Indian Standards) 10500:2012 has recommended an acceptable limit of 10 μg/L of arsenic in drinking water. Out of 5942 river water samples, 48 samples from 30 water quality stations across 14 rivers were found to have arsenic concentrations beyond the acceptable limit. The arsenic concentration varies from 0.000 to 19.47 μg/L. Maximum arsenic concentration (19.47 μg/L) was observed at Kora water quality monitoring station on Rind River (a tributary of Yamuna) on 12.06.2022.

The details of stations where arsenic concentrations (in μg/L) were found to be beyond acceptable limit, categorized by their respective rivers and dates is depicted in the table given below. Figure 19 represents the GIS map of stations where arsenic is found to exceed the BIS limit.

**Table 12: River-wise list of WQ stations with Arsenic values above limit**

| Sl. No. | River/tributary | Station | Date | As(μg/L) | State | District |
|---|---|---|---|---|---|---|
| 1 | Alakananda | Kirtinagar U/S | 11-05-2022 | 15.117 | Uttarakhand | Tehri |
| | Alakananda | Karnaprayag Confluence D/S | 11-05-2022 | 14.548 | Uttarakhand | Chamoli |
| 2 | Bhagirathi | Uttarkashi | 11-05-2022 | 12.070 | Uttarakhand | Uttarkashi |
| 3 | Ganga | Katri Umrauli | 01-03-2022 | 11.988 | Uttar Pradesh | Kannauj |
| | Ganga | Kannauj | 01-03-2022 | 12.383 | Uttar Pradesh | Kannauj |
| | Ganga | Bhitoor | 01-03-2022 | 11.893 | Uttar Pradesh | Kanpur |
| | Ganga | Shastri Bridge | 01-10-2022 | 15.969 | Uttar Pradesh | Prayagraj |
| | Ganga | Shastri Bridge | 11-10-2022 | 17.026 | Uttar Pradesh | Prayagraj |
| | Ganga | Shastri Bridge | 21-10-2022 | 13.683 | Uttar Pradesh | Prayagraj |
| | Ganga | Shastri Bridge | 01-11-2022 | 15.330 | Uttar Pradesh | Prayagraj |
| | Ganga | Shastri Bridge | 11-11-2022 | 14.642 | Uttar Pradesh | Prayagraj |
| | Ganga | Shastri Bridge | 12-12-2022 | 14.372 | Uttar Pradesh | Prayagraj |
| | Ganga | Shastri Bridge | 21-12-2022 | 15.323 | Uttar Pradesh | Prayagraj |
| | Ganga | Chhatnag Allahabad | 21-10-2022 | 12.756 | Uttar Pradesh | Prayagraj |
| | Ganga | Mirzapur | 21-10-2022 | 10.251 | Uttar Pradesh | Mirzapur |
| | Ganga | Ghazipur | 21-10-2022 | 12.908 | Uttar Pradesh | Ghazipur |
| 4 | Ganga/Chhoti Sarju | Akabarpur | 21-10-2022 | 15.693 | Uttar Pradesh | Ambedkar Nagar |
| 5 | Ganga/Deoha/Sukheta | Todarpur | 21-04-2022 | 10.008 | Uttar Pradesh | Hardoi |
| 6 | Ghaghra/Rapti | Kabirganj | 11-03-2022 | 11.464 | Uttar Pradesh | Pilibhit |
| | Ghaghra/Rapti | Kabirganj | 21-03-2022 | 12.896 | Uttar Pradesh | Pilibhit |
| | Ghaghra/Rapti | Kabirganj | 23-05-2022 | 10.499 | Uttar Pradesh | Pilibhit |
| 7 | Gomti | Neemsar | 21-04-2022 | 10.230 | Uttar Pradesh | Sitapur |
| | Gomti | Chandrika Devi | 21-04-2022 | 11.971 | Uttar Pradesh | Lucknow |
| | Gomti | Sultanpur | 21-10-2022 | 10.271 | Uttar Pradesh | Sultanpur |
| | Gomti | Jaunpur | 21-10-2022 | 10.497 | Uttar Pradesh | Jaunpur |
| 8 | Gomti /Sarayan | Sitapur | 11-04-2022 | 10.418 | Uttar Pradesh | Sitapur |
| 9 | Gomti/Sai | Pratapgarh | 01-10-2022 | 10.568 | Uttar Pradesh | Pratap-garh |
| | Gomti/Sai | Pratapgarh | 21-10-2022 | 11.399 | Uttar Pradesh | Pratap-garh |
| | Gomti/Sai | Pratapgarh | 01-11-2022 | 10.145 | Uttar Pradesh | Pratap-garh |
| 10 | Solani | Roorkee U/S | 21-03-2022 | 11.131 | Uttarakhand | Haridwar |
| | Solani | Roorkee U/S | 01-04-2022 | 11.238 | Uttarakhand | Haridwar |
| | Solani | Roorkee D/S | 01-04-2022 | 10.060 | Uttarakhand | Haridwar |
| 11 | Yamuna | Gokul Barrage D/S of Mathura | 21-05-2022 | 10.075 | Uttar Pradesh | Mathura |

| Sl. No. | River/tributary | Station | Date | As(µg/L) | State | District |
|---|---|---|---|---|---|---|
| | Yamuna | Kailash Mandir Benpur U/S of Agra | 11-06-2022 | 13.557 | Uttar Pradesh | Agra |
| | Yamuna | Agra (P.G.) | 12-06-2022 | 13.872 | Uttar Pradesh | Agra(P.G) |
| | Yamuna | Agra (J.B.) | 21-05-2022 | 10.048 | Uttar Pradesh | Agra (J.B) |
| | Yamuna | Agra (J.B.) | 11-06-2022 | 13.422 | Uttar Pradesh | Agra (J.B) |
| | Yamuna | Yamuna Expressway Road Bridge-Etmadpur D/S of Agra city | 21-05-2022 | 10.121 | Uttar Pradesh | Agra |
| | Yamuna | Yamuna Expressway Road Bridge-Etmadpur D/S of Agra city | 11-06-2022 | 14.548 | Uttar Pradesh | Agra |
| | Yamuna | Etawah | 21-04-2022 | 13.258 | Uttar Pradesh | Etawah |
| | Yamuna | Etawah | 22-05-2022 | 10.465 | Uttar Pradesh | Etawah |
| | Yamuna | Etawah | 05-04-2022 | 12.575 | Uttar Pradesh | Etawah |
| | Yamuna | Etawah | 11-06-2022 | 13.967 | Uttar Pradesh | Etawah |
| 12 | Yamuna/Rind | Kora | 12-05-2022 | 15.190 | Uttar Pradesh | Fatehpur |
| | Yamuna/Rind | Kora | 03-05-2022 | 10.162 | Uttar Pradesh | Fatehpur |
| | Yamuna/Rind | Kora | 12-06-2022 | 19.478 | Uttar Pradesh | Fatehpur |
| 13 | Yamuna/Sengar | Lalpur | 22-04-2022 | 11.067 | Uttar Pradesh | Kanpur Dehat |
| 14 | Yamuna/Sindh/Kun-wari | Bhind | 12-06-2022 | 14.799 | Madhya Pradesh | Bhind |

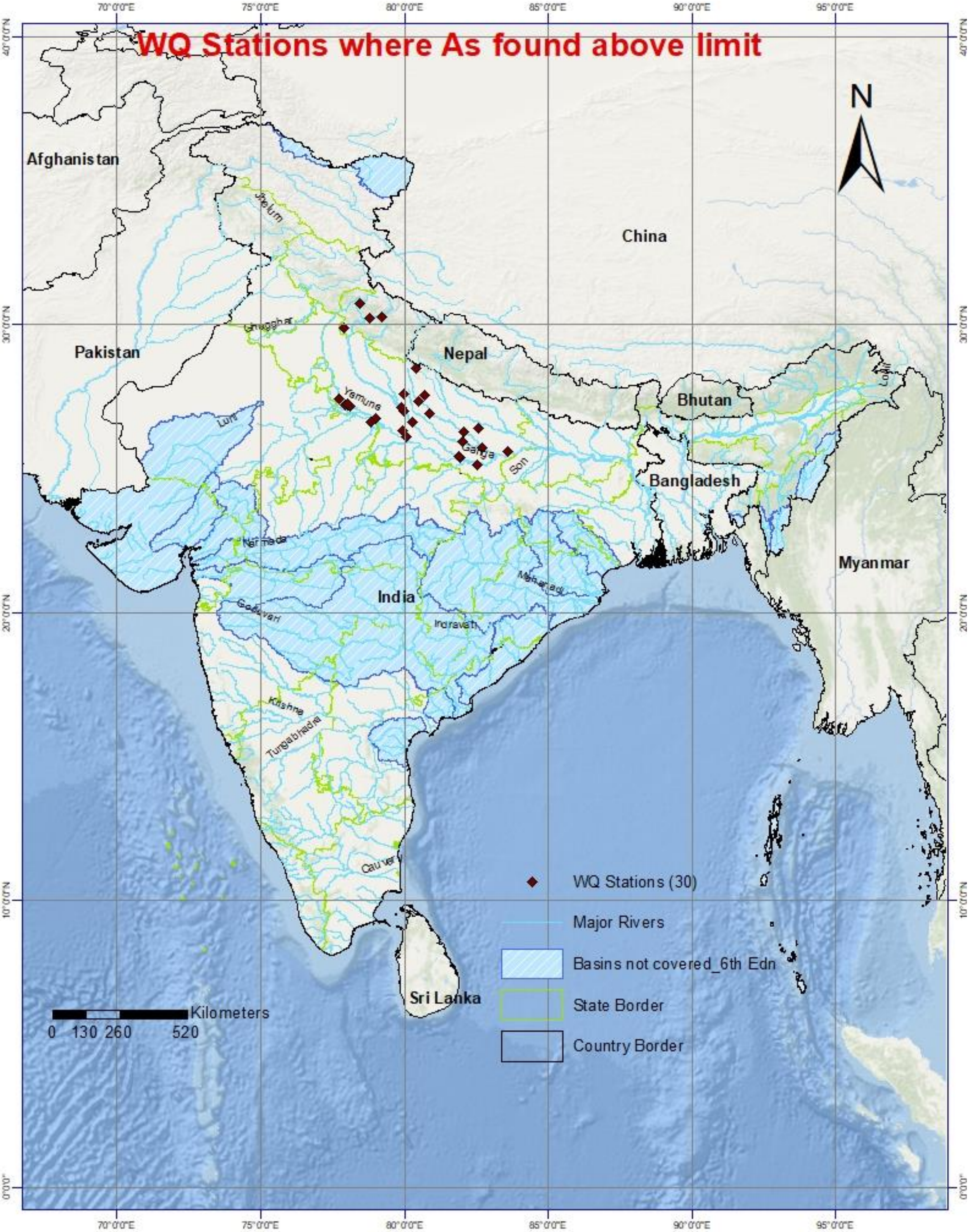


*Figure 19: WQ stations where Arsenic found above acceptable limit*

## Comparison with 4th edition (period: August 2018-December, 2020)

A comparison has been made between the current edition of the report and the 4th edition, which covers the period August 2018-December 2020. In the 4th edition, during the monitoring period from August 2018 to December 2020, a total of 2834 water samples were examined and 8 samples are found to exceed the limit. The overall percentage of samples above the acceptable limit was 0.28%. The highest arsenic concentration was 13.33 µg/L, recorded at Porakudi water quality monitoring station in Arasalar River, a tributary of the Cauvery River, in December 2019. Individual station-wise analysis revealed that arsenic concentrations exceeded the acceptable limit during December 2019 at 8 locations, specifically Bhadrachalam (Godavari), Changsari (Brahmaputra), Faizabad U/S (Ghaghra), Madamon (Pamba), Mirzapur (Ganga), Mohgaoan (Burhner), Moradabad (Ramganga), and Porakudi (Arasalar). However, it is noteworthy that for the remaining monitoring periods, the arsenic concentrations at these stations were within acceptable limits. The assessment of arsenic concentration in rivers during the study period revealed that eight rivers: Godavari, Brahmaputra, Ghaghra, Pamba, Ganga, Burhner, Ramganga and Arasalar, exhibited concentrations surpassing the acceptable limits.

During 2022, out of the 5942 samples collected and analyzed, only 48 samples, which accounts for 0.81 % of total samples; were found to be beyond the acceptable limit for arsenic concentration. Theses samples belong to 30 water quality stations across 14 rivers, encompassing Alakananda, Bhagirathi, Ganga, Ganga/Chhoti Sarju, Sukheta, Rapti, Gomti, Sarayan, Sai, Solani, Yamuna, Rind, Sengar and Kunwari. Notably, this extended and comprehensive monitoring revealed the widespread presence of arsenic in diverse river systems. Maximum arsenic concentration (19.47 µg/L) was observed at Kora water quality monitoring station on Rind River (a tributary of Yamuna) on 12.06.2022.

A GIS map depicting the stations where arsenic values were found above the acceptable limit during both study periods is shown as Figure 20. The common study area of both study periods, there is one common station (Mirzapur in Ganga) which is found to have arsenic exceedance in both study periods.

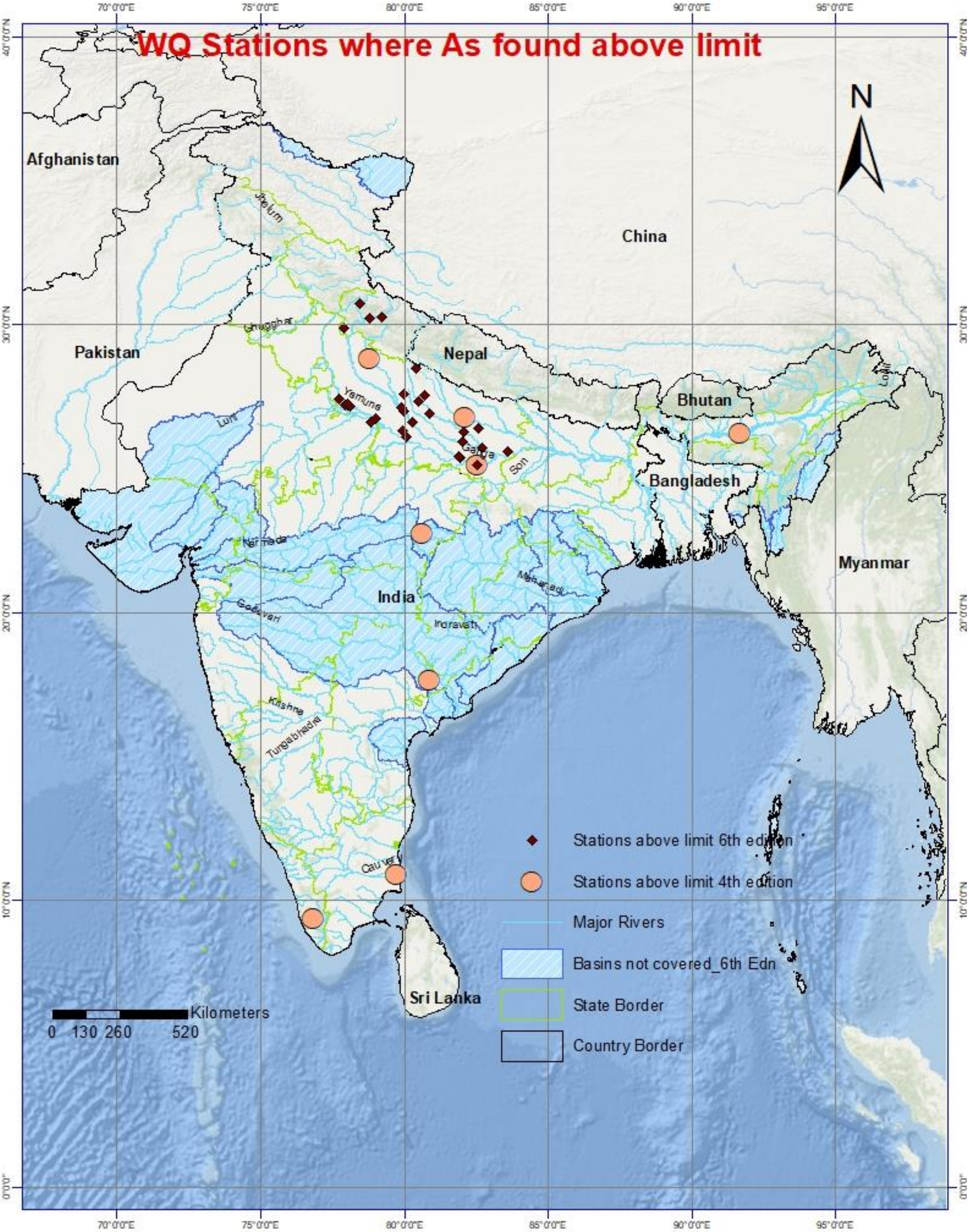


***Figure 20: WQ stations where Arsenic found above acceptable limit (both study periods)***

## 7.2 Cadmium (Cd)

BIS (Bureau of Indian Standards) 10500:2012 has recommended an acceptable limit of 3 µg/L of cadmium in drinking water. Out of total 5942 river water samples analysed, 5 samples from 4 water quality stations across 3 rivers were found to have cadmium concentrations beyond the acceptable limit. The cadmium concentration varies from 0.000 to 5.542 µg/L. Maximum cadmium concentration (5.542 µg/L) was observed at Lucknow water quality monitoring station on Gomti River on 21.01.2022.

The details of stations where cadmium concentrations (in µg/L) were found to be beyond acceptable limit, categorized by their respective rivers and dates is depicted in the table given below.

**Table 13: River-wise list of WQ stations with Cd values above limit**

| Sl. No. | River/tributary | Station | Date | Cd (µg/L) | State | District |
|---|---|---|---|---|---|---|
| 1 | Gomti | Gomti Nagar | 11-02-2022 | 3.126 | Uttar Pradesh | Lucknow |
| | Gomti | Lucknow | 21-01-2022 | 5.542 | Uttar Pradesh | Lucknow |
| 2 | Ponnaiyar | Singasadanapalli | 01-03-2022 | 5.073 | Tamil Nadu | Krishnagiri |
| | Ponnaiyar | Singasadanapalli | 11-03-2022 | 3.647 | Tamil Nadu | Krishnagiri |
| 3 | Seetha | Avershe | 01-07-2022 | 3.623 | Karnataka | Udupi |

The stations with above-limit cadmium values belong to 3 states: Karnataka, Tamil Nadu, and Uttar Pradesh. Figure 21 represents GIS map of WQ stations where Cadmium found above acceptable limit.

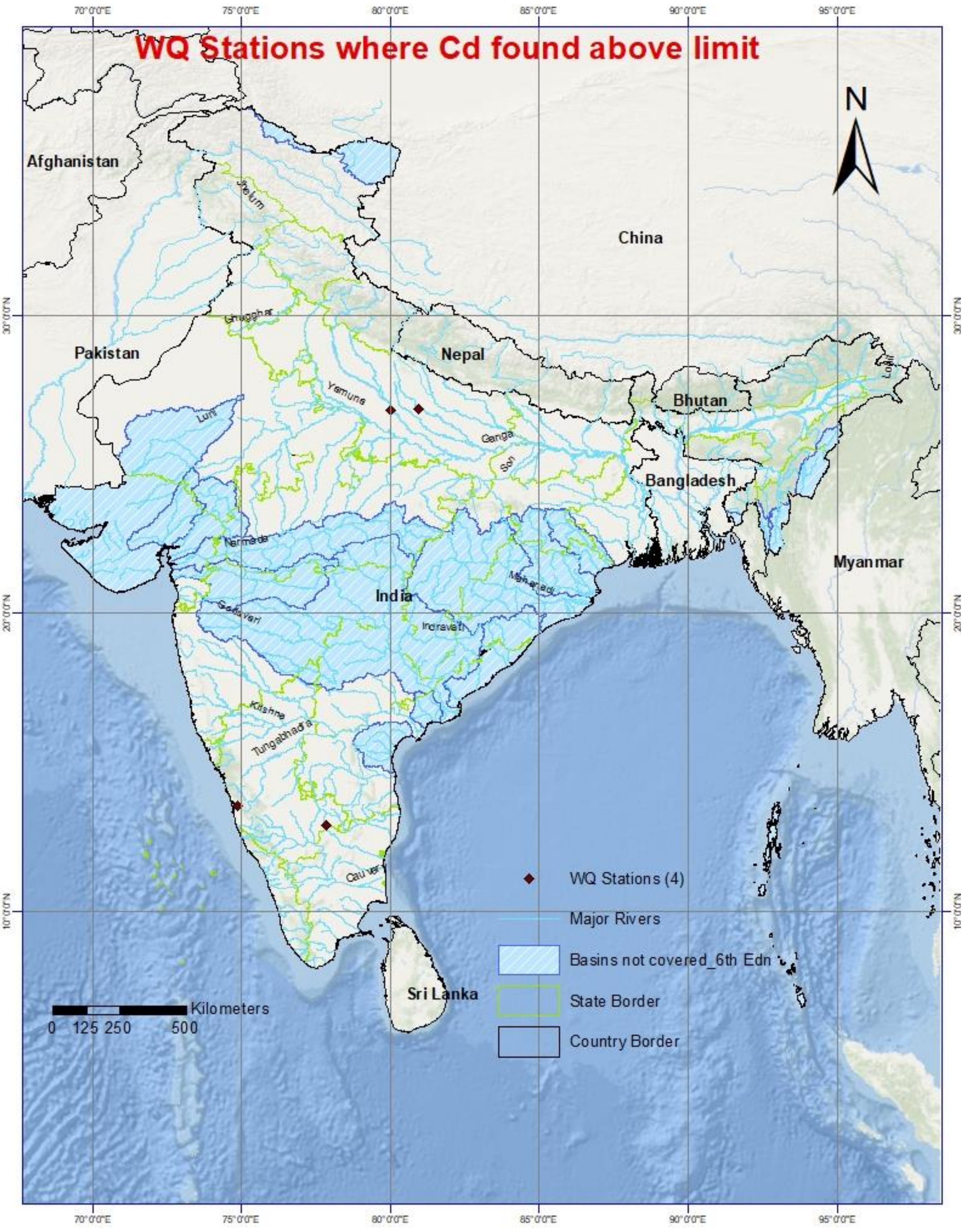


*Figure 21: WQ stations where Cadmium found above acceptable limit*

**Comparison with 4th edition (period: August 2018-December, 2020)**

The data of cadmium found above limit in this report has been compared with the last edition of the report i.e., 4th edition, for the period August 2018-December 2020.

3113 samples were analyzed during the last study period and 11 samples were found above limit (0.35%). The cadmium content in different rivers varied from 0.00 to 12.57 μg/L during this period. The highest cadmium concentration was observed at Todarpur station in the Sukheta River in December 2020. It was found that cadmium concentrations exceeded acceptable limits at 11 stations across 11 rivers. These 11 rivers include Godavari, Bhima, Noyyal, Narmada, Indravati, Munneru, Yamuna, Moyar, Sukheta, Tons, and Damanganga. Values above acceptable limit was observed at stations: Vapi (Damanganga) in August, 2018, Bhadrachalam (Godavari), Deongaon Bridge (Bhima), Hoshangabad (Narmada), Jagdalpur (Indravati), Keesara (Munneru) in August 2019, and Elunuthimangalam (Noyyal), Kuthnuor (Yamuna), Thengumarahada (Moyar), Todarpur (Sukheta), and Tuini (Tons) in December 2020. However, it is noteworthy that for the remaining monitoring periods, the cadmium concentrations at these stations were within acceptable limits.

During the current study period of 2022, out of 5942 samples analyzed, only 5 were found to be beyond the acceptable limit (0.08%). These samples are collected from 4 water quality stations across 3 rivers, encompassing Gomti, Ponnaiyar and Seetha. Maximum cadmium concentration (5.542 μg/L) was observed at Lucknow water quality monitoring station on Gomt River on 21.01.2022.

A GIS map showing stations with cadmium values above limit in the last and current reports is given as Figure 22. From the figure it is clear that, there are no common water quality stations where cadmium concentrations exceeded acceptable limits in both periods.

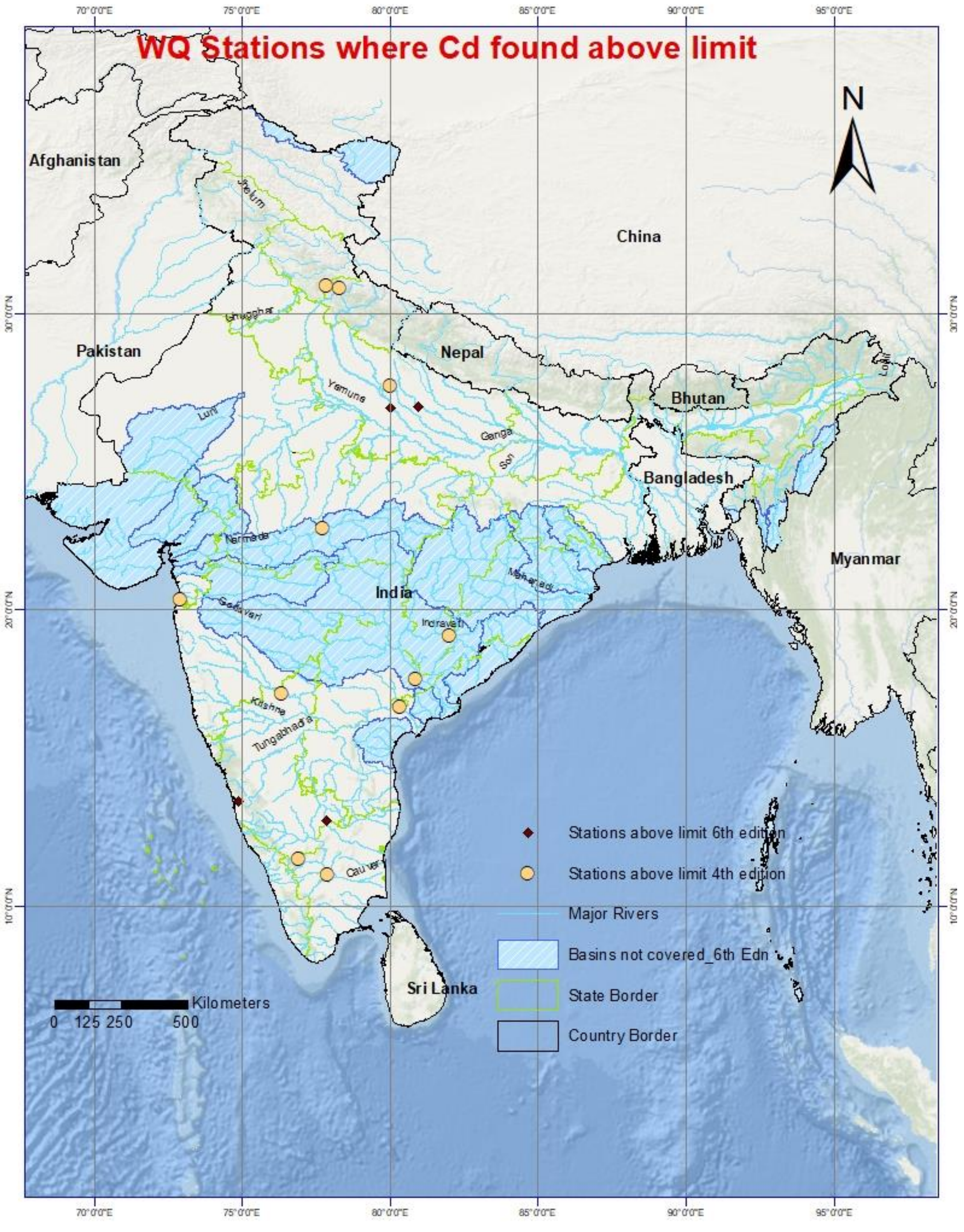


*Figure 22: WQ stations where Cadmium found above acceptable limit (both study periods)*

### 7.3 Chromium (Cr)

BIS (Bureau of Indian Standards) 10500:2012) has recommended an acceptable limit of 50 µg/L of chromium in drinking water. Out of total 5939 river water samples analysed, 17 samples from 16 water quality stations across 16 rivers were found to have chromium concentrations beyond the acceptable limit. The chromium concentration varies from 0.000 to 87.575 µg/L. Maximum chromium concentration (87.575 µg/L) was observed at Udaipur water quality monitoring station on Brahmaputra River on 21.12.2022.

Chromium (Cr) is a heavy metal that can have detrimental effects on aquatic ecosystems and human health when present in elevated concentrations.

The details of stations where chromium concentrations (in µg/L) were found to be beyond acceptable limit, categorized by their respective rivers and dates is depicted in the table given below.

**Table 14: River-wise list of WQ stations with Cr values above limit**

| Sl. No. | River/tributary | Station | Date | Cr (µg/L) | State | District |
|---|---|---|---|---|---|---|
| 1 | Bharathapuzha/ Kannadipuzha | Pudur | 23-08-2022 | 86.028 | Kerala | Palakkad |
| 2 | Bharathapuzha/ Pulanthodu | Pulamanthole | 11-08-2022 | 72.893 | Kerala | Palakkad |
| 3 | Brahmaputra/ Buridehing | Udaipur (Brahmaputra) | 21-12-2022 | 87.575 | Assam | Tinsukia |
| 4 | Cauvery | Kollegal | 21-06-2022 | 75.713 | Karnataka | Chamarajanagar |
| 5 | Gad | Belne Bridge | 11-07-2022 | 54.037 | Maharashtra | Sindudurg |
| 6 | Iruvazhinjipuzha | Thottathinkadavu | 01-09-2022 | 78.271 | Kerala | Kozhikode |
| 7 | Karuvannur | Palakadavu | 01-08-2022 | 57.759 | Kerala | Thrissur |
| | Karuvannur | Palakadavu | 23-08-2022 | 53.223 | Kerala | Thrissur |
| 8 | Kuttyadi | Kuttyadi | 23-08-2022 | 52.263 | Kerala | Kozhikode |
| 9 | Muvattupuzha | Ramamangalam | 11-08-2022 | 59.985 | Kerala | Ernakulam |
| 10 | Pamba | Malakkara | 02-08-2022 | 50.571 | Kerala | Pathanamthitta |
| 11 | Pamba/ Achankovil | Thumpamon | 11-08-2022 | 50.991 | Kerala | Pathanamthitta |
| 12 | Pamba/Manimala | Kallooppara | 01-09-2022 | 79.767 | Kerala | Pathanamthitta |
| 13 | Periyar | Vandiperiyar | 22-08-2022 | 57.052 | Kerala | Idukki |
| 14 | Tungabhadra | Honnali | 21-06-2022 | 63.242 | Karnataka | Davangere |
| 15 | Vamanapuram | Ayilam | 01-08-2022 | 57.14 | Kerala | Thiruvananthapuram |
| 16 | Yamuna | Baghpat | 01-11-2022 | 81.919 | Uttar Pradesh | Baghpat |

Figure 23 represents the GIS map of stations with chromium values above limit.

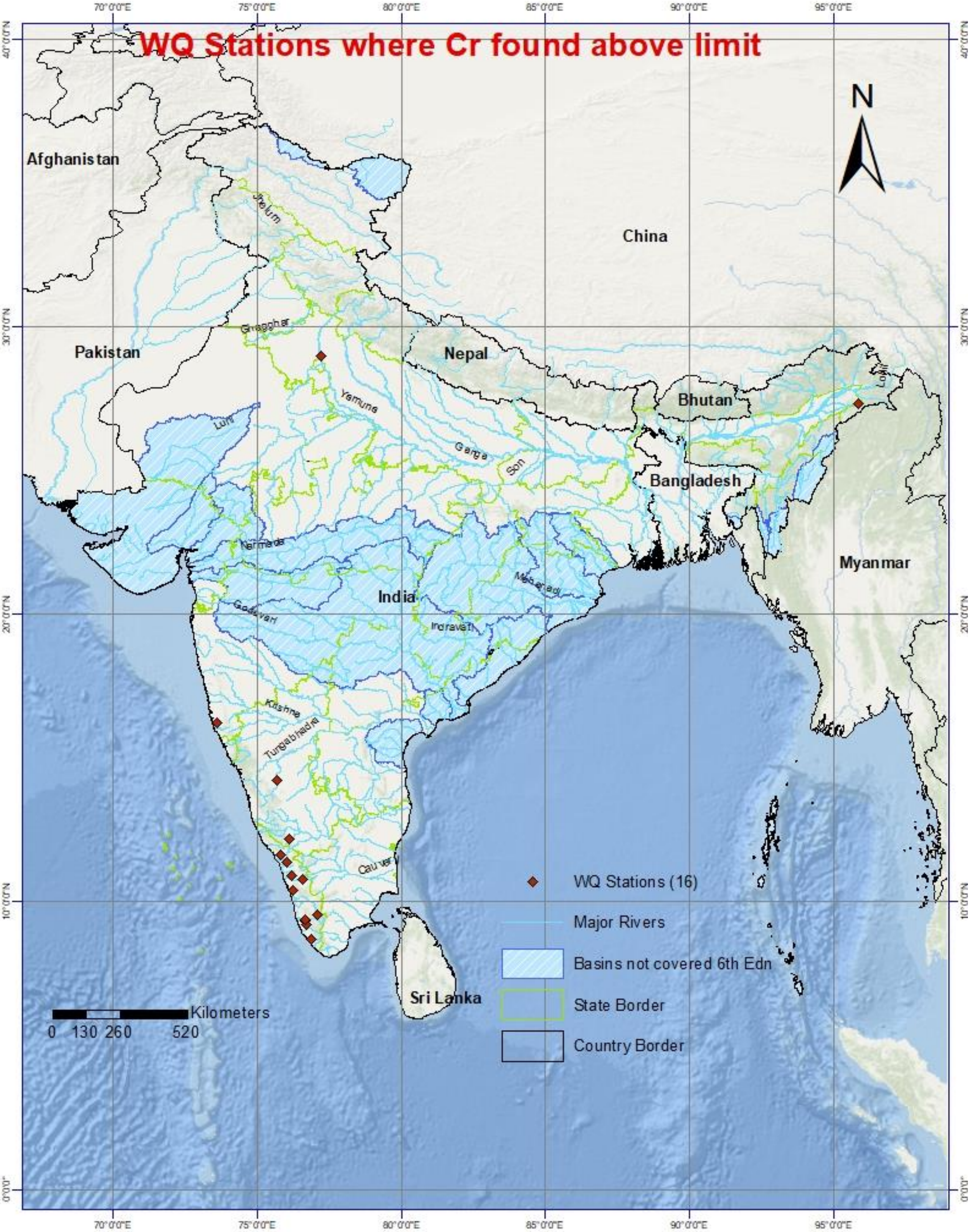


*Figure 23: WQ stations where Chromium found above acceptable limit*

**Comparison with 4th edition (period: August 2018-December, 2020)**

The chromium concentration varied from 0.00 to 180.47 µg/L during the period from August 2018 to December 2020. The maximum chromium concentration was observed at the M.B.P.L. water quality monitoring station on the Hasdeo River in December 2019. Chromium concentrations exceeded acceptable limits at 46 stations which belong to 34 rivers: Yamuna, Kunderu, Vaigai, Chulband, Wainganga, Yamuna, Wardha, Ramganga, Mahanadi, Dhansiri (South), Hasdeo, Sone, Ghaghra, Phalgu, Dhaleswari, Torsa, Tungabhadra, Kagna, Lakshmanthirtha, Kadalundi, Teesta, Kharkai, Shetruni, Gomti, Godavari, Bharathapuzha, Brahmani, Sind, Kharun, Kinnerasani, Betwa, Digaru, Um Sohryngkew, and Iruvazhinjipuzha.

Analysis conducted during 2022 involved the observation of chromium concentrations above the acceptable limit of 50 µg/L at 16 water quality monitoring stations across 16 rivers. This extended the widespread presence of chromium in diverse river systems: Kannadipuzha, Pulanthodu, Buridehing, Cauvery, Gad, Iruvazhinjipuzha, Karuvannur, Kuttyadi, Muvattupuzha, Pamba, Achankovil, Manimala, Periyar, Rapti, Tungabhadra, Vamanapuram, and Yamuna. Maximum chromium concentration (87.575 µg/L) was observed at Udaipur water quality monitoring station on Brahmaputra River on 21.12.2022.

There is one common water quality station with chromium exceedance in both reports: Thottathinkadavu water quality station at Iruvazhinjipuzha River. WQ stations with above-limit chromium concentrations during both study periods are depicted in Fig. 24.

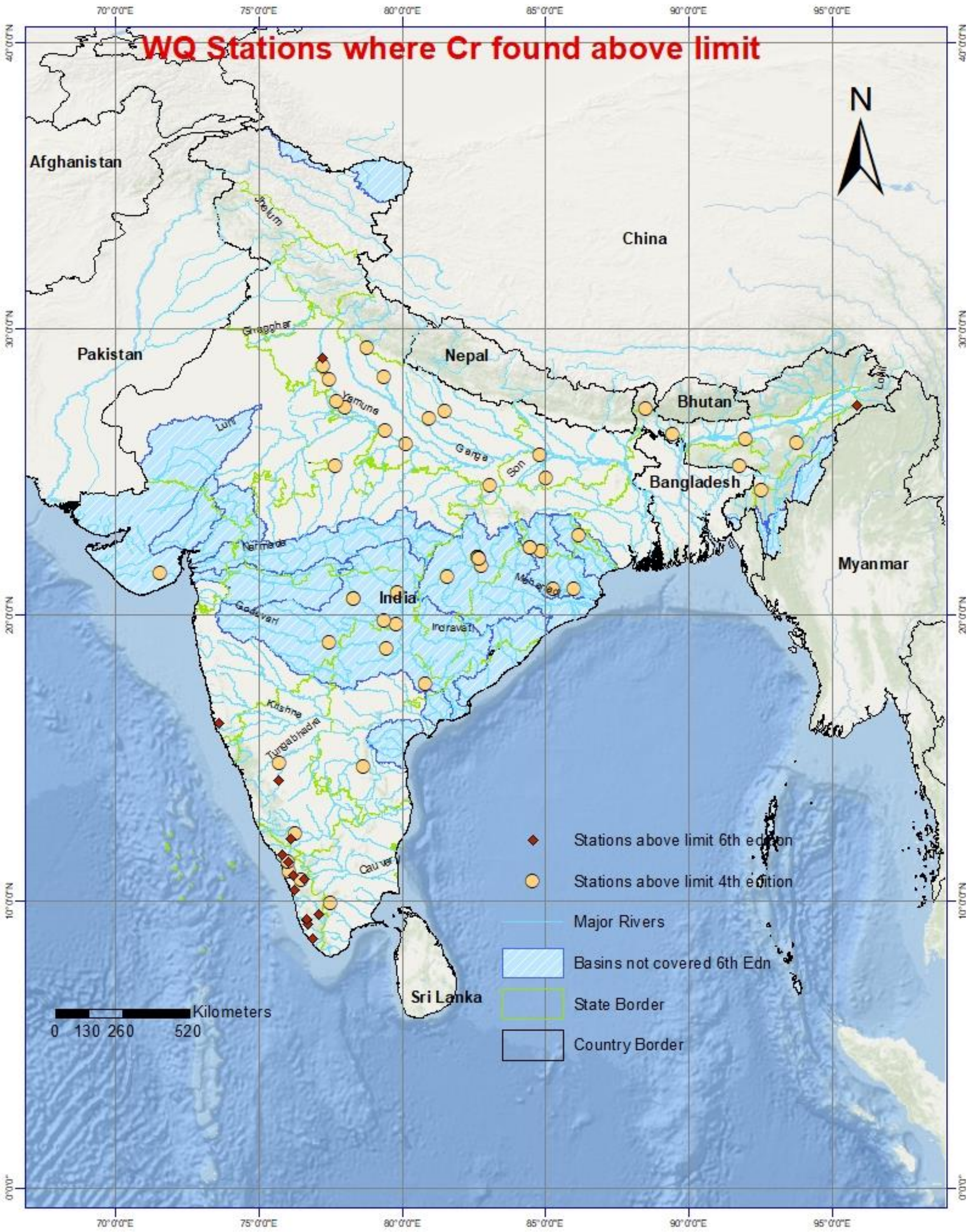


*Figure 24: WQ stations where Chromium found above acceptable limit (both study periods)*

### 7.4 Copper (Cu)

BIS (Bureau of Indian Standards) 10500:2012 has recommended an acceptable limit of 50 µg/L of copper in drinking water. Out of total 5941 river water samples analysed, 5 samples from 5 water quality stations across 5 rivers were found to have copper concentrations beyond the acceptable limit. The copper concentration varies from 0.000 to 98.097 µg/L. Maximum copper concentration (98.097 µg/L) was observed at Avarankuppam water quality monitoring station on Palar River on 01.11.2022.

The details of stations where copper concentrations (in µg/L) were found to be beyond acceptable limit, categorized by their respective rivers and dates is depicted in the table given below.

**Table 15: River-wise list of WQ stations with Cu values above limit**

| Sl. No. | River/tributary | Station | Date | Cu (µg/L) | State | District |
|---|---|---|---|---|---|---|
| 1 | Ganga | Haridwar | 02-03-2022 | 51.067 | Uttarakhand | Haridwar |
| 2 | Palar | Avarankuppam | 01-11-2022 | 98.097 | Tamil Nadu | Vellore |
| 3 | Ponnaiyar | Gummanur | 21-06-2022 | 73.854 | Tamil Nadu | Krishnagiri |
| 4 | Yamuna/Chambal/Parwati | A.B. Road Crossing | 01-07-2022 | 61.935 | Madhya Pradesh | Guna |
| 5 | Yamuna/Tons | Haripur | 01-12-2022 | 64.031 | Uttarakhand | Dehradun |

The samples whose values are beyond acceptable limit belong to three states: Uttarakhand, Tamil Nadu, and Madhya Pradesh. Figure 25 represents a GIS map of WQ stations where Copper is found above acceptable limit.

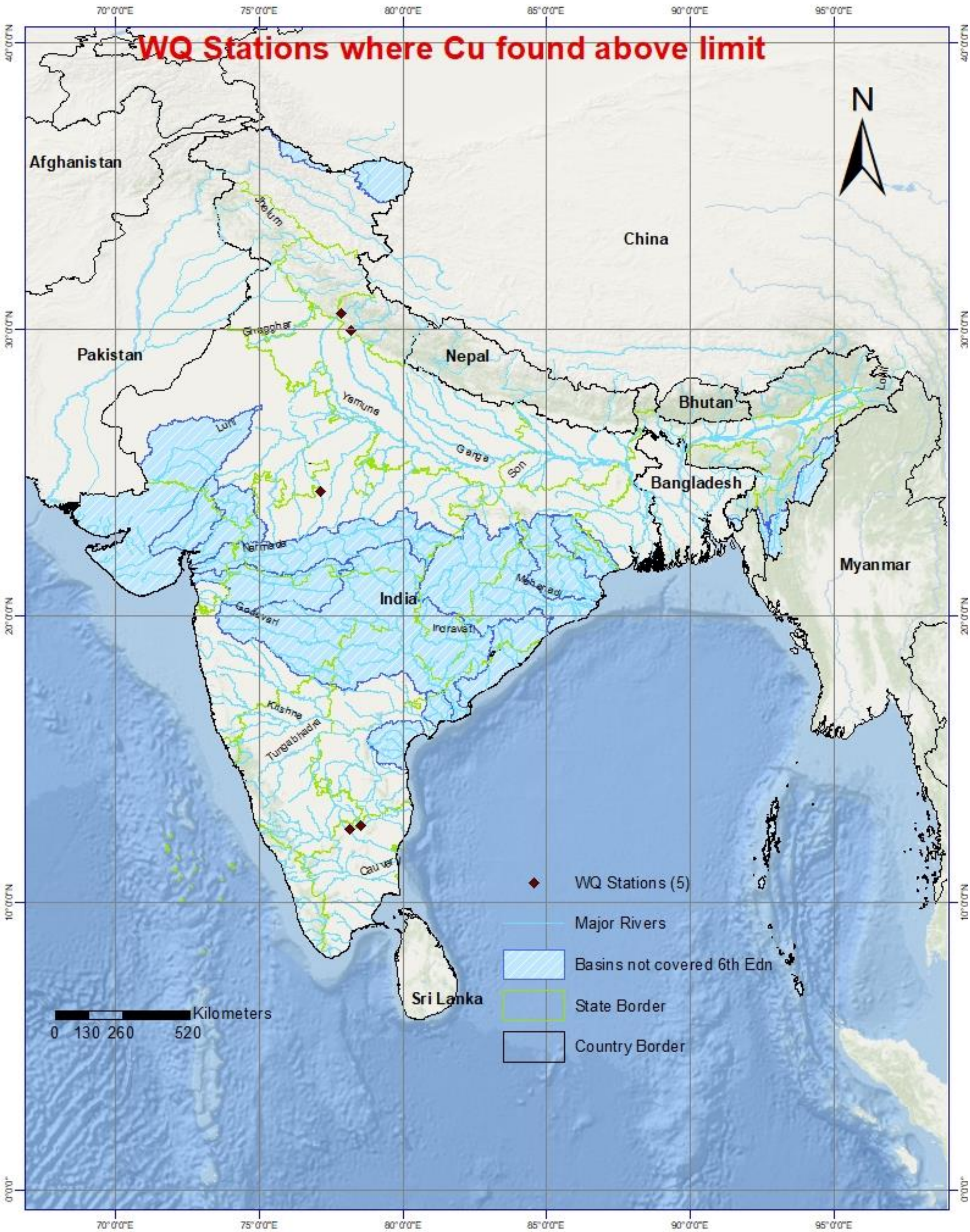


*Figure 25: WQ stations where Copper found above acceptable limit*

**Comparison with 4th edition (period: August 2018-December, 2020)**

During the period from August 2018 to December 2020, a total of 3107 water samples were collected and analysed to assess the Copper content.17 samples; i.e., 0.55 % of the total samples analysed were found to exceed the acceptable limit during August, 2018-December, 2020. The Copper concentration ranged from 0.00 to 132.64 µg/L. The highest Copper concentration (132.64 µg/L) was detected at Badlapur water quality monitoring station on the Ulhas River in December 2019. Notably, Copper concentrations exceeded acceptable limits at 17 stations across different rivers, namely Ulhas, Rapti, Subarnarekha, Wagh, Ghaghra, Ganga, Tawi, Koel, Ramganga, Brahmani, Sai, Tons, Khannaut, Dikhow, Gandak, Periyar and Giri.

In the subsequent period of 2022, out of a total of 5941 river water samples analyzed, 8 samples exceed the limit. This comprises of only 0.08 % of total samples analysed during the study period. These samples were collected from 5 water quality stations across 5 rivers: Ganga, Palar, Ponnaiyar, Parwati, and Tons. The range of copper concentration varied from 0.000 to 178.420 µg/L. The highest copper concentration (178.420 µg/L) was identified at the Tuini (Tons) water quality monitoring station in the Tons River on December 13, 2022. Figure 28 depicts the water quality stations with copper exceedance during both the study periods.

In the common study area between both periods, Copper concentrations exceeded acceptable limits at 14 stations across 14 rivers during August 2018 to December 2020. 11 among these 14 stations were analysed for copper during the current study period also and were found to be safe in terms of copper concentration. This indicates that no station is common in between the previous study period and the 2022 period. However, Ganga River appears to have above-limit concentration in both study periods.

Figure 26 indicates a decrease in both the number of stations and rivers exceeding the acceptable limits of copper during the current study period.

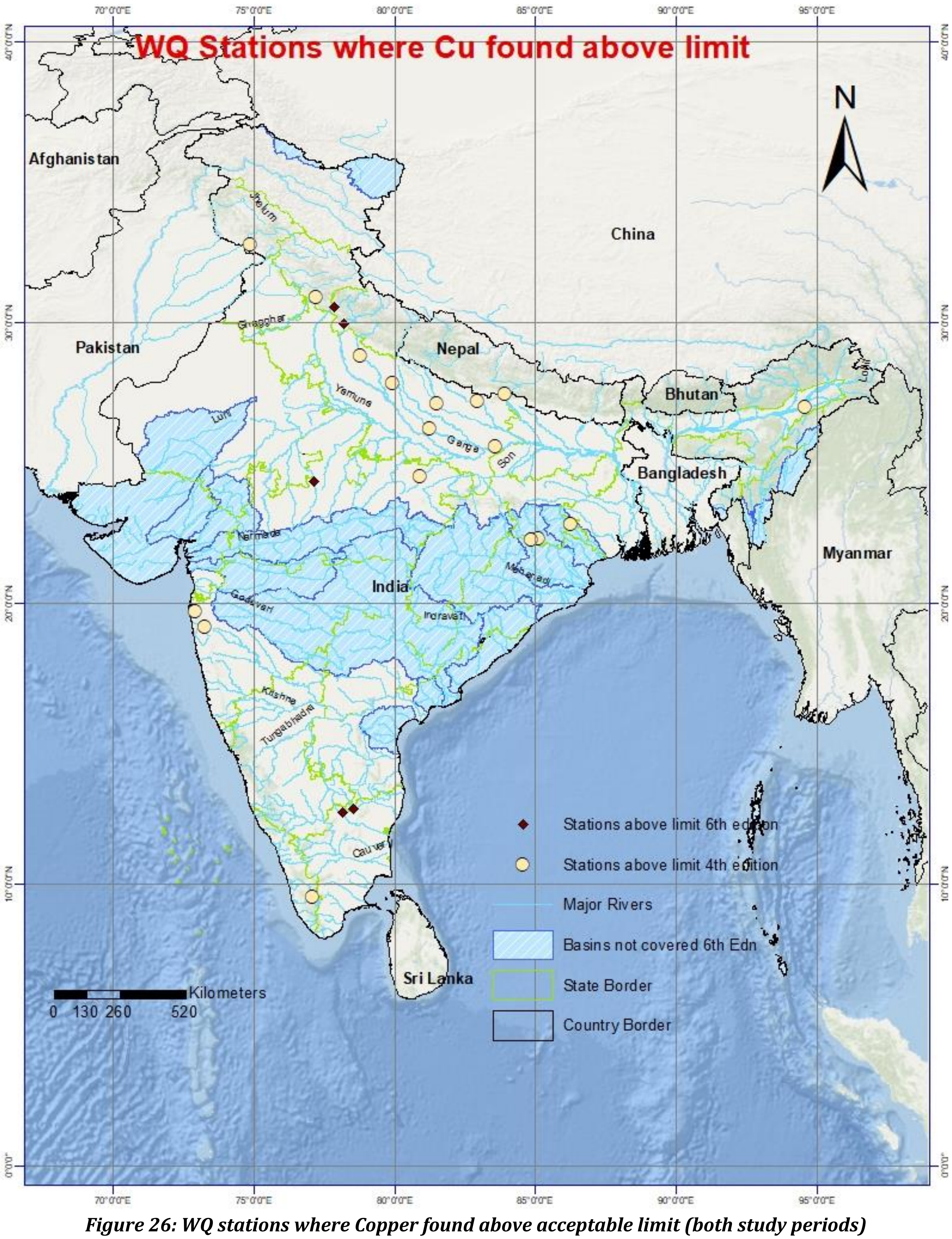


*Figure 26: WQ stations where Copper found above acceptable limit (both study periods)*

## 7.5 Iron (Fe)

BIS has recommended the acceptable limit of 1.0 mg/L (1000 µg/L) for Iron. Out of total 5980 river water samples analysed, 113 samples from 74 water quality stations across 51 rivers were found to have iron concentrations beyond the acceptable limit. The iron concentration varies from 0.000 to 11.387 mg/L. Maximum iron concentration (11.387 mg/L) was observed at Kirtinagar D/S water quality monitoring station on Alakananda River on 11.05.2022.

The details of stations where iron concentrations (in mg/L) were found to be beyond acceptable limit, categorized by their respective rivers and dates is depicted in the table given below.

**Table 16: River-wise list of WQ stations with Fe values above limit**

| Sl. No. | River/tributary | Station | Date | Fe(mg/L) | State | District |
|---|---|---|---|---|---|---|
| 1 | Aghnanashini | Santheguli | 11-08-2022 | 1.124 | Karnataka | Uthara Kannada |
| | Aghnanashini | Santheguli | 01-09-2022 | 2.33 | Karnataka | Uthara Kannada |
| 2 | Alakananda | Kirtinagar D/S | 11-05-2022 | 1.991 | Uttarakhand | Tehri |
| | Alakananda | Kirtinagar U/S | 11-05-2022 | 11.387 | Uttarakhand | Tehri |
| | Alakananda | Srinagar | 11-05-2022 | 1.929 | Uttarakhand | Pauri Garhwal |
| | Alakananda | Srinagar | 11-02-2022 | 1.628 | Uttarakhand | Pauri Garhwal |
| | Alakananda | Srinagar | 12-08-2022 | 1.382 | Uttarakhand | Pauri Garhwal |
| | Alakananda | Rudraprayag (A) | 01-08-2022 | 7.25 | Uttarakhand | Rudraprayag |
| | Alakananda | Rudraprayag (A) | 12-08-2022 | 1.479 | Uttarakhand | Rudraprayag |
| | Alakananda | Rudraprayag (A) | 11-04-2022 | 4.154 | Uttarakhand | Rudraprayag |
| | Alakananda | Karnaprayag Conflu-ence D/S | 01-08-2022 | 1.166 | Uttarakhand | Chamoli |
| | Alakananda | Karnaprayag Conflu-ence D/S | 21-03-2022 | 1.327 | Uttarakhand | Chamoli |
| | Alakananda | Karnaprayag Conflu-ence D/S | 11-04-2022 | 3.086 | Uttarakhand | Chamoli |
| | Alakananda | Karnaprayag Conflu-ence D/S | 11-05-2022 | 11.169 | Uttarakhand | Chamoli |
| | Alakananda | Karnaprayag Conflu-ence D/S | 11-04-2022 | 1.336 | Uttarakhand | Chamoli |
| | Alakananda | Karnaprayag Conflu-ence D/S | 21-04-2022 | 2.156 | Uttarakhand | Chamoli |
| | Alakananda | Karnaprayag Conflu-ence D/S | 12-08-2022 | 1.687 | Uttarakhand | Chamoli |
| 3 | Barak | Fulertal | 01-04-2022 | 1.391 | Assam | Cachar |
| 4 | Bhagirathi | Uttarkashi | 11-04-2022 | 3.809 | Uttarakhand | Uttarkashi |
| | Bhagirathi | Uttarkashi | 21-04-2022 | 1.02 | Uttarakhand | Uttarkashi |
| | Bhagirathi | Uttarkashi | 11-05-2022 | 10.837 | Uttarakhand | Uttarkashi |
| | Bhagirathi | Koteshwar | 12-08-2022 | 1.525 | Uttarakhand | Tehri |
| 5 | Bharathapuzha/ Kannadipuzha | Pudur | 01-09-2022 | 1.071 | Kerala | Palakkad |
| 6 | Bharathapuzha/ Pulanthodu | Pulamanthole | 01-09-2022 | 1.104 | Kerala | Palakkad |
| 7 | Cauvery | Chunchankatte | 01-09-2022 | 2.206 | Karnataka | Mysuru |
| 8 | Cauvery/Arasalar | Porakudi | 12-11-2022 | 1.569 | Tamil Nadu | Nagapattinam |
| 9 | Cauvery/Ayyar | Thandalaiputhur | 29-08-2022 | 1.569 | Tamil Nadu | Thiruchirapalli |
| 10 | Cauvery/Bhavani/Moyar | Thengumarahada | 11-05-2022 | 1.323 | Tamil Nadu | Nilgiris |
| 11 | Cauvery/Hemavati | Sakleshpur | 21-12-2022 | 1.65 | Karnataka | Hassan |
| | Cauvery/Hemavati | Akkihebbal | 11-07-2022 | 2.391 | Karnataka | Mandya |
| 12 | Cauvery/Kabini | T. Narasipur | 01-07-2022 | 2.329 | Karnataka | Mysuru |

| Sl. No. | River/tributary | Station | Date | Fe(mg/L) | State | District |
|---|---|---|---|---|---|---|
| 13 | Cauvery/Noyyal | Alandurai | 11-08-2022 | 1.091 | Tamil Nadu | Coimbatore |
| | Cauvery/Noyyal | Elunuthimangalam | 11-08-2022 | 1.699 | Tamil Nadu | Erode |
| 14 | Cauvery/Thirumalairajanar | Thengudi | 01-07-2022 | 1.662 | Tamil Nadu | Thiruvarur |
| 15 | Ganga | Haridwar D/S | 11-05-2022 | 1.941 | Uttarakhand | Haridwar |
| | Ganga | Haridwar U/S | 11-05-2022 | 2.693 | Uttarakhand | Haridwar |
| | Ganga | Rishikesh D/S | 11-05-2022 | 2.398 | Uttarakhand | Dehradun |
| | Ganga | Rishikesh | 11-05-2022 | 3.498 | Uttarakhand | Dehradun |
| | Ganga | Rishikesh | 01-08-2022 | 2.68 | Uttarakhand | Dehradun |
| | Ganga | Rishikesh | 12-08-2022 | 1.741 | Uttarakhand | Dehradun |
| | Ganga | Rishikesh | 01-09-2022 | 1.024 | Uttarakhand | Dehradun |
| | Ganga | Devprayag(G) | 01-08-2022 | 2.488 | Uttarakhand | Pauri Garhwal |
| 16 | Ganga/Deoha/Sukheta | Todarpur | 01-07-2022 | 3.679 | Uttar Pradesh | Hardoi |
| 17 | Gomti /Sarayan | Sitapur | 01-07-2022 | 2.634 | Uttar Pradesh | Sitapur |
| 18 | Kallada | Pattazhy | 02-08-2022 | 1.827 | Kerala | Kollam |
| | Kallada | Nellipally | 02-08-2022 | 1.665 | Kerala | Kollam |
| 19 | Kopili | Diprang Gaon | 21-04-2022 | 2.295 | Assam | Morigaon |
| 20 | Krishna/Malaprabha | Cholachugudda | 21-10-2022 | 1.285 | Karnataka | Bagalkot |
| | Krishna/Malaprabha | Cholachugudda | 21-12-2022 | 6.615 | Karnataka | Bagalkot |
| 21 | Krishna/Swarnamukhi | Hoovinahole | 11-10-2022 | 1.346 | Karnataka | Chitradurga |
| 22 | Nethravathi | Bantwal | 02-08-2022 | 3.27 | Karnataka | Dakshina Kannada |
| 23 | Palar | Chengalpet | 01-07-2022 | 2.496 | Tamil Nadu | Chengalpet |
| 24 | Pamba | Madamon | 11-08-2022 | 5.352 | Kerala | Pathanamthitta |
| | Pamba | Malakkara | 02-08-2022 | 1.005 | Kerala | Pathanamthitta |
| 25 | Pamba/ Achankovil | Thumpamon | 11-08-2022 | 4.435 | Kerala | Pathanamthitta |
| 26 | Pamba/Manimala | Kallooppara | 02-08-2022 | 1.022 | Kerala | Pathanamthitta |
| 27 | Payaswani | Erinjipuzha | 02-08-2022 | 1.108 | Kerala | Kasargod |
| 28 | Pazhayar | Ashramam | 02-08-2022 | 1.185 | Tamil Nadu | Kanyakumari |
| 29 | Periyar | Vandiperiyar | 22-08-2022 | 1.243 | Kerala | Idukki |
| 30 | Pinder | Karnaprayag | 11-04-2022 | 2.215 | Uttarakhand | Chamoli |
| | Pinder | Karnaprayag | 02-05-2022 | 4.022 | Uttarakhand | Chamoli |
| | Pinder | Karnaprayag | 01-08-2022 | 1.274 | Uttarakhand | Chamoli |
| 31 | Pokoriya | Dherabhabari/ Simul-tala | 21-04-2022 | 3.247 | Assam | Morigaon |
| 32 | Ponnaiyar | Singasadanapalli | 11-01-2022 | 1.138 | Tamil Nadu | Krishnagiri |
| | Ponnaiyar | Singasadanapalli | 11-05-2022 | 2.202 | Tamil Nadu | Krishnagiri |
| | Ponnaiyar | Singasadanapalli | 01-03-2022 | 6.628 | Tamil Nadu | Krishnagiri |
| | Ponnaiyar | Singasadanapalli | 11-03-2022 | 5.454 | Tamil Nadu | Krishnagiri |
| | Ponnaiyar | Singasadanapalli | 21-03-2022 | 2.493 | Tamil Nadu | Krishnagiri |
| | Ponnaiyar | Singasadanapalli | 21-02-2022 | 1.447 | Tamil Nadu | Krishnagiri |
| | Ponnaiyar | Vazhavachanur | 11-12-2022 | 1.326 | Tamil Nadu | Thiruvannamalai |
| 33 | Solani | Roorkee U/S | 21-03-2022 | 2.675 | Uttarakhand | Haridwar |
| | Solani | Roorkee U/S | 11-03-2022 | 1.039 | Uttarakhand | Haridwar |
| | Solani | Roorkee D/S | 21-03-2022 | 1.071 | Uttarakhand | Haridwar |
| 34 | Tunga | Hariharapura | 21-12-2022 | 1.147 | Karnataka | Chikmagalur |
| 35 | Tungabhadra/Bhadra | Lakkavalli | 21-05-2022 | 1.102 | Karnataka | Chikmagalur |
| | Tungabhadra/Bhadra | Lakkavalli | 11-06-2022 | 1.223 | Karnataka | Chikmagalur |
| | Tungabhadra/Bhadra | Lakkavalli | 21-06-2022 | 1.456 | Karnataka | Chikmagalur |
| 36 | Udori | Chotogorjan/KaliajarI | 21-04-2022 | 2.069 | Assam | Morigaon |
| 37 | Vaigai/Suruliar | Theni | 11-04-2022 | 3.715 | Tamil Nadu | Theni |
| | Vaigai/Suruliar | Theni | 01-07-2022 | 1.177 | Tamil Nadu | Theni |
| 38 | Yamuna | Mawi | 01-06-2022 | 1.157 | Uttar Pradesh | Shamli |

| Sl. No. | River/tributary | Station | Date | Fe(mg/L) | State | District |
|---|---|---|---|---|---|---|
| | Yamuna | Paonta | 13-12-2022 | 4.409 | Himachal Pradesh | Simaur |
| | Yamuna | Kalpi | 02-08-2022 | 1.332 | Uttar Pradesh | Jalaun |
| | Yamuna | Rajapur | 02-08-2022 | 1.054 | Uttar Pradesh | Chitrakoot |
| | Yamuna | Rajapur | 23-08-2022 | 1.078 | Uttar Pradesh | Chitrakoot |
| | Yamuna | Pratappur (Yamuna) | 02-08-2022 | 1.143 | Uttar Pradesh | Allahabad |
| | Yamuna | Pratappur (Yamuna) | 01-09-2022 | 1.034 | Uttar Pradesh | Allahabad |
| 39 | Yamuna/Bata | Ganguwala | 21-12-2022 | 1.569 | Himachal Pradesh | Sirmaur |
| 40 | Yamuna/ Chambal | Mandawara | 01-12-2022 | 1.416 | Rajasthan | Kota |
| | Yamuna/ Chambal | Pali | 13-12-2022 | 3.297 | Rajasthan | Sawai-madhopur |
| | Yamuna/ Chambal | Manderial | 21-12-2022 | 1.166 | Rajasthan | Karauli |
| 41 | Yamuna/ Tons | Haripur | 13-12-2022 | 1.033 | Uttarakhand | Dehradun |
| 42 | Yamuna/Betwa | Basoda | 22-07-2022 | 1.52 | Madhya Pradesh | Vidisha |
| | Yamuna/Betwa | Basoda | 23-08-2022 | 1.632 | Madhya Pradesh | Vidisha |
| 43 | Yamuna/Chambal/Parwati | Khatoli | 21-12-2022 | 1.371 | Rajasthan | Kota |
| 44 | Yamuna/Hindon | Galeta | 01-12-2022 | 3.774 | Uttar Pradesh | Meerut |
| | Yamuna/Hindon | Galeta | 21-12-2022 | 4.238 | Uttar Pradesh | Meerut |
| | Yamuna/Hindon | Baleni U/S of Ghaziabad | 01-12-2022 | 1.142 | Uttar Pradesh | Baghpath |
| 45 | Yamuna/Ken | Madla | 22-07-2022 | 1.484 | Madhya Pradesh | Panna |
| | Yamuna/Ken | Madla | 02-08-2022 | 1.277 | Madhya Pradesh | Panna |
| | Yamuna/Ken | Banda | 01-09-2022 | 1.024 | Uttar Pradesh | Banda |
| 46 | Yamuna/Ken/Bearma | Gaisabad | 22-07-2022 | 1.221 | Madhya Pradesh | Damoh |
| | Yamuna/Ken/Bearma | Gaisabad | 23-08-2022 | 1.429 | Madhya Pradesh | Damoh |
| 47 | Yamuna/Ken/Sonar | Garhakota | 11-07-2022 | 3.664 | Madhya Pradesh | Sagar |
| 48 | Yamuna/Rind | Kora | 02-08-2022 | 1.076 | Uttar Pradesh | Fatehpur |
| | Yamuna/Rind | Kora | 11-08-2022 | 7.07 | Uttar Pradesh | Fatehpur |
| | Yamuna/Rind | Kora | 23-08-2022 | 3.395 | Uttar Pradesh | Fatehpur |
| | Yamuna/Rind | Kora | 01-09-2022 | 1.92 | Uttar Pradesh | Fatehpur |
| 49 | Yamuna/Sengar | Lalpur | 11-08-2022 | 1.578 | Uttar Pradesh | Kanpur Dehat |
| | Yamuna/Sengar | Lalpur | 23-08-2022 | 1.642 | Uttar Pradesh | Kanpur Dehat |
| 50 | Yamuna/Sind | Pachauli | 11-07-2022 | 1.399 | Madhya Pradesh | Shivpuri |
| | Yamuna/Sind | Pachauli | 22-07-2022 | 1.467 | Madhya Pradesh | Shivpuri |
| 51 | Yamuna/Uttangan | Arnota | 22-07-2022 | 1.656 | Uttar Pradesh | Agra |

Iron is the element analysed which is found to exceed the limit at maximum number of stations and samples despite of the comparatively higher acceptable limit of 1 mg/L. This shows the abundance of the metals across various rivers. Figure 27 depicts the GIS map of WQ stations where Iron is found to be above limit.

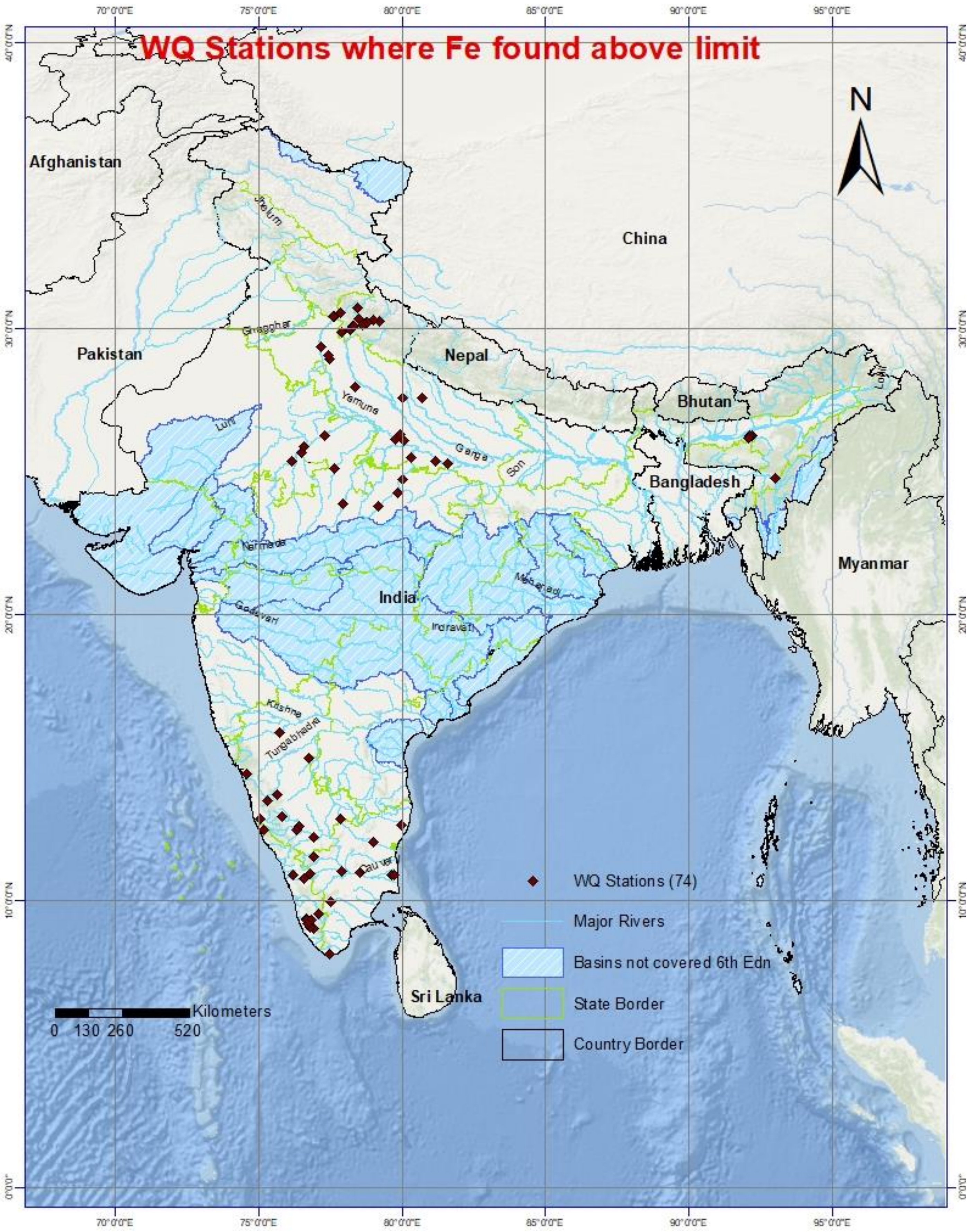


***Figure 27: WQ stations where Iron found above acceptable limit***

**Comparison with 4th edition (period: August 2018-December, 2020)**

In the 4th edition, the acceptable limit of 0.3 mg/L and in the current edition of the report, the revised limit of 1.0 mg/L is being considered. However, 6.87% of the total samples analysed were observed to exceed the iron concentration of 1.0 mg/L during August 2018-December 2020 (214 samples out of 3113). These samples belong to 153 water quality stations across 103 rivers. Maximum Iron concentration (11.24 mg/L) was observed at Farakka/ (HR) water quality monitoring station on Feeder Canal during Aug, 2019.

During 2022, 113 water quality stations were identified with iron concentrations surpassing the acceptable limits. However, only 1.89 % of the total samples analysed are found to exceed the limit (113 samples out of 5980). These samples were collected from 113 water quality monitoring stations across 74 rivers. Maximum iron concentration (11.387 mg/L) was observed at Kirtinagar D/S water quality monitoring station on Alakananda River on 11.05.2022.

Twenty five water quality stations Ashramam, Elunuthimangalam, Erinjipuzha, Fulertal, Galeta, Ganguwala, Kallooppara, Kalpi, Lakkavalli, Lalpur, Madamon, Malakkara, Mandawara, Nellipally, Pattazhy, Pudur, Pulamanthole, Rishikesh, Rishikesh D/S, Santheguli, Sitapur, Srinagar, Thumpamon, Todarpur and Vandiperiyar are identified as common in both the reports in terms of iron exceedance. The common stations demonstrate the persistence of elevated iron concentrations in some stations/rivers, attributed to various factors such as human activities, industrial discharges or natural geogenic sources. Figure 28 is the GIS map of stations with iron exceedance in both study periods.

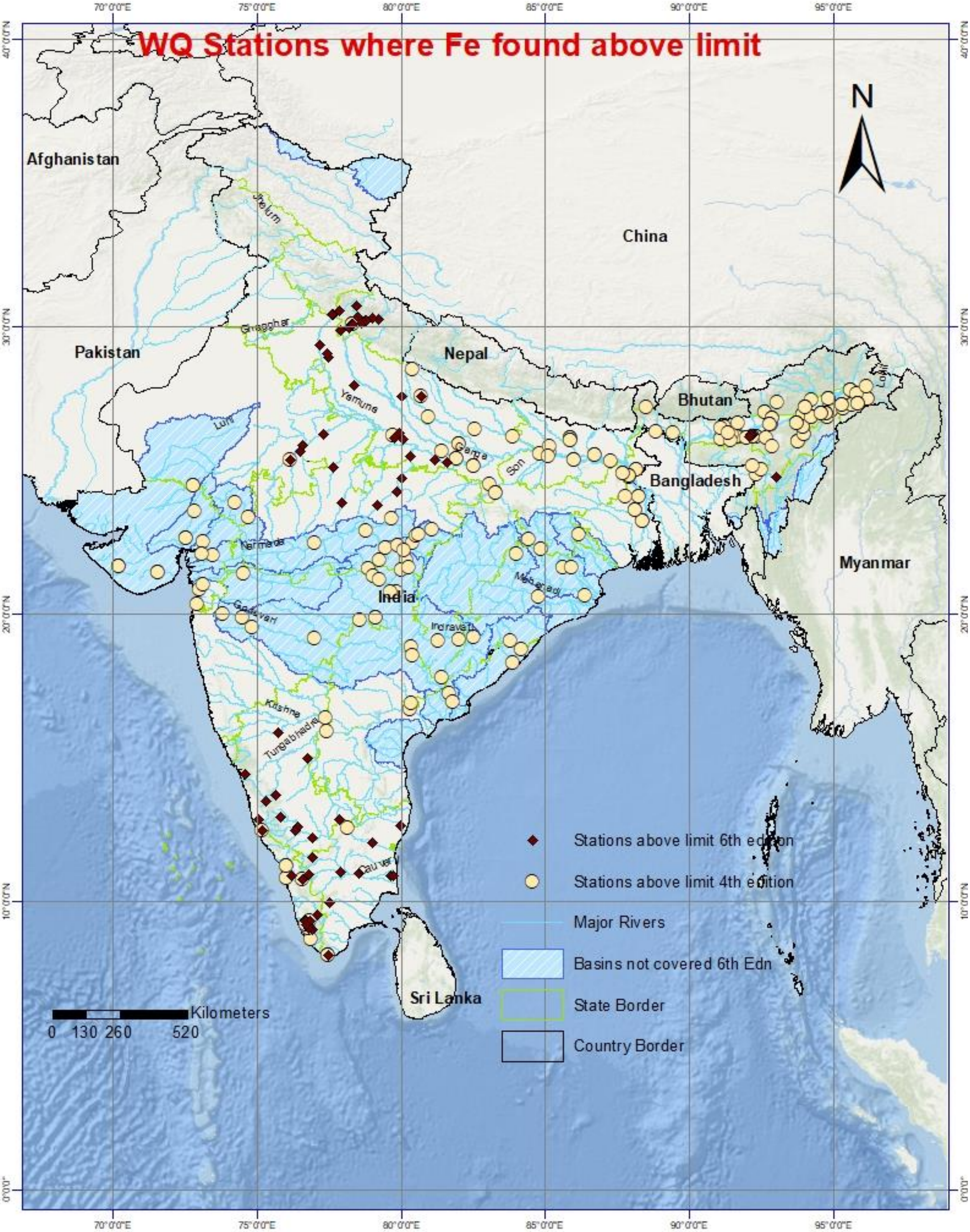


*Figure 28: WQ stations where Iron found above acceptable limit (both study periods)*

## 7.6 Lead (Pb)

Bureau of Indian Standards (10500:2012) has recommended that the acceptable limit for lead is 0.01 mg/L or 10 µg/L in drinking water. Out of total 5942 river water samples analysed, 37 samples from 30 water quality stations across 25 rivers were found to have lead concentrations beyond the acceptable limit. The lead concentration varies from 0.000 to 63.483 µg/L. Maximum lead concentration (63.483 µg/L) was observed at Avershe water quality monitoring station on Seetha River on 01.07.2022.

The details of stations where lead concentrations (in µg/L) were found to be beyond acceptable limit, categorized by their respective rivers and dates are depicted in the table given below.

**Table 17: River-wise list of WQ stations with Pb values above limit**

| Sl. No. | River/tributary | Station | Date | Pb (µg/L) | State | District |
|---|---|---|---|---|---|---|
| 1 | Aghnanashini | Santheguli | 01-07-2022 | 15.309 | Karnataka | Uthara Kannada |
| 2 | Alakananda | Kirtinagar U/S | 11-05-2022 | 14.885 | Uttarakhand | Tehri |
| | Alakananda | Karnaprayag Confluence D/S | 11-05-2022 | 13.969 | Uttarakhand | Chamoli |
| 3 | Bhagirathi | Uttarkashi | 11-05-2022 | 15.95 | Uttarakhand | Uttarkashi |
| 4 | Bharathapuzha/ Kannadipuzha/Aliyar | Ambarampalayam | 21-05-2022 | 11.931 | Tamil Nadu | Coimbatore |
| 5 | Cauvery /Arkavathi | T. Bekuppe | 21-12-2022 | 16.030 | Karnataka | Ramanagara |
| 6 | Cauvery/Lakshmanthirtha | K.M. Vadi | 21-12-2022 | 11.734 | Karnataka | Mysuru |
| 7 | Ganga | Haridwar | 02-03-2022 | 16.389 | Uttarakhand | Haridwar |
| 8 | Gomti/Sai | Pratapgarh | 01-04-2022 | 11.099 | Uttar Pradesh | Pratapgarh |
| 9 | Kallada | Pattazhy | 21-06-2022 | 18.274 | Kerala | Kollam |
| | Kallada | Nellipally | 11-02-2022 | 28.788 | Kerala | Kollam |
| | Kallada | Nellipally | 11-06-2022 | 27.578 | Kerala | Kollam |
| | Kallada | Nellipally | 01-07-2022 | 13.608 | Kerala | Kollam |
| | Kallada | Nellipally | 21-07-2022 | 11.289 | Kerala | Kollam |
| | Kallada | Nellipally | 02-08-2022 | 16.194 | Kerala | Kollam |
| | Kallada | Nellipally | 11-08-2022 | 17.283 | Kerala | Kollam |
| 10 | Krishna/Malaprabha | Cholachugudda | 21-12-2022 | 16.633 | Karnataka | Bagalkot |
| 11 | Muvattupuzha | Ramamangalam | 23-08-2022 | 13.112 | Kerala | Ernakulam |
| 12 | Muvattupuzha/ Kaliyar | Kalampur | 23-08-2022 | 13.544 | Kerala | Ernakulam |
| 13 | Pamba | Madamon | 23-08-2022 | 11.54 | Kerala | Pathanamthitta |
| 14 | Pamba/Manimala | Kallooppara | 11-07-2022 | 11.719 | Kerala | Pathanamthitta |
| 15 | Pennar/Papagani | Kamalapuram | 21-02-2022 | 28.275 | Andhra Pradesh | Kadapa |
| 16 | Ponnaiyar | Singasadanapalli | 01-03-2022 | 13.248 | Tamil Nadu | Krishnagiri |
| | Ponnaiyar | Singasadanapalli | 11-03-2022 | 10.081 | Tamil Nadu | Krishnagiri |
| 17 | Ramganga | Moradabad | 23-05-2022 | 12.954 | Uttar Pradesh | Moradabad |
| 18 | Seetha | Avershe | 01-07-2022 | 63.483 | Karnataka | Udupi |
| 19 | Thambraparni | Kuzhithurai | 11-07-2022 | 11.518 | Tamil Nadu | Knayakumari |
| | Thambraparni | Kuzhithurai | 22-08-2022 | 43.509 | Tamil Nadu | Knayakumari |
| 20 | Tungabhadra | Honnali | 21-12-2022 | 11.117 | Karnataka | Davangere |
| | Tungabhadra | Haralahalli | 21-12-2022 | 13.441 | Karnataka | Haveri |
| 21 | Tungabhadra/Kumudavathi | Kuppellur | 21-12-2022 | 18.288 | Karnataka | Haveri |
| 22 | Tungabhadra/Tunga | Shimoga | 21-12-2022 | 13.093 | Karnataka | Shimoga |
| | Tungabhadra/Tunga | Byaladahalli | 21-12-2022 | 14.874 | Karnataka | Davanagere |
| | Tungabhadra/Tunga | Hariharapura | 21-12-2022 | 10.88 | Karnataka | Chikmagalur |
| 23 | Yamuna | Kuthnuor | 13-09-2022 | 16.882 | Uttarakhand | Uttarkashi |
| 24 | Yamuna/ Chambal | Tal | 21-10-2022 | 10.777 | Madhya Pradesh | Ratlam |
| 25 | Yamuna/Tons | Haripur | 01-12-2022 | 37.394 | Uttarakhand | Dehradun |
| | Yamuna/Tons | Tuini (Tons) | 13-12-2022 | 13.955 | Uttarakhand | Dehradun |

A GIS map of WQ stations where lead is found above acceptable limit is depicted in Figure 29.

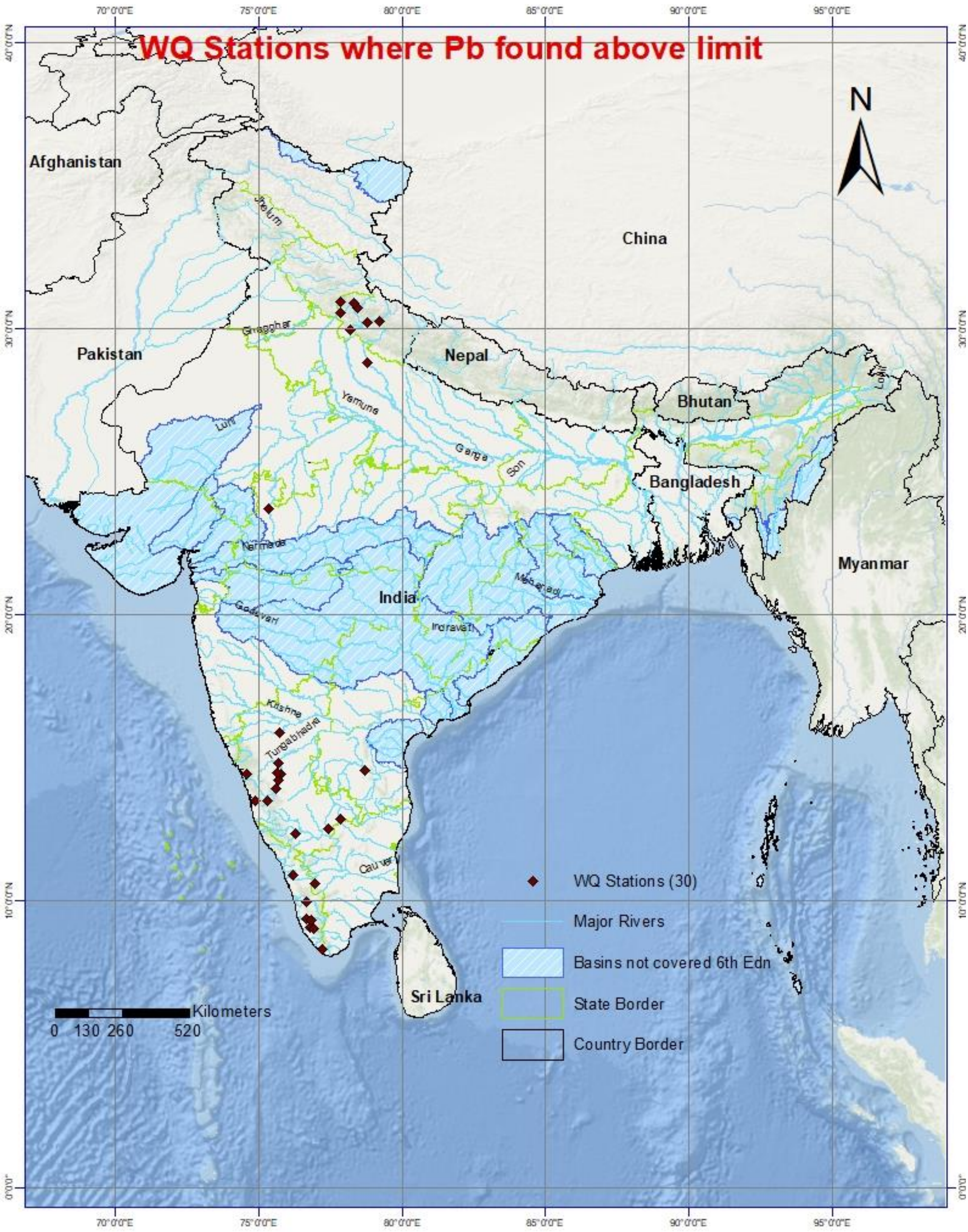


*Figure 29: WQ stations where Lead found above acceptable limit*

**Comparison with 4th edition (period: August 2018-December, 2020)**

During the period from August 2018 to December 2020, a total of 3111 water samples were collected and analysed and 36 samples were found to exceed the acceptable limit (1.16%). The Lead concentration in 3113 samples varied from 0.00 to 67.55 µg/L. The highest concentration (67.55 µg/L) was recorded at Chopan water quality monitoring station in the Sone River, in May 2020. The data reveals that a total number of 34 water quality stations namely Agra (J.B.), Agra (P.G.), Ankinghat, Berhampore, Bhalwara, Chaklagaon, Chel, Chenimari, Chopan, Dindori, Domohani, Englishbazar, Farakka/(HR), Garhmukteshwar, Hanskhali, Hoshangabad, Kalanaur, Karnal, Katwa, Kumarapalayam, Lowara, Manakkad, Manot, Mawi, Miao, Muthankera, Naugaon, Nellipally, Rudraprayag, Sitapur, Thimmanahalli, Tuini/tons, Varanasi, and Yashwant Nagar. These stations belong to 24 rivers, namely Alaknanda, Bhagirathi, Buridehing, Chel, Churni, Feeder Canal, Ganga, Gaur, Giri, Kabini, Kallada, Mahananda, Manas, Narmada, Noa-dehing, Sarayan, Shetruni, Sone, Teesta, Thodupuzha, Tons, Varahanadhi, Yagachi, and Yamuna, exceeded the acceptable lead concentration limit.

Subsequently, during the 2022 period, out of total 5942 river water samples analysed, 37 samples from 30 water quality stations across 25 rivers surpassed the acceptable limit for lead levels. Maximum lead concentration (63.483 µg/L) was observed at Avershe water quality monitoring station in Seetha River on 01.07.2022.

Figure 30 represents the GIS map of stations affected with Pb in both reports. In the common study area of both reports, 29 stations were found to exceed the acceptable limit of lead during August, 2018-December, 2020. Two (02) stations among 29 are found to have lead exceedance during both study periods. These stations are Nellipally in Kallada and Tuini in Tons.

Figure 30 is the GIS map of stations with lead exceedance in both study periods.

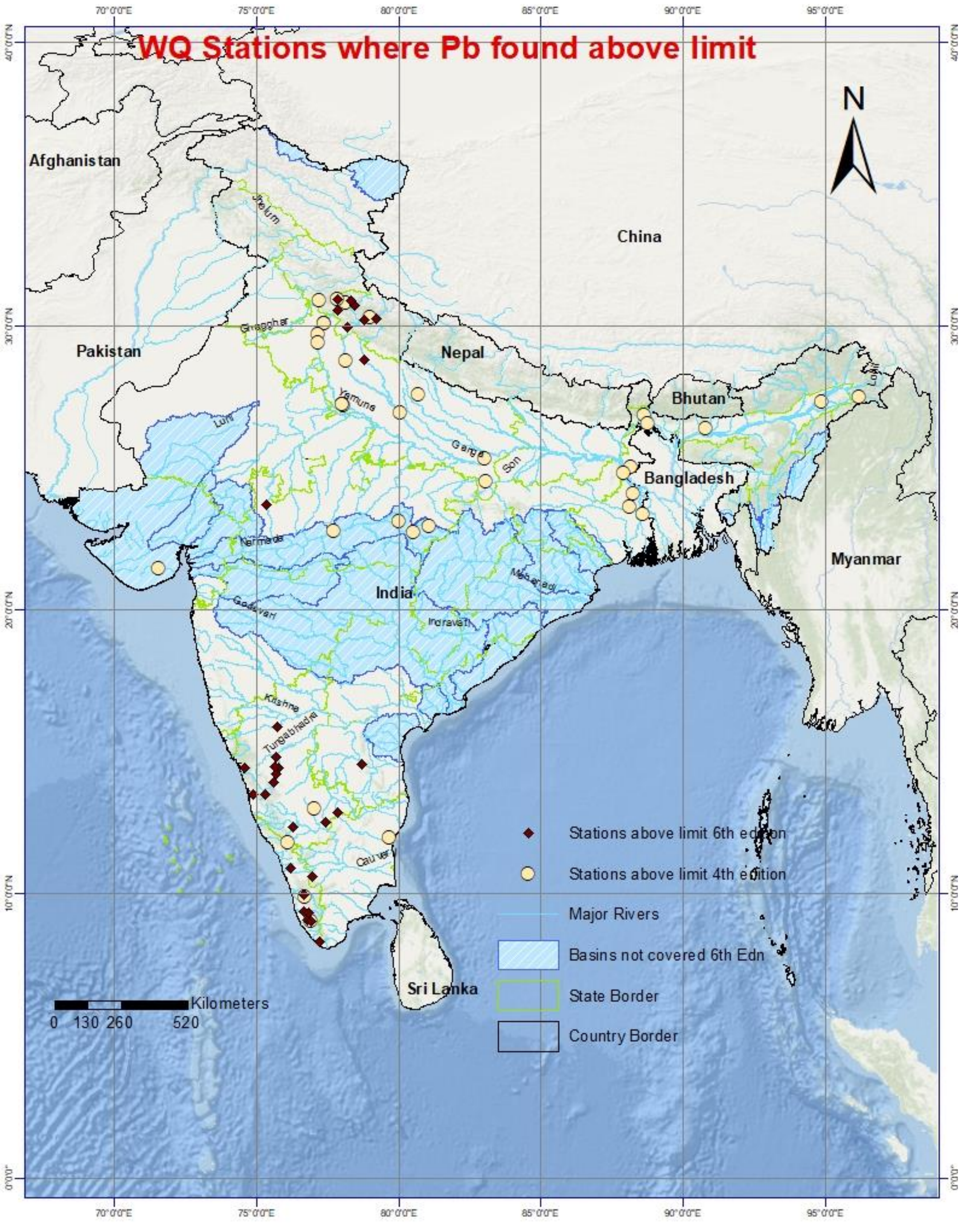


*Figure 30: WQ stations where Lead found above acceptable limit (both study periods)*

## 7.7 Mercury (Hg)

BIS (Bureau of Indian Standards) 10500:2012 has recommended an acceptable limit of 1 µg/L of mercury in drinking water. Out of total 5941 river water samples analysed, 18 samples from 18 water quality stations across 11 rivers were found to have mercury concentrations beyond the acceptable limit. The mercury concentration varies from 0.000 to 8.903 µg/L. Maximum mercury concentration (8.903 µg/L) was observed at Palla U/S Delhi water quality monitoring station on Yamuna River on 01.05.2022.

The details of stations where mercury concentrations (in µg/L) were found to be beyond acceptable limit, categorized by their respective rivers and dates is depicted in the table given below.

**Table 18: River-wise list of WQ stations with Hg values above limit**

| Sl. No. | River/tributary | Station | Date | Hg (µg/L) | State | District |
|---|---|---|---|---|---|---|
| 1 | Cauvery/Arkavathi | Kokkedoddy | 01-07-2022 | 2.181 | Karnataka | Ramanagara |
| | Cauvery/Arkavathi | T. Bekuppe | 01-07-2022 | 1.509 | Karnataka | Ramanagara |
| 2 | Cauvery/Hemavathi | M.H. Halli | 11-05-2022 | 1.518 | Karnataka | Hassan |
| 3 | Gomti | Gomti Nagar | 01-02-2022 | 1.838 | Uttar Pradesh | Lucknow |
| 4 | Pamba | Malakkara | 21-04-2022 | 2.706 | Kerala | Pathanamthitta |
| | Pamba | Madamon | 11-04-2022 | 1.968 | Kerala | Pathanamthitta |
| 5 | Pennar/Kunderu | Alladupalli | 21-07-2022 | 1.028 | Andhra Pradesh | Kadapa |
| 6 | Pinder | Karnaprayag | 11-03-2022 | 3.829 | Uttarakhand | Chamoli |
| 7 | Tungabhadra | Honnali | 01-07-2022 | 1.147 | Karnataka | Davangere |
| 8 | Tungabhadra/Tunga | Holehonnur | 01-07-2022 | 1.072 | Karnataka | Shimoga |
| 9 | Yamuna | Palla U/S Delhi | 01-05-2022 | 8.903 | Delhi | North West Delhi |
| | Yamuna | Delhi Railway Bridge | 01-03-2022 | 1.464 | Delhi | North Delhi |
| | Yamuna | Mohana (Yamuna) | 02-03-2022 | 2.942 | Haryana | Faridabad |
| | Yamuna | Gokul Barrage D/S of Mathura | 04-05-2022 | 1.736 | Uttar Pradesh | Mathura |
| | Yamuna | Agra (J.B.) | 21-04-2022 | 2.036 | Uttar Pradesh | Agra (J.B) |
| | Yamuna | Yamuna Expressway Road Bridge-Etmadpur D/S of Agra city | 22-04-2022 | 3.148 | Uttar Pradesh | Agra |
| 10 | Yamuna/Chambal/Parwati | Kota-By Pass Hanging Road Bridge U/S of Kota City | 11-08-2022 | 1.724 | Rajasthan | Kota |
| 11 | Yamuna/Sahibi | Dhansa | 11-07-2022 | 2.135 | Delhi | South West Delhi |

Figure 31 represents GIS map of WQ stations where mercury is found above acceptable limit.

### Comparison with 4th edition (period: August 2018-December, 2020)

Comparison cannot be done as the parameter Mercury was not included in the last edition due to the unavailability of instrument component (mercury lamp).

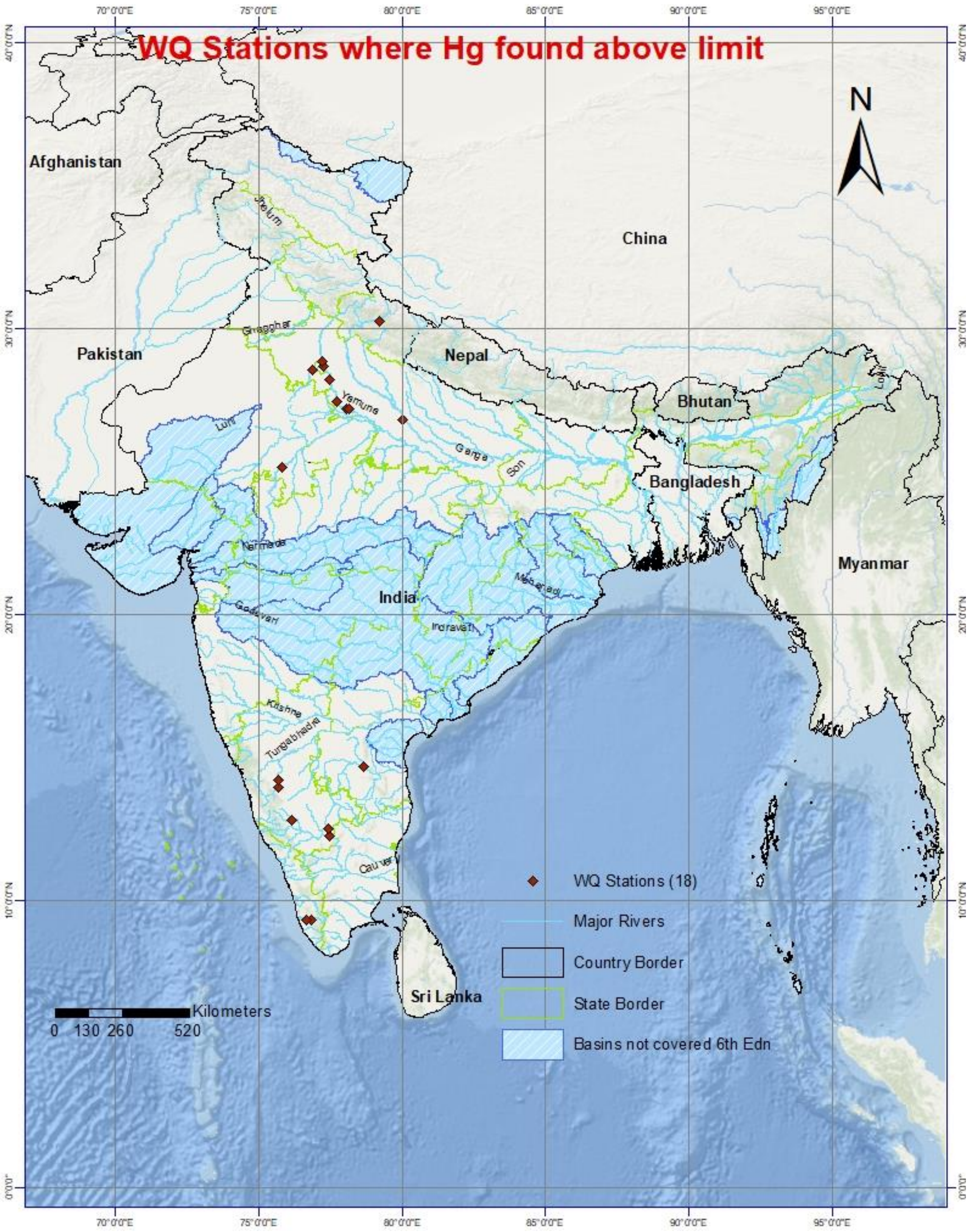


*Figure 31: WQ stations where Mercury found above acceptable limit*

## 7.8 Nickel (Ni)

BIS (Bureau of Indian Standards) 10500:2012 has recommended an acceptable limit of 20 µg/L of nickel in drinking water. Out of total 5942 river water samples analysed, 11 samples from 11 water quality stations across 9 rivers were found to have nickel concentrations beyond the acceptable limit. The nickel concentration varies from 0.000 to 69.01 µg/L. Maximum nickel concentration (69.01 µg/L) was observed at Madamon water quality monitoring station on Pamba River on 23.08.2022.

The details of stations where nickel concentrations (in µg/L) were found to be beyond acceptable limit, categorized by their respective rivers and dates is depicted in the table given below.

**Table 19: River-wise list of WQ stations with Ni values above limit**

| Sl. No. | River/tributary | Station | Date | Ni(µg/L) | State | District |
|---|---|---|---|---|---|---|
| 1 | Cauvery | Biligundulu | 01-07-2022 | 20.263 | Tamil Nadu | Krishnagiri |
| 2 | Cauvery/Chinnar | Hogenakkal | 01-11-2022 | 63.456 | Tamil Nadu | Dharmapuri |
| 3 | Cauvery/Kabini | T. Narasipur | 21-12-2022 | 33.583 | Karnataka | Mysuru |
| 4 | Cauvery/Marudaiyar | Varanavasi | 15-06-2022 | 31.256 | Tamil Nadu | Ariyalur |
| 5 | Cauvery/Yagachi | Thimmanahalli | 21-12-2022 | 21.036 | Karnataka | Hassan |
| 6 | Jhanji | Jhanji/Teok | 20-04-2022 | 30.73 | Assam | Jorhat |
| 7 | Pamba | Madamon | 23-08-2022 | 69.01 | Kerala | Pathanamthitta |
| 8 | Yamuna | Palla U/S Delhi | 13-12-2022 | 21.339 | Delhi | North West Delhi |
| | Yamuna | Delhi Railway Bridge | 01-12-2022 | 23.511 | Delhi | North Delhi |
| | Yamuna | Etawah | 05-04-2022 | 20.364 | Uttar Pradesh | Etawah |
| 9 | Yamuna/Hindon | Noida D/S of Ghaziabad | 02-03-2022 | 28.664 | Uttar Pradesh | Gautam Budh Nagar |

Six states, namely Assam, Delhi, Karnataka, Kerala, Tamil Nadu, and Uttar Pradesh are found to be affected by the issue of Nickel contamination. Figure 32 represents the GIS map of WQ stations with nickel values above limit.

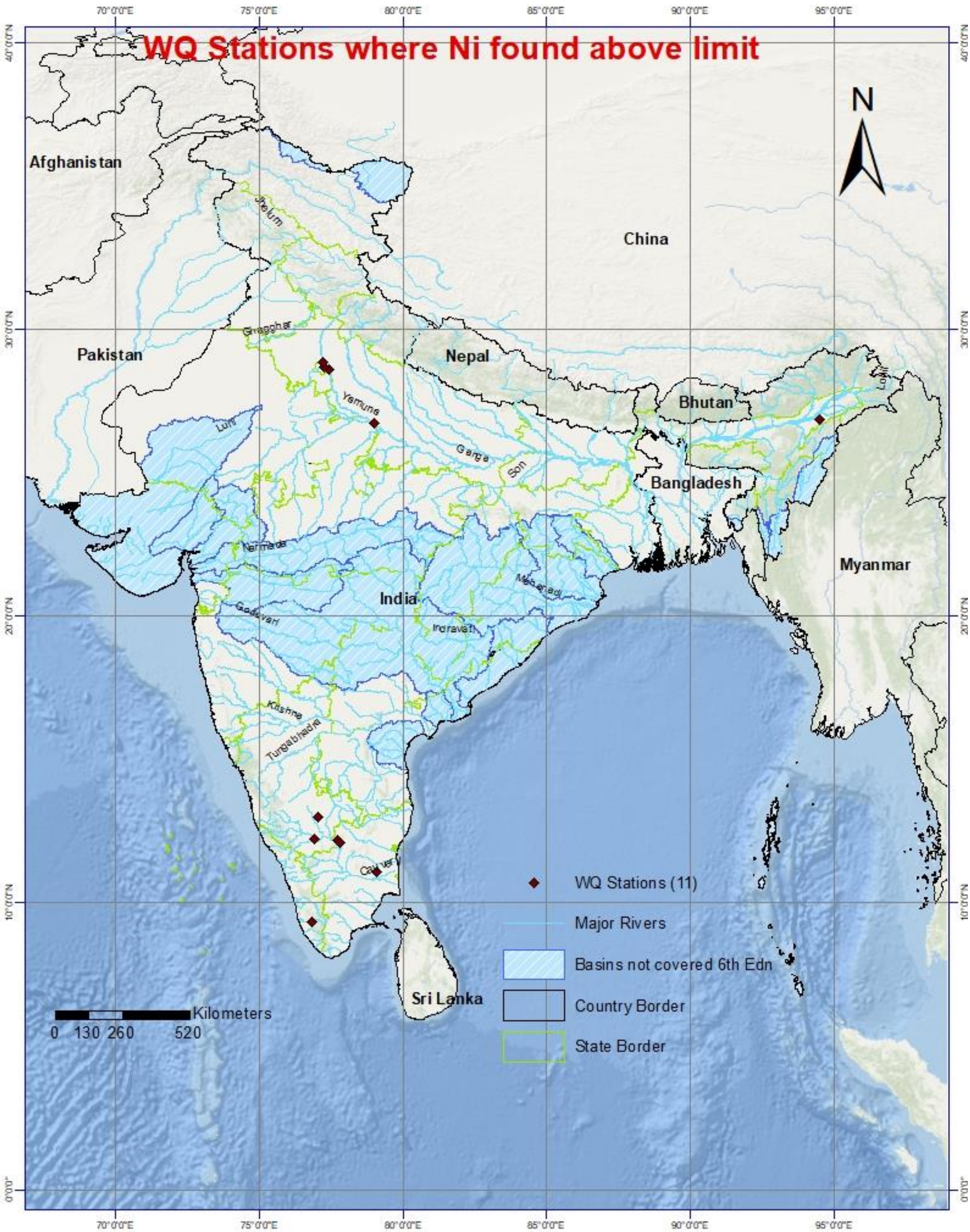


*Figure 32: WQ stations where Nickel found above acceptable limit*

**Comparison with 4th edition (period: August 2018-December, 2020)**

The comprehensive analysis of water quality during two distinct periods: from August 2018 to December 2020 and subsequently 2021-2022, has provided valuable insights into nickel concentrations in Indian rivers.

In the 4$^{th}$ edition of the report, out of 3111 water samples collected, nickel concentrations exceeded acceptable limits at 265 samples collected from 199 stations across 120 rivers. The maximum nickel concentration (242.90 µg/L) was observed at Elunuthimangalam water quality monitoring station in Noyyal River during December 2020.

In the subsequent period of 2022, out of 5942 water samples analyzed, 11 samples from 11 water quality stations across 9 rivers were found to have nickel concentrations beyond the acceptable limit. Maximum nickel concentration (69.01 µg/L) was observed at Madamon water quality monitoring station on Pamba River on 23.08.2022.

The GIS map in Figure 39 illustrates the stations which have exceeded the Ni limit in both the current and previous reports. In the common study area of both study periods, 139 stations were found to exceed acceptable limit of nickel during last study period. 11 stations among 139 are found to exceed acceptable limit during current study period , 58 stations are found to be within the limit of nickel concentration but exceed the limit of other metals analysed, 48 stations are found to be within acceptable limits of all 9 metals analysed whereas 22 stations are not analysed during the current study period. The data indicates a considerable decrease in the number of stations exceeding acceptable nickel concentrations.

Figure 33 is the GIS map of stations with nickel exceedance in both study periods.Only three stations: Biligundulu, Delhi Railway Bridge and Etawah are common to both periods: August 2018 to December 2020, as well as 2022. 4 Rivers: Cauvery, Pamba, Hindon and Yamuna are observed to have above-limit nickel concentrations during both the study periods.

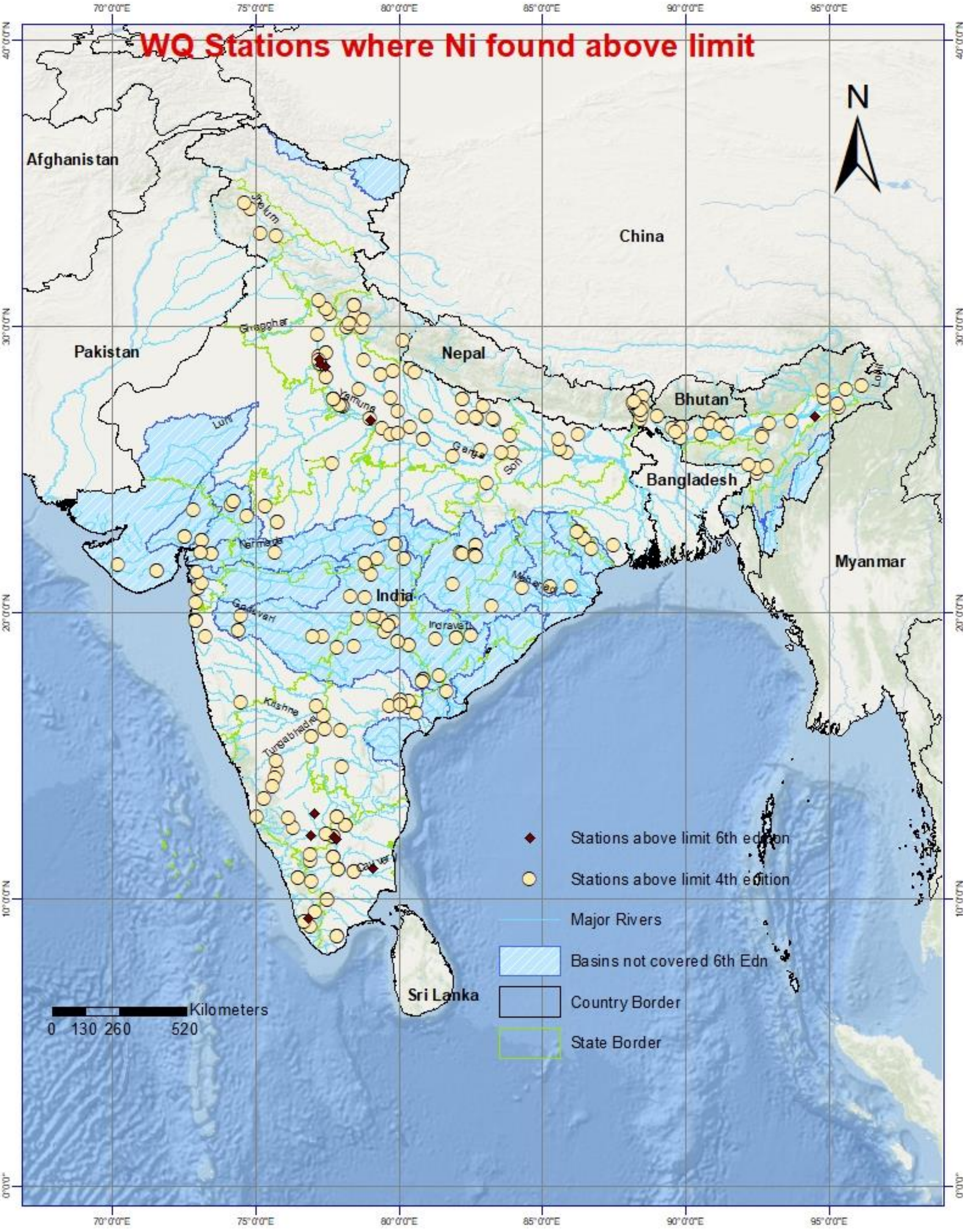


*Figure 33: WQ stations where Nickel found above acceptable limit (both study periods)*

### 7.9 Zinc (Zn)

BIS (Bureau of Indian Standards) 10500:2012 has recommended acceptable limit of 5 mg/L (5000 µg/L) of Zinc in drinking water. Out of total 5940 river water samples analysed; no sample is found to have zinc concentration beyond the acceptable limit. The zinc concentration varies from 0.000 to 950.535 µg/L. Maximum zinc concentration (950.535 µg/L) was observed at Haridwar water quality monitoring station on Ganga River on 01.05.2022.

## 8. CONCLUSION

The analysis results of 9 metals analysed in samples collected from 328 water quality monitoring stations spread over 10 river basins were considered for the study. Drinking water standard; BIS: 10500:2012 is used as a benchmark due to the absence of any river-specific water quality standards.

- The comprehensive analysis of water samples across numerous stations has revealed concerning levels of various heavy metals, each governed by specific acceptable limits prescribed by BIS (10500:2012).
- All metals are found to be within the acceptable limits at 187 monitored stations while at 141 stations, at least one metal was found to be beyond the acceptable limits prescribed by BIS (10500:2012).
- The results underscore the pervasive nature of metal exceedance, with multiple stations showing elevated concentrations of arsenic, cadmium, chromium, copper, iron, lead, mercury, and nickel.
- Arsenic, with an acceptable limit of 10 µg/L, exhibited elevated levels in 48 samples from 30 stations among the 5942 samples analysed.
- Similarly, cadmium surpassed the acceptable limit of 3 µg/L in 5 samples from 4 stations.
- Chromium, copper, and nickel also presented challenges, exceeding their respective limits in 16, 5, and 11 stations across various rivers.
- The significant concern arises with iron, where 113 samples from 74 stations surpassed the acceptable limit of 1000 µg/L (1 mg/L). Iron is observed to have highest abundance showing beyond - limit concentrations at maximum number of samples and stations.
- Lead, with a limit of 10 µg/L, demonstrated elevated levels in 37 samples from 30 stations.
- Mercury breached the acceptable limit of 1 µg/L in 18 samples from 18 stations, emphasizing the widespread presence of this toxic element.
- Madamon in Pamba River is found to be the most-affected station. However, only 3 out of 17 samples collected were found to exceed the acceptable limits. The other 14 samples are safe in terms of all metals. The metals above limit may be contributed from deposition of domestic and industrial sewage, agricultural runoff during the monsoon period and waste from quarries in the upstream of site.
- Haripur, Honnali, Kallooppara, Karnaprayag Confluence D/S, Kirtinagar U/S, Malakkara, Singasadanapalli and Uttarkashi are water quality monitoring stations where 3 metals were observed to breach the acceptable limits prescribed by BIS.

These findings emphasize the immediate need for proactive measures to address water quality issues and implement effective remediation strategies. It is imperative to prioritize the protection of water resources to ensure the well-being of ecosystems and safeguard public health from the detrimental effects of heavy metal contamination.

The overall summary of the results is given in the tables given below:

**Table 20: Overall Statistics of Analysis**

| Sl. No | Parameters | No. of Stations where metal found above acceptable limit |
|---|---|---|
| 1 | Arsenic only | 17 |
| 2 | Cadmium only | 1 |
| 3 | Chromium only | 8 |
| 4 | Copper only | 3 |
| 5 | Iron only | 49 |
| 6 | Lead only | 13 |
| 7 | Mercury only | 7 |
| 8 | Nickel only | 6 |
| 9 | Zinc only | 0 |
| 10 | Two or More metals | 37 |
| **Total WQ stations where one or more metals found above acceptable limits** | | 141 |
| **Total WQ Stations where all toxic metals found within acceptable limits** | | 187 |
| **Total WQ Stations under study** | | 328 |

**Table 21: Overall Status of 141 stations where one or more metals found above acceptable limits**

| | |
|---|---|
| No. of stations where 4 metals found to be above limit | 1 |
| No. of stations where 3 metals found to be above limit | 8 |
| No. of stations where 2 metals found to be above limit | 28 |
| No. of stations where only 1 metal found to be above limit | 104 |

- Tables above show that there is one station where four metals were found to exceed the limit, eight stations where three metals were above the limit, and twenty-eight stations where two metals exceeded the limit.
- It is evident from the tables that, out of 141 stations where one or more metals are found above acceptable limits, 104 stations have only 1 metal which exceeds the limit. Among these 104 stations, 49 stations have only Iron exceeding the limit. This means that, only Iron metal is found to breach the limit at 47.12 % of the 141 stations affected.
- However, it is important to note that there are 187 WQ stations where all the toxic metals are found within acceptable limits.

**Table 22: Basin-wise Summary of Analysis**

| Sl. No. | Basin | No. of WQ stations studied | WQ stations where one or more metals found above acceptable limits |
|---|---|---|---|
| 1 | Brahmaputra | 30 | 5 |
| 2 | Cauvery | 41 | 19 |
| 3 & 4 | East Flowing Rivers between Pennar and Cauvery Basin and East Flowing Rivers South of Cauvery Basin | 17 | 6 |
| 5 | Ganga | 161 | 75 |
| 6 | Indus | 10 | 0 |
| 7 | Krishna | 12 | 10 |
| 8 | Meghna/Barak | 13 | 1 |
| 9 | Pennar | 8 | 2 |
| 10 | West Flowing Rivers South of Tapi Basin | 36 | 23 |

Table 22 above shows the total number of water quality (WQ) stations monitored and the number of stations where one or more metals were found above acceptable limits across different basins. The Ganga basin has the highest number of WQ stations monitored, with 161 stations, out of which 75 stations are reported metal exceedance. The West Flowing Rivers South of Tapi Basin comes at second place with 23 out of 36 stations reporting metal exceedance.

The high level of metal exceedance observed in several WQ stations across different basins may be attributed to both industrial and geogenic reasons. Industrial activities such as mining, manufacturing, and waste disposal can release large amounts of toxic metals into the rivers. Geogenic factors such as natural weathering and erosion of rocks and soils can also contribute to metal contamination in rivers.

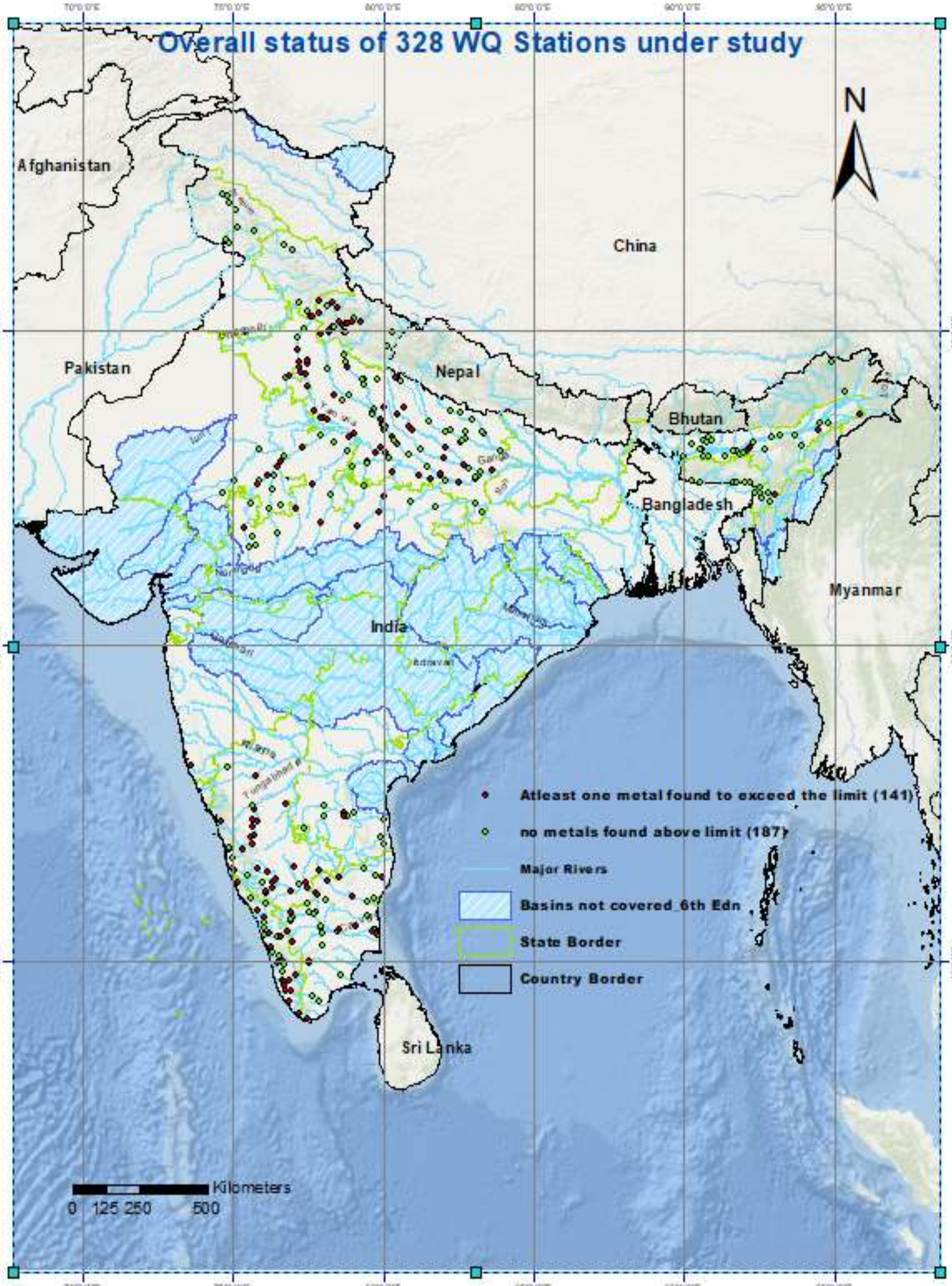


*Figure 34: Overall status of 328 stations under study*

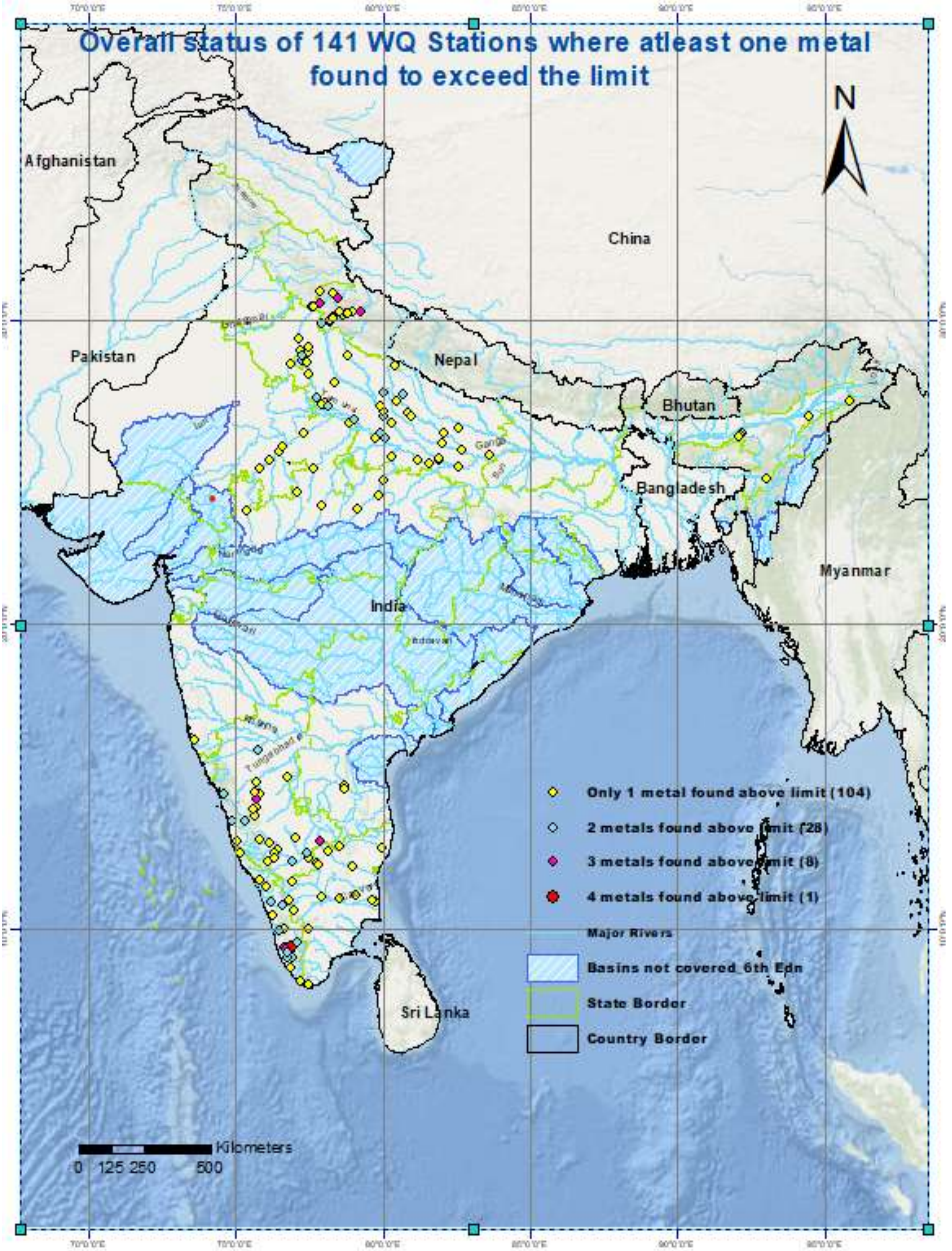


*Figure 35: Overall status of 141 stations where at least one metal is found above the limit*

## Comparison with 4th edition

### Table 23: Comparison of Metal-wise Analysis Result

| Analysis result (2021) | | | | | | | Analysis result (Aug 2018-Dec 2020) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sl. No. | Heavy metal | Acceptable limit as per BIS:10500, 2012 (in µg/L) | No. of samples analysed | No. of samples where metal found within acceptable limit | No. of samples where metal found above acceptable limit | % of samples where metal found above acceptable limit | No. of samples analysed | No. of samples where metal found within acceptable limit | No. of samples where metal found above acceptable limit | % of samples where metal found above acceptable limit |
| 1 | Arsenic (As) | 10 | 5942 | 5894 | 48 | 0.81 | 2834 | 2826 | 8 | **0.28** |
| 2 | Cadmium (Cd) | 3 | 5942 | 5937 | 5 | 0.08 | 3113 | 3102 | 11 | **0.35** |
| 3 | Chromium (Cr) | 50 | 5939 | 5922 | 17 | 0.29 | 3106 | 3056 | 50 | **1.61** |
| 4 | Copper (Cu) | 50 | 5941 | 5936 | 5 | 0.08 | 3107 | 3090 | 17 | **0.55** |
| 5 | Lead (Pb) | 10 | 5942 | 5905 | 37 | 0.62 | 3111 | 3075 | 36 | **1.16** |
| 6 | Nickel (Ni) | 20 | 5942 | 5931 | 11 | 0.19 | 3099 | 2834 | 265 | **8.55** |
| 7 | Iron (Fe) | 1000 | 5980 | 5867 | 113 | 1.89 | 3113 | 2357 | 214 | **6.87** |
| 8 | Zinc (Zn) | 5000 | 5940 | 5940 | 0 | 0.00 | 3113 | 3113 | 0 | **0.00** |
| 9 | Mercury (Hg) | 1 | 5941 | 5923 | 18 | 0.30 | - | - | - | - |

### Table 24: Overall Comparison of 2 reports

| WQ stations | 2022 | Aug 2018-Dec 2020 | WQ samples | 2022 | Aug 2018-Dec 2020 |
|---|---|---|---|---|---|
| No. of stations where no metal found above acceptable limit | 187 | 180 | No. of samples where no metal found above acceptable limit | 5748 | 2058 |
| No. of stations where at least one metal found above acceptable limit | 141 | 508 | No. of samples where at least one metal found above acceptable limit | 232 | 1055 |
| **Total stations under study** | **328** | **688** | **Total stations under study** | **5980** | **3113** |

# 9. MEASURES & WAY FORWARD

Metal contamination is a serious problem that needs immediate attention to protect our environment. Below are some measures and ways to move forward with tackling metal contamination:

1. **Continued Surveillance & Analysis:** Conduct regular water quality testing to identify the specific trace and toxic metals present in the river water. This information will help to design an appropriate mitigation strategy.
2. **Identify pollution sources:** At the first stage, it is important to identify the sources of metal pollution to prevent further contamination of rivers.
3. **Control measures for the release of pollutants to rivers:** various control measures can be implemented to mitigate the release of pollutants into rivers, promoting sustainable water quality. These measures encompass a range of strategies:
   - The effluent treatment system can be improved by enhancing both the treatment processes and the overall management of wastewater discharge. This may involve upgrading existing treatment facilities, adopting advanced technologies, and implementing stringent monitoring protocols. Additionally, exploring new metal technologies for water treatment and incorporating innovative approaches to enhance the efficiency and effectiveness of water treatment processes is necessary. It involves staying abreast of advancements in technology to continually improve the treatment of water contaminated with metals.
   - Agricultural field practices related to irrigation can be enhanced to minimize the introduction of metal contaminants into rivers. This may include adopting precision irrigation techniques, optimizing fertilizer usage, and promoting sustainable farming practices.
   - Recycling and reuse of wastewater after proper treatment can be implemented to reduce the overall demand for freshwater resources and prevent the discharge of untreated or inadequately treated wastewater into rivers.
   - Research studies on metal pollution in sediment can be conducted to gain a deeper understanding of the dynamics and sources of metal accumulation.
   - Heavy metals can be removed through various methods such as chemical-based filtration, electrochemical treatments, membrane-based processes, biosorbents, etc. These techniques aim to selectively extract or neutralize metal pollutants from water, ensuring cleaner discharge.
   - Controlling the release of metals from soils through excavation, in-situ fixing or/and phytoremediation practices can be implemented. These methods target contaminated soil, preventing the further leaching of metals into rivers.

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# 11. ANNEXURE I

**List of 328 Water Quality Monitoring Stations**

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 1 | A.B.Road Crossing | Cu | Madhya Pradesh | Guna | Ganga | Yamuna/Chambal/Parwati | 24.37 | 77.10 |
| 2 | A.P.Puram | no metals found above limit | Tamil Nadu | Tirunelveli | East Flowing Rivers between Pennar and Kanyakumari | Tambraparani/Chittar | 8.90 | 77.65 |
| 3 | Addoor | no metals found above limit | Karnataka | Dakshina Kannada | West Flowing Rivers from Tadri to Kanyakumari | Gurupur | 12.93 | 74.95 |
| 4 | Agra (J.B.) | As, Hg | Uttar Pradesh | Agra (J.B) | Ganga | Yamuna | 27.20 | 78.04 |
| 5 | Agra (P.G.) | As | Uttar Pradesh | Agra(P.G) | Ganga | Yamuna | 27.25 | 78.02 |
| 6 | Aie NH Crossing | no metals found above limit | Assam | Barpeta | Brahmaputra | Aie | 26.50 | 90.65 |
| 7 | Akabarpur | As | Uttar Pradesh | Ambedkar Nagar | Ganga | Ganga/Chhoti Sarju | 26.43 | 82.56 |
| 8 | Akhnoor | no metals found above limit | Jammu & Kashmir | Jammu | Indus | Chenab | 32.90 | 74.76 |
| 9 | Akkihebbal | Fe | Karnataka | Mandya | Cauvery | Cauvery/Hemavathi | 12.60 | 76.40 |
| 10 | Aklera | no metals found above limit | Rajasthan | Jhalawar | Ganga | Yamuna/Chambal/Kalisindh/Parwan | 24.43 | 76.60 |
| 11 | Alandurai | Fe | Tamil Nadu | Coimbatore | Cauvery | Cauvery/Noyyal | 10.95 | 76.79 |
| 12 | Alladupalli | Hg | Andhra Pradesh | Kadapa | Pennar | Pennar/Kunderu | 14.72 | 78.67 |
| 13 | Ambarampalayam | Pb | Tamil Nadu | Coimbatore | West Flowing Rivers from Tadri to Kanyakumari | Bharathapuzha/Kannadipuzha/Aliyar | 10.63 | 76.95 |
| 14 | Ambasamudram | no metals found above limit | Tamil Nadu | Theni | East Flowing Rivers between Pennar and Kanyakumari | Vaigai | 9.93 | 77.51 |
| 15 | Ankinghat | no metals found above limit | Uttar Pradesh | Kanpur Nagar | Ganga | Ganga | 26.93 | 80.04 |
| 16 | Anna Purna Ghat | no metals found above limit | Assam | Cachar | Meghna/Barak | Barak | 24.83 | 92.79 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 17 | Annavasal | no metals found above limit | Pondicherry | Karaikal | Cauvery | Cauvery/Nattar | 10.97 | 79.76 |
| 18 | Arangaly | no metals found above limit | Kerala | Thrissur | West Flowing Rivers from Tadri to Kanyakumari | Periyar/Chalakudy | 10.28 | 76.32 |
| 19 | Arcot | no metals found above limit | Tamil Nadu | Ranipet | East Flowing Rivers between Pennar and Kanyakumari | Palar | 12.91 | 79.33 |
| 20 | Arnota | Fe | Uttar Pradesh | Agra | Ganga | Yamuna/Uttangan | 27.96 | 78.36 |
| 21 | Ashramam | Fe | Tamil Nadu | Kanyakumari | West Flowing Rivers from Tadri to Kanyakumari | Pazhayar | 8.16 | 77.46 |
| 22 | Augustmuni D/S | no metals found above limit | Uttarakhand | Rudraprayag | Ganga | Mandakini | 30.39 | 79.02 |
| 23 | Augustmuni U/S | no metals found above limit | Uttarakhand | Rudraprayag | Ganga | Mandakini | 30.40 | 79.04 |
| 24 | Auraiya | no metals found above limit | Uttar Pradesh | Auraiya | Ganga | Yamuna | 26.43 | 78.36 |
| 25 | Avarankuppam | Cu | Tamil Nadu | Vellore | East Flowing Rivers between Pennar and Kanyakumari | Palar | 12.68 | 78.54 |
| 26 | Avershe | Cd,Pb | Karnataka | Udupi | West Flowing Rivers from Tadri to Kanyakumari | Seetha | 13.52 | 74.88 |
| 27 | Ayilam | Cr | Kerala | Thiruvanthapuram | West Flowing Rivers from Tadri to Kanyakumari | Vamanapuram | 8.72 | 76.85 |
| 28 | Ayodhya | no metals found above limit | Uttar Pradesh | Ayodhya | Ganga | Ghaghra | 26.81 | 82.21 |
| 29 | Badar Pur Ghat | no metals found above limit | Assam | Karimganj | Meghna/Barak | Barak | 24.87 | 92.52 |
| 30 | Baghpat | Cr | Uttar Pradesh | Baghpat | Ganga | Yamuna | 28.99 | 77.20 |
| 31 | Baleni U/S of Ghaziabad | Fe | Uttar Pradesh | Baghpath | Ganga | Yamuna/Hindon | 28.96 | 77.47 |
| 32 | Balrampur | no metals found above limit | Uttar Pradesh | Balrampur | Ganga | Ghaghra/Rapti | 27.45 | 82.21 |
| 33 | Baluaghat | no metals found above limit | Uttar Pradesh | Varanasi | Ganga | Ganga | 25.42 | 83.18 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 34 | Banda | Fe | Uttar Pradesh | Banda | Ganga | Yamuna/Ken | 25.48 | 80.31 |
| 35 | Bangapani(Munsyari) | no metals found above limit | Uttarakhand | Pithoragarh | Ganga | Mahalai/Gauri Ganga | 29.96 | 80.30 |
| 36 | Banglabasti | no metals found above limit | Assam | Nagaon | Brahmaputra | Harianadi | 26.20 | 92.67 |
| 37 | Bansi | no metals found above limit | Uttar Pradesh | Siddarthnagar | Ganga | Ghaghra/Rapti | 27.18 | 82.93 |
| 38 | Bantwal | Fe | Karnataka | Dakshina Kannada | West Flowing Rivers from Tadri to Kanyakumari | Nethravathi | 12.88 | 75.04 |
| 39 | Baranwada | no metals found above limit | Rajasthan | Sawai-madhopur | Ganga | Yamuna/Chambal/Banas | 26.00 | 76.67 |
| 40 | Bareilly | no metals found above limit | Uttar Pradesh | Bareilly | Ganga | Ramganga | 28.30 | 79.37 |
| 41 | Barod | no metals found above limit | Rajasthan | Kota | Ganga | Yamuna/Chambal/Kalisindh | 25.38 | 76.33 |
| 42 | Basantpur(Ganga) | no metals found above limit | Uttar Pradesh | Bijnaur | Ganga | Ganga | 28.43 | 79.35 |
| 43 | Basoda | Fe | Madhya Pradesh | Vidisha | Ganga | Yamuna/Betwa | 23.88 | 77.92 |
| 44 | Basti | no metals found above limit | Uttar Pradesh | Basti | Ganga | Ghaghra/Kwano | 26.78 | 82.71 |
| 45 | Basti D/S | no metals found above limit | Uttar Pradesh | Basti | Ganga | Ghaghra/Kwano | 26.77 | 82.73 |
| 46 | Basti U/S | no metals found above limit | Uttar Pradesh | Basti | Ganga | Ghaghra/Kwano | 26.80 | 82.71 |
| 47 | Beki Road Bridge | no metals found above limit | Assam | Barpeta | Brahmaputra | Beki | 26.49 | 90.92 |
| 48 | Belne Bridge | Cr | Maharashtra | Sindudurg | West Flowing Rivers from Tapi to Tadri | Gad | 16.22 | 73.61 |
| 49 | Bendrahalli | no metals found above limit | Karnataka | Chamarajanagar | Cauvery | Cauvery/Suvarnavathi | 12.15 | 76.08 |
| 50 | Bhadana Village D/S of Kota city | no metals found above limit | Rajasthan | Kota | Ganga | Yamuna/Chambal/Parwati | 25.24 | 75.88 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 51 | Bhind | As | Madhya Pradesh | Bhind | Ganga | Yamuna/Sindh/Kunwari | 26.62 | 78.84 |
| 52 | Bhitaura | no metals found above limit | Uttar Pradesh | Fatehpur | Ganga | Ganga | 26.04 | 80.85 |
| 53 | Bhitoor | As | Uttar Pradesh | Kanpur | Ganga | Ganga | 26.62 | 80.28 |
| 54 | Bigod | no metals found above limit | Rajasthan | Bhilwara | Ganga | Yamuna/Chambal/Banas | 25.25 | 75.04 |
| 55 | Biligundulu | Ni | Tamil Nadu | Krishnagiri | Cauvery | Cauvery | 12.18 | 77.72 |
| 56 | Birdghat | no metals found above limit | Uttar Pradesh | Gorakhpur | Ganga | Ghaghra/Rapti | 26.74 | 83.34 |
| 57 | Biswanath Ghat | no metals found above limit | Assam | Biswanath | Brahmaputra | Brahmaputra | 26.66 | 93.17 |
| 58 | Byaladahalli | Pb | Karnataka | Davanagere | Krishna | Tungabhadra/Haridra | 14.43 | 75.78 |
| 59 | Byrnihat | no metals found above limit | Meghalaya | Ri-Bhoi | Brahmaputra | Brahmaputra/Umtru | 26.04 | 91.87 |
| 60 | Chandrika Devi | As | Uttar Pradesh | Lucknow | Ganga | Gomti | 26.93 | 80.86 |
| 61 | Chengalpet | Fe | Tamil Nadu | Chengalpet | East Flowing Rivers between Pennar and Kanyakumari | Palar | 12.65 | 79.95 |
| 62 | Chennur | no metals found above limit | Andhra Pradesh | Kadapa | Pennar | Pennar | 14.57 | 78.80 |
| 63 | Chhatnag Allahabad | As | Uttar Pradesh | Prayagraj | Ganga | Ganga | 25.39 | 81.92 |
| 64 | Chittorgarh | no metals found above limit | Rajasthan | Chittorgarh | Ganga | Yamuna/Chambal/Banas/Gambhiri | 24.87 | 74.64 |
| 65 | Cholachugudda | Pb,Fe | Karnataka | Bagalkot | Krishna | Krishna/Malaprabha | 15.87 | 75.72 |
| 66 | Chopan | no metals found above limit | Uttar Pradesh | Sonbhadra | Ganga | Ganga/Sone | 24.53 | 83.05 |
| 67 | Chotogorjan/KaliajarI | Fe | Assam | Morigaon | Brahmaputra | Udori | 26.28 | 92.19 |
| 68 | Chunchankatte | Fe | Karnataka | Mysuru | Cauvery | Cauvery | 12.51 | 76.30 |
| 69 | Dabri | no metals found above limit | Uttar Pradesh | Shahjahanpur | Ganga | Ramganga | 27.50 | 79.70 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 70 | Dadahu(Renuka) | no metals found above limit | Himachal Pradesh | Sirmaur | Ganga | Yamuna/Giri | 30.60 | 77.44 |
| 71 | Dadri | no metals found above limit | Haryana | Jhajjar | Ganga | Yamuna/Sahibi | 28.52 | 76.76 |
| 72 | Dawki | no metals found above limit | Meghalaya | Jaintia Hills | Meghna/Barak | Meghna/Umngot | 25.19 | 92.02 |
| 73 | Delhi Railway Bridge | Hg,Ni | Delhi | North Delhi | Ganga | Yamuna | 28.66 | 77.25 |
| 74 | Deoprayag(G) | Fe | Uttarakhand | Pauri Garhwal | Ganga | Ganga | 30.14 | 78.60 |
| 75 | Dhamkund | no metals found above limit | Jammu & Kashmir | Ramban | Indus | Chenab | 33.24 | 75.15 |
| 76 | Dhaneta | no metals found above limit | Uttar Pradesh | Bareilly | Ganga | Ramganga / Bahgul | 28.42 | 79.81 |
| 77 | Dhansa | Hg | Delhi | South West Delhi | Ganga | Yamuna/Sahibi | 28.54 | 76.87 |
| 78 | Dhareri | no metals found above limit | Madhya Pradesh | Ujjain | Ganga | Yamuna/Chambal | 23.13 | 75.51 |
| 79 | Dherabhabari/ Simultala | Fe | Assam | Morigaon | Brahmaputra | pokoriya | 26.25 | 92.13 |
| 80 | Dholai | no metals found above limit | Assam | Cachar | Meghna/Barak | Barak/Rukni | 24.59 | 92.84 |
| 81 | Dholpur | no metals found above limit | Rajasthan | Dholpur | Ganga | Yamuna/Chambal | 26.66 | 77.90 |
| 82 | Dhubri | no metals found above limit | Assam | Barpeta | Brahmaputra | Brahmaputra | 26.01 | 89.99 |
| 83 | Dimapara | no metals found above limit | Meghalaya | South Garo Hills | Meghna/Barak | Meghna/Bugi | 25.23 | 90.25 |
| 84 | Diprang Gaon | Fe | Assam | Morigaon | Brahmaputra | Brahmaputra/Kopili | 26.18 | 92.10 |
| 85 | Duddhi | no metals found above limit | Uttar Pradesh | Sonbhadra | Ganga | Ganga/Sone/Kanhar | 24.23 | 83.27 |
| 86 | Dudhnoi | no metals found above limit | Assam | Goalpara | Brahmaputra | Dhudnoi | 25.98 | 90.79 |
| 87 | Elginbridge | no metals found above limit | Uttar Pradesh | Barabanki | Ganga | Ghaghra | 27.10 | 81.48 |
| 88 | Elunuthimangalam | Fe | Tamil Nadu | Erode | Cauvery | Cauvery/Noyyal | 11.03 | 77.89 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 89 | Erinjipuzha | Fe | Kerala | Kasargod | West Flowing Rivers from Tadri to Kanyakumari | Payaswani | 12.48 | 75.15 |
| 90 | Etawah | As,Ni | Uttar Pradesh | Etawah | Ganga | Yamuna | 26.75 | 78.99 |
| 91 | Faizabad U/S | no metals found above limit | Uttar Pradesh | Faizabad | Ganga | Ghaghra | 26.78 | 82.08 |
| 92 | Fakirabazar | no metals found above limit | Assam | Karimganj | Meghna/Barak | Kushiyara/Longai | 24.85 | 92.35 |
| 93 | Fatehgarh | no metals found above limit | Uttar Pradesh | Farukhabad | Ganga | Ganga | 27.40 | 79.63 |
| 94 | Fulertal | Fe | Assam | Cachar | Meghna/Barak | Barak | 24.79 | 93.02 |
| 95 | Gaisabad | Fe | Madhya Pradesh | Damoh | Ganga | Yamuna/Ken/Bearma | 24.24 | 79.84 |
| 96 | Galeta | Fe | Uttar Pradesh | Meerut | Ganga | Yamuna/Hindon | 29.08 | 77.44 |
| 97 | Gandhavayal | no metals found above limit | Tamil Nadu | Coimbatore | Cauvery | Cauvery/Gandhayar | 11.37 | 76.99 |
| 98 | Ganguwala | Fe | Himachal Pradesh | Sirmaur | Ganga | Yamuna/Bata | 30.44 | 77.58 |
| 99 | Garampani/Tenganighat | no metals found above limit | Assam | Golaghat | Brahmaputra | Brahmaputra/Dhansiri(South) | 26.33 | 93.89 |
| 100 | Garhakota | Fe | Madhya Pradesh | Sagar | Ganga | Yamuna/Ken/Sonar | 23.78 | 79.14 |
| 101 | Garhmukteshwar | no metals found above limit | Uttar Pradesh | Ghaziabad | Ganga | Ganga | 28.77 | 78.14 |
| 102 | Garrauli | no metals found above limit | Madhya Pradesh | Chhatarpur | Ganga | Yamuna/Betwa/Dhasan | 25.08 | 79.34 |
| 103 | Ghat | no metals found above limit | Uttarakhand | Pithoragarh | Ganga | Ghaghra/Sharda/Sarju | 29.50 | 80.13 |
| 104 | Ghazipur | As | Uttar Pradesh | Ghazipur | Ganga | Ganga | 25.59 | 83.61 |
| 105 | Goalpara | no metals found above limit | Assam | Goalpara | Brahmaputra | Brahmaputra | 26.20 | 90.58 |
| 106 | Gokak Falls | no metals found above limit | Karnataka | Belgaum | Krishna | Krishna/Ghatprabha | 16.17 | 74.80 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 107 | Gokul Barrage D/S of Mathura | As,Hg | Uttar Pradesh | Mathura | Ganga | Yamuna | 27.44 | 77.71 |
| 108 | Gomti Nagar | Cd,Hg | Uttar Pradesh | Lucknow | Ganga | Gomti | 26.82 | 80.01 |
| 109 | Gopurajapuram | no metals found above limit | Tamil Nadu | Nagapattinam | Cauvery | Cauvery/ Puravidaiyanar | 10.85 | 79.80 |
| 110 | Gorakhpur D/S | no metals found above limit | Uttar Pradesh | Gorakhpur | Ganga | Ghaghra/Rapti | 26.71 | 83.35 |
| 111 | Gorakhpur U/S | no metals found above limit | Uttar Pradesh | Gorakhpur | Ganga | Ghaghra/Rapti | 26.75 | 83.32 |
| 112 | Gummanur | Cu | Tamil Nadu | Krishnagiri | East Flowing Rivers between Pennar and Kanyakumari | Ponnaiyar | 12.56 | 78.14 |
| 113 | Gumrabazar | no metals found above limit | Assam | Cachar | Meghna/Barak | Meghna/Surma/ Gumra | 25.01 | 92.51 |
| 114 | Guwahati D.C Court | no metals found above limit | Assam | Kamrup | Brahmaputra | Brahmaputra | 26.19 | 91.75 |
| 115 | Halady | no metals found above limit | Karnataka | Udupi | West Flowing Rivers from Tadri to Kanyakumari | Halady | 13.58 | 74.86 |
| 116 | Hamirpur | no metals found above limit | Uttar Pradesh | Hamirpur | Ganga | Yamuna | 25.96 | 80.15 |
| 117 | Haralahalli | Pb | Karnataka | Haveri | Krishna | Tungabhadra | 14.83 | 75.67 |
| 118 | Haridwar | Cu,Pb | Uttarakhand | Haridwar | Ganga | Ganga | 29.98 | 78.19 |
| 119 | Haridwar D/S | Fe | Uttarakhand | Haridwar | Ganga | Ganga | 29.96 | 78.17 |
| 120 | Haridwar U/S | Fe | Uttarakhand | Haridwar | Ganga | Ganga | 29.97 | 78.18 |
| 121 | Hariharapura | Pb,Fe | Karnataka | Chikmagalur | Krishna | Tungabhadra/Tunga | 13.52 | 75.30 |
| 122 | Haripur | Cu,Pb,Fe | Uttarakhand | Dehradun | Ganga | Yamuna/Tons | 30.54 | 77.83 |
| 123 | Hathikhana | no metals found above limit | Uttar Pradesh | Fatehgarh | Ganga | Ganga | 27.35 | 79.64 |
| 124 | Hogenakkal | Ni | Tamil Nadu | Dharmapuri | Cauvery | Cauvery/Chinnar | 12.12 | 77.79 |
| 125 | Holehonnur | Hg | Karnataka | Shimoga | Krishna | Tungabhadra/Tunga | 13.98 | 75.69 |
| 126 | Honnali | Cr, Hg, Pb | Karnataka | Davangere | Krishna | Tungabhadra | 14.24 | 75.66 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 127 | Hoovinahole | Fe | Karnataka | Chitradurga | Krishna | Krishna/Swarnamukhi | 14.98 | 76.75 |
| 128 | Jajmau | no metals found above limit | Uttar Pradesh | Kanpur | Ganga | Ganga | 26.41 | 80.44 |
| 129 | Jammu(Sidhra) | no metals found above limit | Jammu & Kashmir | Jammu | Indus | Chenab/Tawi | 32.76 | 74.88 |
| 130 | Jaunpur | As | Uttar Pradesh | Jaunpur | Ganga | Gomti | 25.74 | 82.69 |
| 131 | Jhalawar(seasonal) | no metals found above limit | Rajasthan | Jhalawar | Ganga | Yamuna/Chambal | 24.37 | 76.21 |
| 132 | Jhanji/Teok | Ni | Assam | Jorhat | Brahmaputra | Jhanji | 26.85 | 94.49 |
| 133 | Jhansi- Mirjapur Highway Road Bridge D/S of Sahijna | no metals found above limit | Uttar Pradesh | Hamirpur | Ganga | Betwa | 25.94 | 80.16 |
| 134 | K.M.Vadi | Pb | Karnataka | Mysuru | Cauvery | Cauvery/Lakshmanthirtha | 12.35 | 76.29 |
| 135 | Kabirganj | As | Uttar Pradesh | Pilibhit | Ganga | Ghaghra/Rapti | 28.50 | 80.38 |
| 136 | Kachlabridge | no metals found above limit | Uttar Pradesh | Badaun | Ganga | Ganga | 27.93 | 78.86 |
| 137 | Kailash Mandir Benpur U/S of Agra | As | Uttar Pradesh | Agra | Ganga | Yamuna | 27.24 | 77.93 |
| 138 | Kalampur | Pb | Kerala | Ernakulam | West Flowing Rivers from Tadri to Kanyakumari | Muvattupuzha/ Kaliyar | 9.99 | 76.63 |
| 139 | Kalanaur | no metals found above limit | Uttar Pradesh | Saharanpur | Ganga | Yamuna | 30.07 | 77.35 |
| 140 | Kallooppara | Cr, Fe,Pb | Kerala | pathanamthitta | West Flowing Rivers from Tadri to Kanyakumari | Pamba/Manimala | 9.40 | 76.65 |
| 141 | Kalpi | Fe | Uttar Pradesh | Jalaun | Ganga | Yamuna | 26.13 | 79.76 |
| 142 | Kamalapuram | Pb | Andhra Pra-desh | Kadapa | Pennar | Pennar/Papagani | 14.58 | 78.68 |
| 143 | Kannauj | As | Uttar Pradesh | Kannauj | Ganga | Ganga | 27.01 | 79.98 |
| 144 | Kanpur | no metals found above limit | Uttar Pradesh | Kanpur Nagar | Ganga | Ganga | 26.47 | 80.38 |
| 145 | Karathodu | no metals found above limit | Kerala | Malappuram | West Flowing Rivers from Tadri to Kanyakumari | Kadalundi | 11.06 | 76.04 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 146 | Karnal | no metals found above limit | Haryana | Karnal | Ganga | Yamuna | 29.76 | 77.13 |
| 147 | Karnaprayag | Fe,Hg | Uttarakhand | Chamoli | Ganga | Pinder | 30.26 | 79.22 |
| 148 | Karnaprayag Confluence D/S | As,Pb,Fe | Uttarakhand | Chamoli | Ganga | Ganga/Alakananda | 30.26 | 79.21 |
| 149 | Kasganj | no metals found above limit | Uttar Pradesh | Etah | Ganga | Kali | 27.79 | 78.63 |
| 150 | Katri Umrauli | As | Uttar Pradesh | Kannauj | Ganga | Ganga | 27.15 | 79.88 |
| 151 | Kazipura | no metals found above limit | Uttar Pradesh | Moradabad | Ganga | Ramganga | 28.99 | 78.74 |
| 152 | Kharkhana | no metals found above limit | Meghalaya | West Jaintia Hills | Meghna/Barak | Meghna/Myntdu | 25.16 | 92.21 |
| 153 | Khatoli | Fe | Rajasthan | Kota | Ganga | Yamuna/Chambal/Parwati | 25.68 | 76.48 |
| 154 | Kidangoor | no metals found above limit | Kerala | Kottayam | West Flowing Rivers from Tadri to Kanyakumari | Meenachil | 9.68 | 76.61 |
| 155 | Kirtinagar D/S | Fe | Uttarakhand | Tehri | Ganga | Ganga/Alakananda | 30.23 | 78.73 |
| 156 | Kirtinagar U/S | As,Pb,Fe | Uttarakhand | Tehri | Ganga | Ganga/Alakananda | 30.23 | 78.77 |
| 157 | Kodumudi | no metals found above limit | Tamil Nadu | Erode | Cauvery | Cauvery | 11.08 | 77.89 |
| 158 | Kokkedoddy | Hg | Karnataka | Ramanagara | Cauvery | Cauvery/Arkavathy | 12.30 | 77.44 |
| 159 | Kokrajhar | no metals found above limit | Assam | Kokrajhar | Brahmaputra | Gaurang | 26.40 | 90.25 |
| 160 | Kollegal | Cr | Karnataka | Chamarajanagar | Cauvery | Cauvery | 12.19 | 76.10 |
| 161 | Kora | As,Fe | Uttar Pradesh | Fatehpur | Ganga | Yamuna/Rind | 26.11 | 80.05 |
| 162 | Kota-By Pass Hanging Road Bridge u/s of Kota City | Hg | Rajasthan | Kota | Ganga | Yamuna/Chambal/Parwati | 25.14 | 75.80 |
| 163 | Koteshwar | Fe | Uttarakhand | Tehri Garhwal | Ganga | Ganga/Bhagirathi | 30.26 | 78.50 |
| 164 | Krishnabihari/Machaigaon | no metals found above limit | Assam | Golaghat | Brahmaputra | Dirai | 27.07 | 94.79 |
| 165 | Krishnai | no metals found above limit | Assam | Goalpara | Brahmaputra | Krishnai | 26.03 | 90.67 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 166 | Kudalaiyathur | no metals found above limit | Tamil Nadu | Cuddalore | East Flowing Rivers between Pennar and Kanyakumari | Vellar | 11.42 | 79.47 |
| 167 | Kudige | no metals found above limit | Karnataka | Kodagu | Cauvery | Cauvery | 12.50 | 75.96 |
| 168 | Kudlur | no metals found above limit | Karnataka | Chamarajanagara | Cauvery | Cauvery/Palar | 11.84 | 77.46 |
| 169 | Kuldah Bridge | no metals found above limit | Madhya Pradesh | Sidhi | Ganga | Ganga/Sone | 24.41 | 81.70 |
| 170 | Kulsi | no metals found above limit | Assam | Kamrup (Rural) | Brahmaputra | Kulsi | 25.98 | 91.39 |
| 171 | Kumarapalayam | no metals found above limit | Pondicherry | Pondicherry | East Flowing Rivers between Pennar and Kanyakumari | Varahanadhi | 11.98 | 79.68 |
| 172 | Kumbidi | no metals found above limit | Kerala | Palakkad | West Flowing Rivers from Tadri to Kanyakumari | Bharathapuzha | 10.85 | 76.02 |
| 173 | Kuniyil | no metals found above limit | Kerala | Malappuram | West Flowing Rivers from Tadri to Kanyakumari | Chaliyar | 11.24 | 76.02 |
| 174 | Kuppellur | Pb | Karnataka | Haveri | Krishna | Tungabhadra/Kumudavathi | 14.50 | 75.63 |
| 175 | Kurua/Polaguri | no metals found above limit | Assam | Darang | Brahmaputra | Brahmaputra | 26.43 | 92.31 |
| 176 | Kuruabahi/Ririgaon | no metals found above limit | Assam | Golaghat | Brahmaputra | Brahmaputra/Dhansiri(South) | 26.67 | 93.69 |
| 177 | Kuthnuor | Pb | Uttarakhand | Uttarkashi | Ganga | Yamuna | 30.87 | 78.30 |
| 178 | Kuttyadi | Cr | Kerala | Kozhikode | West Flowing Rivers from Tadri to Kanyakumari | Kuttyadi | 11.63 | 75.78 |
| 179 | Kuzhithurai | Pb | Tamil Nadu | Kanyakumari | West Flowing Rivers from Tadri to Kanyakumari | Thambraparani | 8.31 | 77.19 |
| 180 | Lakkavalli | Fe | Karnataka | Shimoga | Krishna | Bhadra | 13.71 | 75.65 |
| 181 | Lakshmananpatti | no metals found above limit | Tamil Nadu | Dindigul | Cauvery | Cauvery/Kodaganar | 10.50 | 77.95 |
| 182 | Lalpur | As,Fe | Uttar Pradesh | Kanpur Dehat | Ganga | Yamuna/Sengar | 26.31 | 79.92 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 183 | Ligribari/B.G Road | no metals found above limit | Assam | Sibsagar | Brahmaputra | Brahmaputra/Pakaria | 27.07 | 94.53 |
| 184 | Lucknow | Cd | Uttar Pradesh | Lucknow | Ganga | Gomti | 26.86 | 80.95 |
| 185 | M.H.Halli | Hg | Karnataka | Hassan | Cauvery | Cauvery/Hemavathi | 12.82 | 76.13 |
| 186 | Madamon | Fe,Hg,Pb,Ni | Kerala | pathanamthitta | West Flowing Rivers from Tadri to Kanyakumari | Pamba | 9.36 | 76.84 |
| 187 | Madla | Fe | Madhya Pra-desh | Panna | Ganga | Yamuna/Ken | 24.73 | 80.01 |
| 188 | Magaral | no metals found above limit | Tamil Nadu | Kancheepuram | East Flowing Rivers be-tween Pennar and Kanyakumari | Palar/Cheyyar | 12.71 | 79.75 |
| 189 | Mahidpur | no metals found above limit | Madhya Pra-desh | Ujjain | Ganga | Yamuna/Chambal/Shipra | 23.48 | 75.64 |
| 190 | Maighat | no metals found above limit | Uttar Pradesh | Jaunpur | Ganga | Gomti | 25.64 | 82.85 |
| 191 | Malakkara | Cr,Fe,Hg | Kerala | pathanamthitta | West Flowing Rivers from Tadri to Kanyakumari | Pamba | 9.33 | 76.66 |
| 192 | Manakkad | no metals found above limit | Kerala | idukki | West Flowing Rivers from Tadri to Kanyakumari | Thodupuzha | 9.91 | 76.69 |
| 193 | Manas NH Crossing | no metals found above limit | Assam | Barpeta | Brahmaputra | Manas | 26.46 | 90.75 |
| 194 | Mandawara | Fe | Rajasthan | Kota | Ganga | Yamuna/Chambal | 25.39 | 76.15 |
| 195 | Manderial | Fe | Rajasthan | Karauli | Ganga | Yamuna/ Chambal | 26.27 | 77.28 |
| 196 | Mankara | no metals found above limit | Kerala | Palakkad | West Flowing Rivers from Tadri to Kanyakumari | Bharathapuzha | 10.76 | 76.49 |
| 197 | Marol | no metals found above limit | Karnataka | Haveri | Krishna | Tungabhadra/Varada | 14.94 | 75.62 |
| 198 | Matijuri | no metals found above limit | Assam | Hailakandi | Meghna/Barak | Barak/ Katakhal/ Dhaleshwari | 24.65 | 92.61 |
| 199 | Mawi | Fe | Uttar Pradesh | Muzaffar Nagar | Ganga | Yamuna | 29.38 | 77.15 |
| 200 | Mehandipur | no metals found above limit | Uttar Pradesh | Kannauj | Ganga | Ganga | 27.01 | 79.99 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 201 | Meja Road | no metals found above limit | Uttar Pradesh | Allahabad | Ganga | Ganga/Tons | 25.23 | 82.04 |
| 202 | Menangudi | no metals found above limit | Tamil Nadu | Thiruvarur | Cauvery | Cauvery/Noolar | 10.95 | 79.70 |
| 203 | Mirzapur | As | Uttar Pradesh | Mirzapur | Ganga | Ganga | 25.16 | 82.53 |
| 204 | Mohana (Betwa) | no metals found above limit | Uttar Pradesh | Jalaun | Ganga | Yamuna/Betwa | 25.82 | 79.46 |
| 205 | Mohana(Yamuna) | Hg | Haryana | Faridabad | Ganga | Yamuna | 28.22 | 77.46 |
| 206 | Moradabad | Pb | Uttar Pradesh | Moradabad | Ganga | Ramganga | 28.83 | 78.80 |
| 207 | Murappanadu | no metals found above limit | Tamil Nadu | Tuticorin | East Flowing Rivers between Pennar and Kanyakumari | Thambraparani | 8.71 | 77.84 |
| 208 | Musiri | no metals found above limit | Tamil Nadu | Thiruchirapalli | Cauvery | Cauvery | 10.94 | 78.44 |
| 209 | Muthankera | no metals found above limit | Kerala | Wynad | Cauvery | Cauvery/Kabini | 11.81 | 76.08 |
| 210 | Nagalamedike | no metals found above limit | Karnataka | Tumkur | Pennar | Pennar | 14.19 | 77.37 |
| 211 | Naidupet | no metals found above limit | Andhra Pradesh | Nellore | East Flowing Rivers between Pennar and Kanyakumari | Swarnamukhi | 13.95 | 79.90 |
| 212 | Nallamaranpatty | no metals found above limit | Tamil Nadu | Karur | Cauvery | Cauvery/Amaravathi | 10.88 | 77.98 |
| 213 | Nallathur | no metals found above limit | Pondicherry | Karaikal | Cauvery | Cauvery/Nandalar | 11.00 | 79.75 |
| 214 | Nandipalli | no metals found above limit | Andhra Pradesh | Kadapa | Pennar | Pennar/Sagaileru | 14.72 | 79.02 |
| 215 | Naugaon | no metals found above limit | Uttarakhand | Uttarakashi | Ganga | Yamuna | 30.79 | 78.14 |
| 216 | Neeleswaram | no metals found above limit | Kerala | Ernakulam | West Flowing Rivers from Tadri to Kanyakumari | Periyar | 10.18 | 76.50 |
| 217 | Neemsar | As | Uttar Pradesh | Sitapur | Ganga | Gomti | 27.35 | 80.48 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 218 | Nellipally | Pb,Fe | Kerala | Kollam | West Flowing Rivers from Tadri to Kanyakumari | Kallada | 9.03 | 76.925000 |
| 219 | Nellithurai | no metals found above limit | Tamil Nadu | Coimbatore | Cauvery | Cauvery/Bhavani | 11.29 | 76.89 |
| 220 | Nellore | no metals found above limit | Andhra Pradesh | Nellore | Pennar | Pennar | 14.47 | 79.99 |
| 221 | Noida D/S of Ghaziabad | Ni | Uttar Pradesh | Gautam Budh Nagar | Ganga | Yamuna/Hindon | 28.60 | 77.42 |
| 222 | Odandurai | no metals found above limit | Tamil Nadu | Coimbatore | Cauvery | Cauvery/Kallar | 11.32 | 76.89 |
| 223 | Orai -Rath Marg Road-Bridge Chikasi U/S of Sahijna city | no metals found above limit | Uttar Pradesh | Jalaune | Ganga | Betwa | 25.81 | 79.46 |
| 224 | Pachauli | Fe | Madhya Pradesh | Shivpuri | Ganga | Yamuna/Sindh | 25.10 | 77.65 |
| 225 | Palakadavu | Cr | Kerala | Thrissur | West Flowing Rivers from Tadri to Kanyakumari | Karuvannur | 10.43 | 76.24 |
| 226 | Pali | Fe | Rajasthan | Sawai-madhopur | Ganga | Yamuna/Chambal | 25.86 | 76.58 |
| 227 | Paliakalan | no metals found above limit | Uttar Pradesh | Lakhimpur Khiri | Ganga | Ghaghra/Sharda | 28.38 | 80.55 |
| 228 | Palla U/S Delhi | Hg,Ni | Delhi | North West Delhi | Ganga | Yamuna | 28.85 | 77.21 |
| 229 | Panbari | no metals found above limit | Assam | Barpeta | Brahmaputra | Burisuti | 26.59 | 90.83 |
| 230 | Pancharatna | no metals found above limit | Assam | Goalpara | Brahmaputra | Brahmaputra | 26.21 | 90.55 |
| 231 | Pandu | no metals found above limit | Assam | Kamrup (Metro) | Brahmaputra | Brahmaputra | 26.18 | 91.67 |
| 232 | Paonta | Fe | Himachal Pradesh | Simaur | Ganga | Yamuna | 30.43 | 77.62 |
| 233 | Paramakudi | no metals found above limit | Tamil Nadu | Ramanathapuram | East Flowing Rivers between Pennar and Kanyakumari | Vaigai | 9.55 | 78.59 |
| 234 | Parmarth Ghat | no metals found above limit | Uttar Pradesh | Kanpur | Ganga | Ganga | 26.49 | 80.34 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 235 | Parsohan Ghat | no metals found above limit | Uttar Pradesh | Sidharthnagar | Ganga | Ghaghra/Ratpi/Burhi Rapti | 27.40 | 82.56 |
| 236 | Pasighat | no metals found above limit | Arunachal Pradesh | East Sinag | Brahmaputra | Brahmaputra/Siang | 28.07 | 95.34 |
| 237 | Pattazhy | Fe,Pb | Kerala | Kollam | West Flowing Rivers from Tadri to Kanyakumari | Kallada | 9.07 | 76.76 |
| 238 | Peralam | no metals found above limit | Tamil Nadu | Thiruvarur | Cauvery | Cauvery/Vanjiyar | 10.97 | 79.66 |
| 239 | Perumannu | no metals found above limit | Kerala | Cannanore | West Flowing Rivers from Tadri to Kanyakumari | Valapatnam | 11.98 | 75.59 |
| 240 | Porakudi | Fe | Tamil Nadu | Nagapattinam | Cauvery | Cauvery/Arasalar | 10.90 | 79.71 |
| 241 | Prang | no metals found above limit | Jammu & Kashmir | Gandarbal | Indus | Sind | 34.26 | 74.78 |
| 242 | Pratapgarh | As | Uttar Pradesh | Pratapgarh | Ganga | Gomti/Sai | 25.93 | 82.00 |
| 243 | Pratappur(Yamuna) | Fe | Uttar Pradesh | Allahabad | Ganga | Yamuna | 25.30 | 81.57 |
| 244 | Prem Nagar | no metals found above limit | Jammu & Kashmir | Doda | Indus | Chenab | 33.16 | 75.70 |
| 245 | Pudur | Cr,Fe | Kerala | Palakkad | West Flowing Rivers from Tadri to Kanyakumari | Bharathapuzha/Kannadipuzha/Ali-yar | 10.78 | 76.58 |
| 246 | Pulamanthole | Cr,Fe | Kerala | Palakkad | West Flowing Rivers from Tadri to Kanyakumari | Bharathapuzha/Pulanthodu | 10.90 | 76.20 |
| 247 | Pulikukku | no metals found above limit | Karnataka | Dakshina Kannada | West Flowing Rivers from Tadri to Kanyakumari | Kumaradhara | 12.71 | 75.47 |
| 248 | Raebareli | no metals found above limit | Uttar Pradesh | Raebareli | Ganga | Gomti/Sai | 26.20 | 81.25 |
| 249 | Rajapur | Fe | Uttar Pradesh | Chitrakoot | Ganga | Yamuna | 25.39 | 81.15 |
| 250 | Rajghat(Yamuna) | no metals found above limit | Uttar Pradesh | Lalitpur | Ganga | Yamuna/Betwa | 24.77 | 78.24 |
| 251 | Ram Munshi Bagh | no metals found above limit | Jammu & Kashmir | Sirnagar | Indus | Jhelum | 34.06 | 74.83 |
| 252 | Ramamangalam | Cr,Pb | Kerala | Ernakulam | West Flowing Rivers from Tadri to Kanyakumari | Muvattupuzha | 9.94 | 76.48 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 253 | Regauli | no metals found above limit | Uttar Pradesh | Gorakhpur | Ganga | Ghaghra/Rapti | 26.76 | 83.29 |
| 254 | Rishikesh | Fe | Uttarakhand | Dehradun | Ganga | Ganga | 30.10 | 78.30 |
| 255 | Rishikesh D/S | Fe | Uttarakhand | Dehradun | Ganga | Ganga | 30.08 | 78.29 |
| 256 | Rishikesh U/S | no metals found above limit | Uttarakhand | Dehradun | Ganga | Ganga | 30.13 | 78.33 |
| 257 | Roorkee D/S | As,Fe | Uttarakhand | Haridwar | Ganga | Solani | 29.88 | 77.90 |
| 258 | Roorkee U/S | As,Fe | Uttarakhand | Haridwar | Ganga | Solani | 29.89 | 77.89 |
| 259 | Rudraprayag (A) | Fe | Uttarakhand | Rudraprayag | Ganga | Ganga/Alakananda | 30.29 | 78.98 |
| 260 | Safapora | no metals found above limit | Jammu & Kashmir | Baramulla | Indus | Jhelum | 34.30 | 74.62 |
| 261 | Saidpur | no metals found above limit | Uttar Pradesh | Ghazipur | Ganga | Ganga | 25.53 | 83.22 |
| 262 | Sakleshpur | Fe | Karnataka | Hassan | Cauvery | Cauvery/Hemavathi | 12.94 | 75.79 |
| 263 | Sangam(Jhelum) | no metals found above limit | Jammu & Kashmir | Anantnag | Indus | Jhelum | 33.83 | 75.07 |
| 264 | Sangod | no metals found above limit | Rajasthan | Kota | Ganga | Yamuna/Chambal/Kalisindh/Par-wan | 24.96 | 76.30 |
| 265 | Santheguli | Fe,Pb | Karnataka | Uthara Kannada | West Flowing Rivers from Tadri to Kanyakumari | Aghnanashini | 14.43 | 74.59 |
| 266 | Sarangpur | no metals found above limit | Madhya Pra-desh | Rajgarh | Ganga | Yamuna/Chambal/Kalisindh | 23.55 | 76.47 |
| 267 | Satna | no metals found above limit | Madhya Pra-desh | Satna | Ganga | Ganga/Tons | 24.56 | 80.91 |
| 268 | Satpuli D/S | no metals found above limit | Uttarakhand | Pauri | Ganga | Nayar | 29.94 | 78.70 |
| 269 | Satpuli U/S | no metals found above limit | Uttarakhand | Pauri | Ganga | Nayar | 29.92 | 78.71 |
| 270 | Savandapur | no metals found above limit | Tamil Nadu | Erode | Cauvery | Cauvery/Bhavani | 11.52 | 77.51 |
| 271 | Seohara | no metals found above limit | Uttar Pradesh | Bijnaur | Ganga | Ramganga | 29.24 | 78.66 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 272 | Seondha | no metals found above limit | Madhya Pradesh | Datia | Ganga | Yamuna/Sindh | 26.17 | 78.80 |
| 273 | Sevanur | no metals found above limit | Tamil Nadu | Erode | Cauvery | Cauvery/Chittar | 11.55 | 77.73 |
| 274 | Shahjina | no metals found above limit | Uttar Pradesh | Hamirpur | Ganga | Yamuna/Betwa | 25.94 | 80.15 |
| 275 | Shahzadpur | no metals found above limit | Uttar Pradesh | Kaushambi | Ganga | Ganga | 25.67 | 81.43 |
| 276 | Shastri Bridge | As | Uttar Pradesh | Prayagraj | Ganga | Ganga | 25.44 | 81.89 |
| 277 | Shella | no metals found above limit | Meghalaya | East Khasi Hills | Meghna/Barak | Meghna/Surma/Umiew | 25.18 | 91.64 |
| 278 | Shimoga | Pb | Karnataka | Shimoga | Krishna | Tungabhadra/Tunga | 13.93 | 75.59 |
| 279 | Sibbari | no metals found above limit | Meghalaya | South Garo Hills | Meghna/Barak | Meghna/ Dareng | 25.18 | 90.51 |
| 280 | Silghat | no metals found above limit | Assam | Nagaon | Brahmaputra | Brahmaputra | 26.62 | 92.94 |
| 281 | Singasadanapalli | Cd,Pb,Fe | Tamil Nadu | Krishnagiri | East Flowing Rivers between Pennar and Kanyakumari | Ponnaiyar | 12.87 | 77.84 |
| 282 | Singavaram | no metals found above limit | Andhra Pradesh | Anantapur | Pennar | Pennar/Chitravathi | 14.60 | 78.01 |
| 283 | Sitapur | As,Fe | Uttar Pradesh | Sitapur | Ganga | Gomti /Sarayan | 27.57 | 80.69 |
| 284 | Sonapur(Digaru) | no metals found above limit | Assam | Kamrup (Rural) | Brahmaputra | Digaru | 26.12 | 91.98 |
| 285 | Srinagar | Fe | Uttarakhand | Pauri Garhwal | Ganga | Ganga/Alakananda | 30.23 | 78.78 |
| 286 | Sultanpur | As | Uttar Pradesh | Sultanpur | Ganga | Gomti | 26.28 | 82.07 |
| 287 | Sulurpet | no metals found above limit | Andhra Pradesh | Nellore | East Flowing Rivers between Pennar and Kanyakumari | Kalingi | 13.71 | 80.01 |
| 288 | T. Bekuppe | Hg,Pb | Karnataka | Mandya | Cauvery | Cauvery/Arkavathy | 12.51 | 77.43 |
| 289 | T.K.Halli | no metals found above limit | Karnataka | Mandya | Cauvery | Cauvery/Shimsha | 12.42 | 77.19 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 290 | T.Narasipur | Fe,Ni | Karnataka | Mysuru | Cauvery | Cauvery/Kabini | 12.23 | 76.89 |
| 291 | Tadapatri | no metals found above limit | Andhra Pradesh | Anantapur | Pennar | Pennar | 14.92 | 78.02 |
| 292 | Tal | Pb | Madhya Pradesh | Ratlam | Ganga | Yamuna/Chambal | 23.72 | 75.35 |
| 293 | Tanda D/S | no metals found above limit | Uttar Pradesh | Ambedkar Nagar | Ganga | Ghaghra | 26.54 | 82.70 |
| 294 | Tanda U/S | no metals found above limit | Uttar Pradesh | Ambedkar Nagar | Ganga | Ghaghra | 26.53 | 82.63 |
| 295 | Tandi | no metals found above limit | Himachal Pradesh | Lahoul & Spiti | Indus | Chandrabhaga/Bhaga | 32.55 | 76.98 |
| 296 | Thandalaiputhur | Fe | Tamil Nadu | Thiruchirapalli | Cauvery | Cauvery/Ayyar | 10.99 | 78.51 |
| 297 | Thengudi | Fe | Tamil Nadu | Thiruvarur | Cauvery | Cauvery/Thirumalairajanar | 10.92 | 79.64 |
| 298 | Thengumarahada | Fe | Tamil Nadu | Nilgiris | Cauvery | Cauvery/Bhavani/Moyar | 11.57 | 76.92 |
| 299 | Theni | Fe | Tamil Nadu | Theni | East Flowing Rivers between Pennar and Kanyakumari | Vaigai/Suruliar | 10.00 | 77.49 |
| 300 | Therriaghat | no metals found above limit | Meghalaya | East Khasi Hills | Meghna/Barak | Um Sohrygnkew | 25.18 | 91.77 |
| 301 | Thevur | no metals found above limit | Tamil Nadu | Salem | Cauvery | Cauvery/Sarabenga | 11.53 | 77.75 |
| 302 | Thimmanahalli | Ni | Karnataka | Hassan | Cauvery | Cauvery/Yagachi | 12.98 | 77.02 |
| 303 | Thoppur | no metals found above limit | Tamil Nadu | Salem | Cauvery | Cauvery/Thoppaiyar | 11.94 | 78.06 |
| 304 | Thottathinkadavu | Cr | Kerala | Kozhikode | West Flowing Rivers from Tadri to Kanyakumari | Iruvazhinjipuzha | 11.36 | 76.00 |
| 305 | Thumpamon | Cr,Fe | Kerala | Pathanamthitta | West Flowing Rivers from Tadri to Kanyakumari | Pamba/Achankovil | 9.22 | 76.71 |
| 306 | Tiharkheda | no metals found above limit | Uttar Pradesh | Bareilly | Ganga | Ramganga | 28.42 | 79.29 |
| 307 | Todarpur | As,Fe | Uttar Pradesh | Hardoi | Ganga | Ganga/Deoha/ sukheta | 27.58 | 80.00 |
| 308 | Tonk | no metals found above limit | Rajasthan | Tonk | Ganga | Yamuna/Chambal/Banas | 26.20 | 75.84 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 309 | Tuini (Pabar) | no metals found above limit | Himachal Pradesh | Dehradun | Ganga | Yamuna/Pabar | 30.95 | 77.85 |
| 310 | Tuini (Tons) | Pb | Uttarakhand | Dehradun | Ganga | Yamuna/Tons | 30.94 | 77.85 |
| 311 | Tumri | no metals found above limit | Madhya Pradesh | Mandsaur | Ganga | Yamuna/Chambal/Ratem | 24.53 | 75.60 |
| 312 | Turtipar | no metals found above limit | Uttar Pradesh | Ballia | Ganga | Ghaghra | 26.17 | 83.86 |
| 313 | Tuting | no metals found above limit | Arunachal Pradesh | Upper Siang | Brahmaputra | Brahmaputra/ Siang | 28.98 | 94.90 |
| 314 | Udaipur (Brahmaputra) | Cr | Assam | Tinsukia | Brahmaputra | Brahmaputra/Buri Dihing | 27.34 | 95.85 |
| 315 | Udaipur(Chandrabhaga) | no metals found above limit | Himachal Pradesh | Lahoul & Spiti | Indus | Chandrabhaga | 32.72 | 76.67 |
| 316 | Udi | no metals found above limit | Uttar Pradesh | Etawah | Ganga | Yamuna/Chambal | 25.70 | 78.94 |
| 317 | Ujjain | no metals found above limit | Madhya Pradesh | Ujjain | Ganga | Yamuna/Chambal/Shipra | 23.17 | 75.77 |
| 318 | Urachikottai | no metals found above limit | Tamil Nadu | Erode | Cauvery | Cauvery | 11.48 | 77.70 |
| 319 | Uttarkashi | As,Pb,Fe | Uttarakhand | Uttarkashi | Ganga | Ganga/Bhagirathi | 30.73 | 78.45 |
| 320 | V.S. Bridge | no metals found above limit | Uttar Pradesh | Varanasi | Ganga | Ganga | 25.26 | 83.03 |
| 321 | Vandiperiyar | Cr,Fe | Kerala | Idukki | West Flowing Rivers from Tadri to Kanyakumari | Periyar | 9.57 | 77.09 |
| 322 | Varanasi | no metals found above limit | Uttar Pradesh | Varanasi | Ganga | Ganga | 25.32 | 83.04 |
| 323 | Varanavasi | Ni | Tamil Nadu | Ariyalur | Cauvery | Cauvery/Marudaiyar | 11.09 | 79.08497 |
| 324 | Vazhavachanur | Fe | Tamil Nadu | Thiruvannamalai | East Flowing Rivers between Pennar and Kanyakumari | Ponnaiyar | 12.07 | 78.98 |
| 325 | Villupuram | no metals found above limit | Tamil Nadu | Villupuram | East Flowing Rivers between Pennar and Kanyakumari | Ponnaiyar | 11.87 | 79.46 |

| Sl. No. | Station | Metal found above limit | State/UT | District | Basin | River/tributary | Latitude | Longitude |
|---|---|---|---|---|---|---|---|---|
| 326 | Yamuna Expressway Road Bridge-Etmadpur D/S of Agra city | As,Hg | Uttar Pradesh | Agra | Ganga | Yamuna | 27.18 | 78.12 |
| 327 | Yashwant nagar | no metals found above limit | Himachal Pradesh | Simaur | Ganga | Yamuna/Giri | 30.88 | 77.21 |
| 328 | Yennehole | no metals found above limit | Karnataka | Dakshina Kannada | West Flowing Rivers from Tadri to Kanyakumari | Swarna | 13.29 | 74.98 |

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