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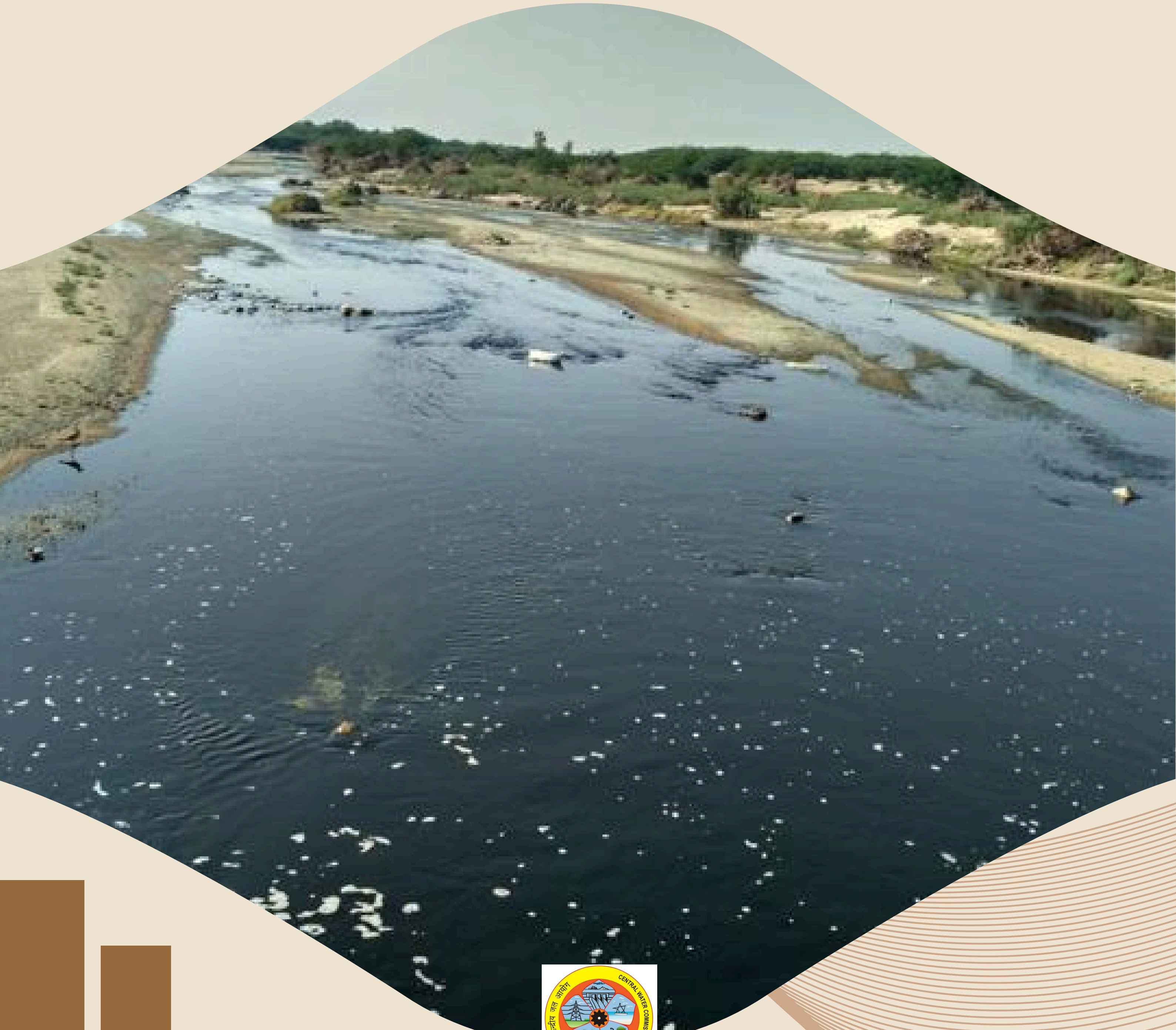
GOVERNMENT OF INDIA
Ministry of Jal Shakti
Department of Water Resources
River Development and Ganga Rejuvenation

STATUS OF TRACE AND TOXIC METALS IN RIVERS OF INDIA

7th Edition
(January to December 2023)



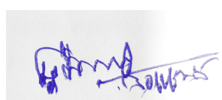
Central Water Commission

JANUARY, 2025

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 on January 2025, CWC is having 05 Level-III Water Quality Laboratories, duly accredited by NABL.

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 7th 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 2023, in relation to 300 stations across various parts of India. The previous editions of this study were published in May 2014, April 2018, August 2019, December 2021 and August 2024.

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.



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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.

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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 300 water quality monitoring stations of CWC from January to December 2023. 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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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
km	kilometers
M.ha	Million hectres
MCL	Maximum Contaminant Level
mm	millimeter
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
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 samples collected during January, 2023 to December, 2023 from 10 river basins of India (Pennar, EFR between Pennar-Cauvery, Cauvery, Indus, Krishna, Godavari, WFR South of Tapi. EFR South of Cauvery. Ganga, Yamuna Basin) 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 5911 river water samples, 10 samples from 03 water quality stations were found to have arsenic concentrations beyond the acceptable limit. The arsenic concentration varies from 0.000 to 17.59 µg/L. Maximum arsenic concentration (17.59 µg/L) was observed at Lalpur water quality monitoring station on Sengar River (a tributary of Yamuna) on 21.06.2023.

As Acceptable Limit as BIS 10500: 2012	10 µg/L
No. of Samples Tested	5911
No. of samples where metal found above acceptable limit	10
No. of Stations where metal found above acceptable limit	03
No. of Basin / Rivers where metal found above acceptable limit	02/03

Cadmium (Cd)

BIS (Bureau of Indian Standard) 10500:2012 has recommended an acceptable limit of 3 µg/L of cadmium in drinking water. Out of total 5940 river water samples analysed, 1 samples from 1 water quality stations were found to have cadmium concentrations beyond the acceptable limit. The cadmium concentration varies from 0.000 to 10.59 µg/L. Maximum cadmium concentration (10.59 µg/L) was observed at Thevur water quality monitoring station on Sarabenga River on 01-02-2023.

Cd Acceptable Limit as BIS 10500: 2012	3 µg/L
No. of Samples Tested	5940
No. of samples where metal found above acceptable limit	1
No. of Stations where metal found above acceptable limit	1
No. of Basins / Rivers where metal found above acceptable limit	1/1

Chromium (Cr)

BIS (Bureau of Indian Standard) 10500:2012) has recommended an acceptable limit of 50 µg/L of chromium in drinking water. Out of total 5730 river water samples analysed, 87 samples from 27 water quality stations were found to have chromium concentrations beyond the acceptable limit. The chromium concentration varies from 0.000 to 84.61 µg/L. Maximum chromium concentration (84.61 µg/L) was observed at Biligundulu water quality monitoring station on Cauvery River on 12-06-2023.

Cr Acceptable Limit as BIS 10500: 2012	50 µg/L
No. of Samples Tested	5730
No. of samples where metal found above acceptable limit	87
No. of Stations where metal found above acceptable limit	27
No. of Basins / Rivers where metal found above acceptable limit	6/21

Copper (Cu)

BIS (Bureau of Indian Standard) 10500:2012) has recommended an acceptable limit of 50 µg/L of copper in drinking water. Out of total 5940 river water samples analysed, 3 samples from 3 water quality stations were found to have copper concentrations beyond the acceptable limit. The copper concentration varies from 0.000 to 107.01 µg/L. Maximum copper concentration (107.01 µg/L) was observed at Nellithurai water quality monitoring station on Bhavani River on 13-02-2023.

Cu Acceptable Limit as BIS 10500: 2012	50 µg/L
No. of Samples Tested	5940
No. of samples where metal found above acceptable limit	3
No. of Stations where metal found above acceptable limit	3
No. of Basins / Rivers where metal found above acceptable limit	3/3

Iron (Fe)

BIS has recommended the acceptable limit of 1.0 mg/L (1000 µg/L) for Iron. Out of total 5768 river water samples analysed, 292 samples from 63 water quality stations were found to have iron concentrations beyond the acceptable limit. The iron concentration varies from 0.000 to 5.99 mg/L. Maximum iron concentration (5.99 mg/L) was observed at Murappanadu water quality monitoring station on Tambraparani River on 02.11.2023.

Fe Acceptable Limit as BIS 10500: 2012	1000 µg/L
No. of Samples Tested	5768
No. of samples where metal found above acceptable limit	292
No. of Stations where metal found above acceptable limit	63
No. of Basins / Rivers where metal found above acceptable limit	8/49

Lead (Pb)

Bureau of Indian Standard (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 5890 river water samples analysed, 76 samples from 23 water quality stations were found to have lead concentrations beyond the acceptable limit. The lead concentration varies from 0.000 to 75.51 µg/L. Maximum lead concentration (75.51 µg/L) was observed at Kudige water quality monitoring station on Cauvery River on 14-11-2023.

Pb Acceptable Limit as BIS 10500: 2012	10 µg/L
No. of Samples Tested	5890
No. of samples where metal found above acceptable limit	76
No. of Stations where metal found above acceptable limit	23
No. of Basins / Rivers where metal found above acceptable limit	7/20

Mercury (Hg)

BIS (Bureau of Indian Standard) 10500:2012) has recommended an acceptable limit of 1 µg/L of mercury in drinking water. Out of total 5897 river water samples analysed, 28 samples from 14 water quality stations were found to have mercury concentrations beyond the acceptable limit. The mercury concentration varies from 0.000 to 4.79 µg/L. Maximum mercury concentration (4.79 µg/L) was observed at Rajahmundry water quality monitoring station on Godavari River on 20-10-2023.

Hg Acceptable Limit as BIS 10500: 2012	1 µg/L
No. of Samples Tested	5897
No. of samples where metal found above acceptable limit	28
No. of Stations where metal found above acceptable limit	14
No. of Rivers where metal found above acceptable limit	4/10

Nickel (Ni)

BIS (Bureau of Indian Standard) 10500:2012) has recommended an acceptable limit of 20 µg/L of nickel in drinking water. Out of total 5898 river water samples analysed, 17 samples from 06 water quality stations were found to have nickel concentrations beyond the acceptable limit.The nickel concentration varies from 0.000 to 66.64 µg/L. Maximum nickel concentration (66.64 µg/L) was observed at Musiri water quality monitoring station on Cauvery River on 11-05-2023.

Ni Acceptable Limit as BIS 10500: 2012	20 µg/L
No. of Samples Tested	5898
No. of samples where metal found above acceptable limit	17
No. of Stations where metal found above acceptable limit	06
No. of Basins / Rivers where metal found above acceptable limit	02/04

Zinc (Zn)

BIS (Bureau of Indian Standard) 10500:2012) has recommended acceptable limit of 5 mg/L (5000 µg/L) of Zinc in drinking water. Out of total 5946 river water samples analysed, no sample is found to have zinc concentration beyond the acceptable limit. The zinc concentration varies from 0.000 to 4990 µg/L. Maximum zinc concentration (4990 µg/L) was observed at Hariharapura water quality monitoring station on Tunga River on 22.08.2023.

Zn Acceptable Limit as BIS 10500: 2012	5000 µg/L
No. of Samples Tested	5946
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 300 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 212 out of 300 monitored stations while at 88 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	5911	5901	10	0.16
2	Cadmium (Cd)	3	5940	5939	1	0.02
3	Chromium (Cr)	50	5730	5643	87	1.52
4	Copper (Cu)	50	5940	5937	3	0.05
5	Iron (Fe)	1000	5768	5476	292	5.06
6	Lead (Pb)	10	5890	5814	76	1.29
7	Mercury (Hg)	1	5897	5869	28	0.47
8	Nickel (Ni)	20	5898	5881	17	0.29
9	Zinc (Zn)	5000	5946	5946	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. Byproducts 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.

1.8 Fossil 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 most 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 miscarriag-es

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 fisherman 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.

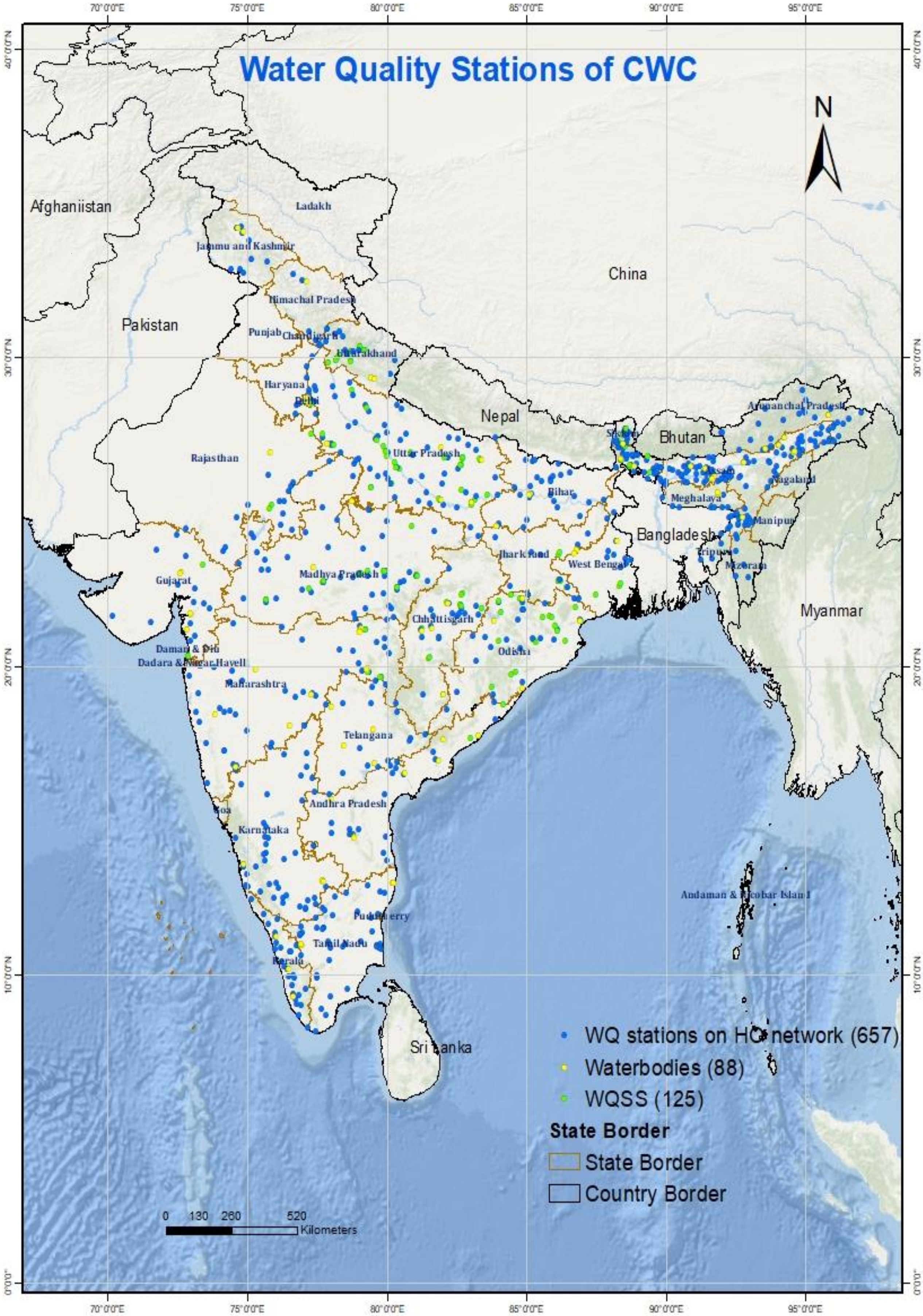

Figure* 1: *Water quality network of CWC (01.01.2023)

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
29	**Total**	**182**	**373**	**102**	**125**	**88**	**870**
	Grand Total	**782**				**88**	**870**

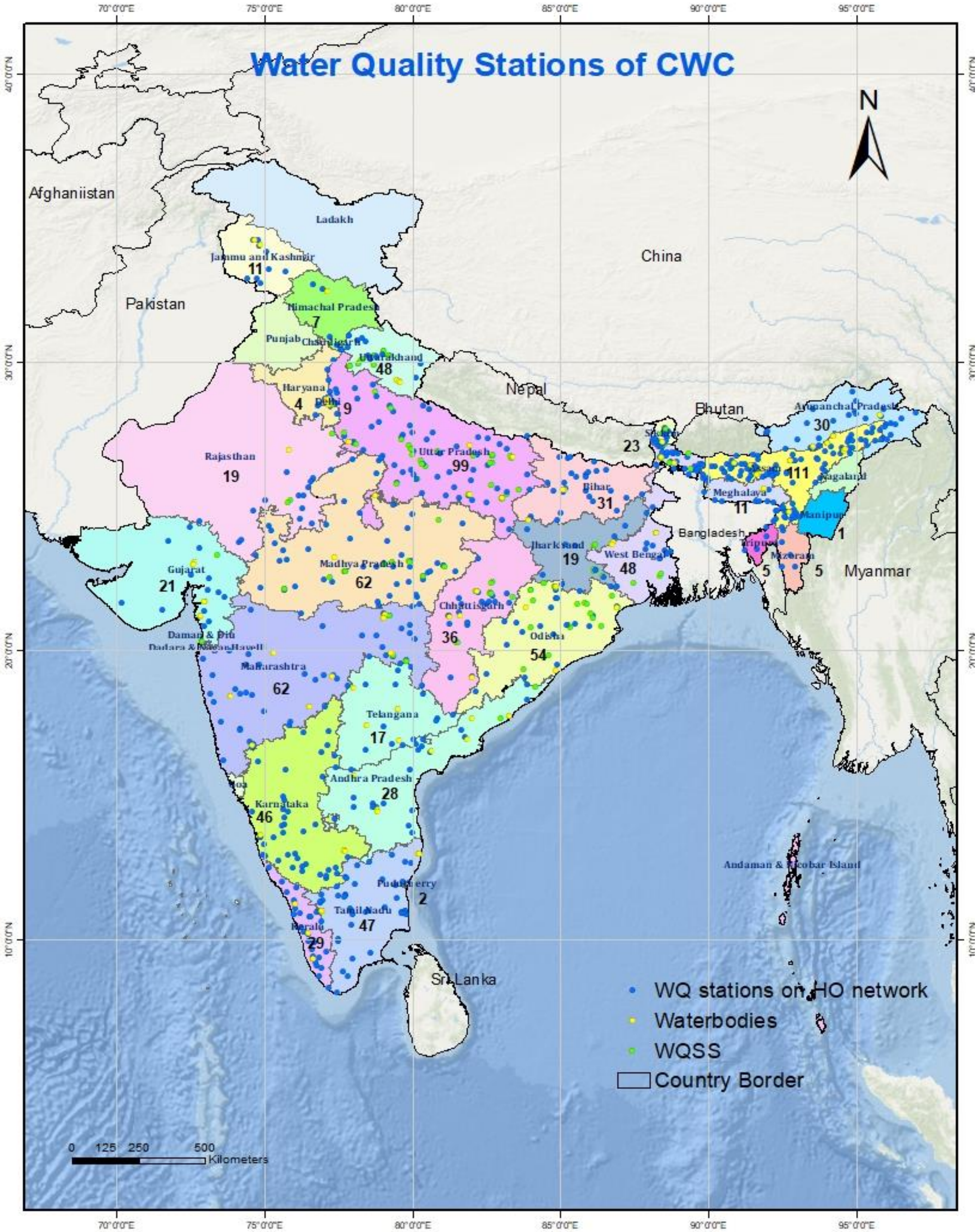

Figure 2: State-wise distribution of Water Quality Stations monitored by CWC

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 and 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
15	**Total**	**182**	**373**	**102**	**125**	**88**	**870**
	Grand Total	**782**				**88**	**870**

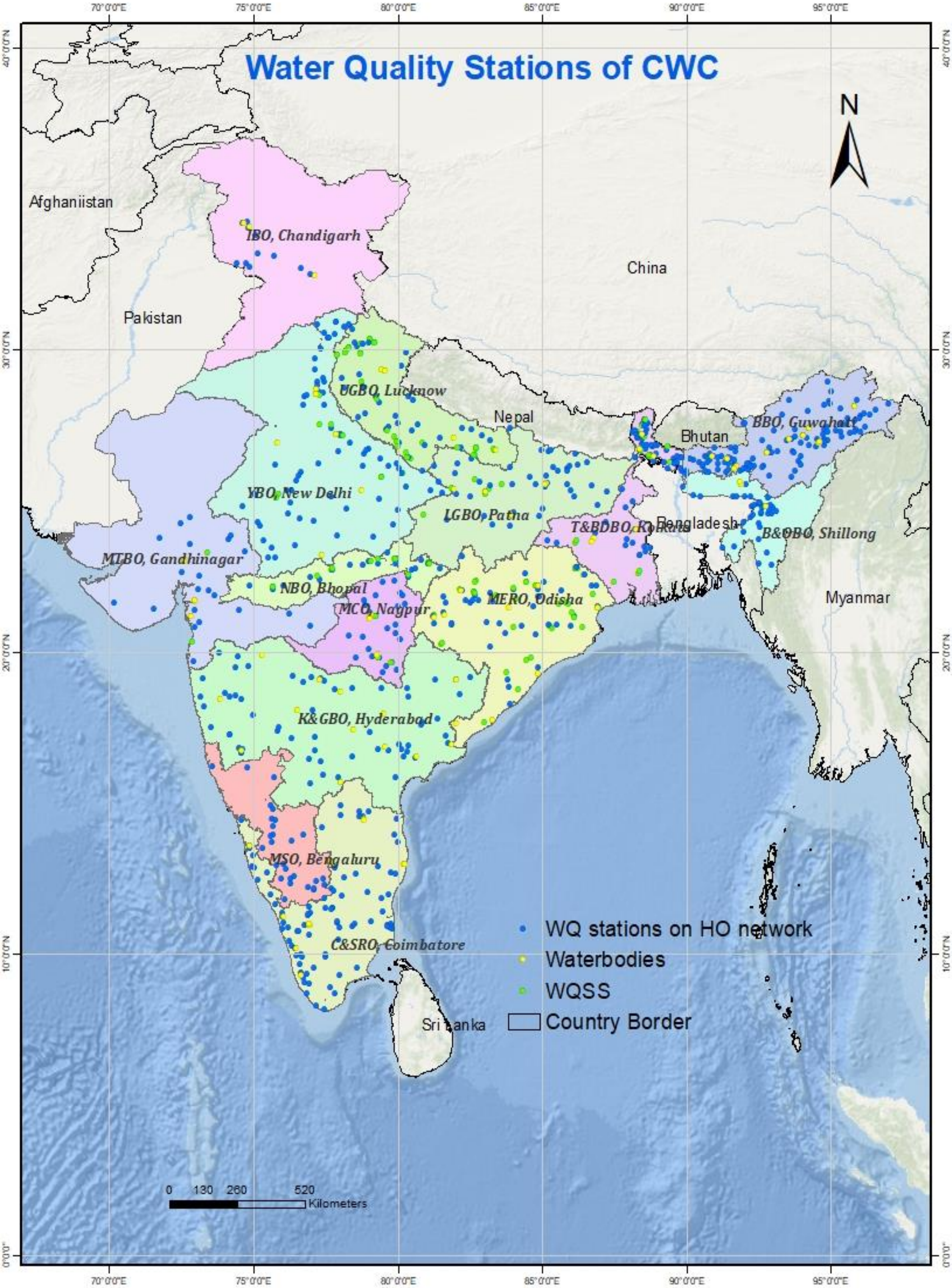

Figure 3: Organisation-Wise Distribution of Water Quality Stations Monitored by CWC

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

Sl. No.	Basin	GDQ	GDSQ	GQ	WQSS	Water Bodies	Total
1	Barak and Others Basin	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 (Up to 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
24	**Total**	**182**	**373**	**102**	**125**	**88**	**870**
	Grand Total	**782**				**88**	**870**

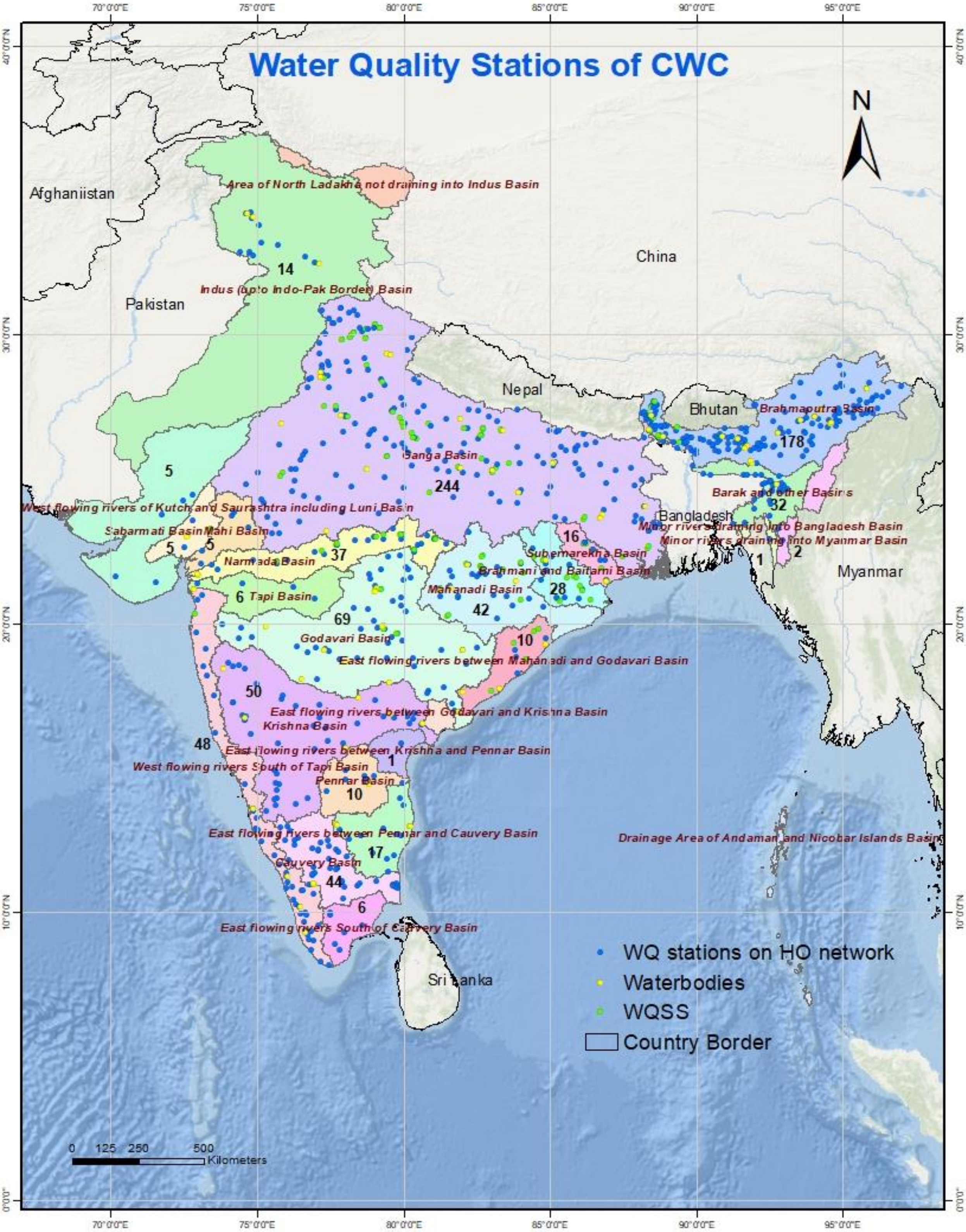

***Figure 4*: Map showing the basin-wise distribution of water quality Stations monitored by CWC**

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 got 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

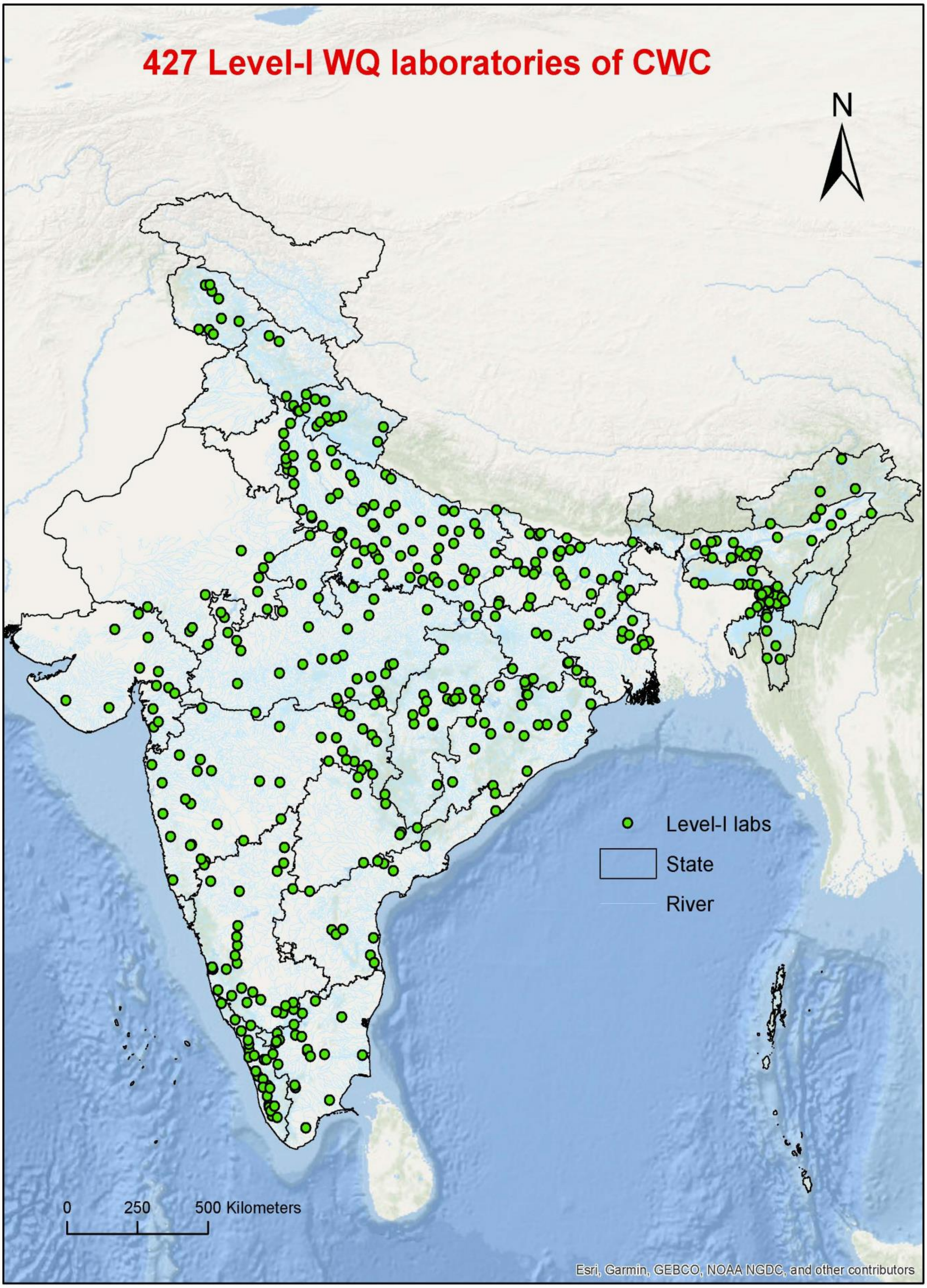

Figure 5: Level-I Water quality laboratories of CWC

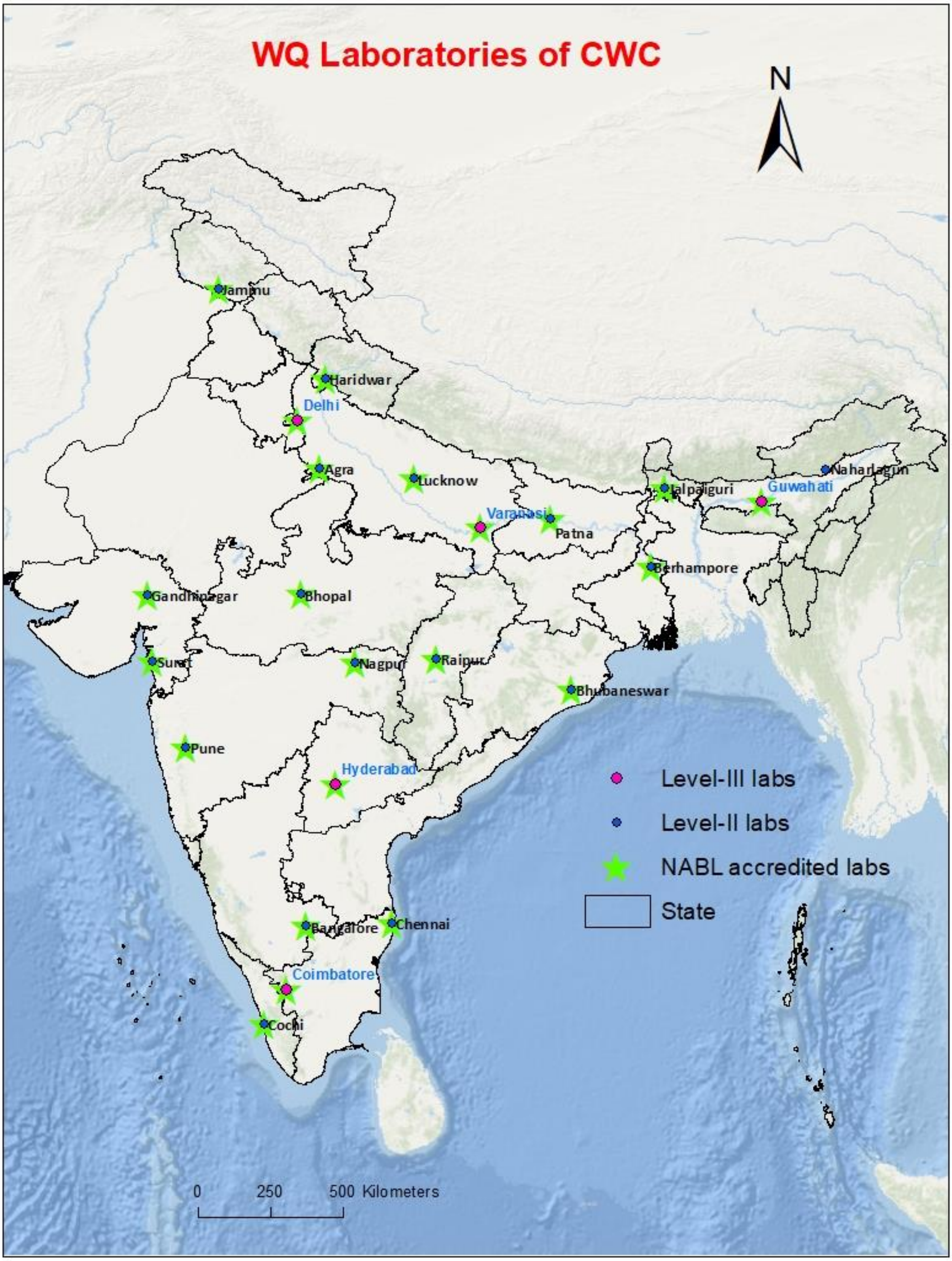

Figure 6: Level-II/III Water quality laboratories of CWC

5. STUDY AREA

The analysis results of 9 trace & toxic metals of water samples from 300 water quality monitoring stations of CWC are considered for the study (Figure 7). This involves the data analysis of 5946 samples collected during January, 2023 to December, 2023 from 10 river basins of India.

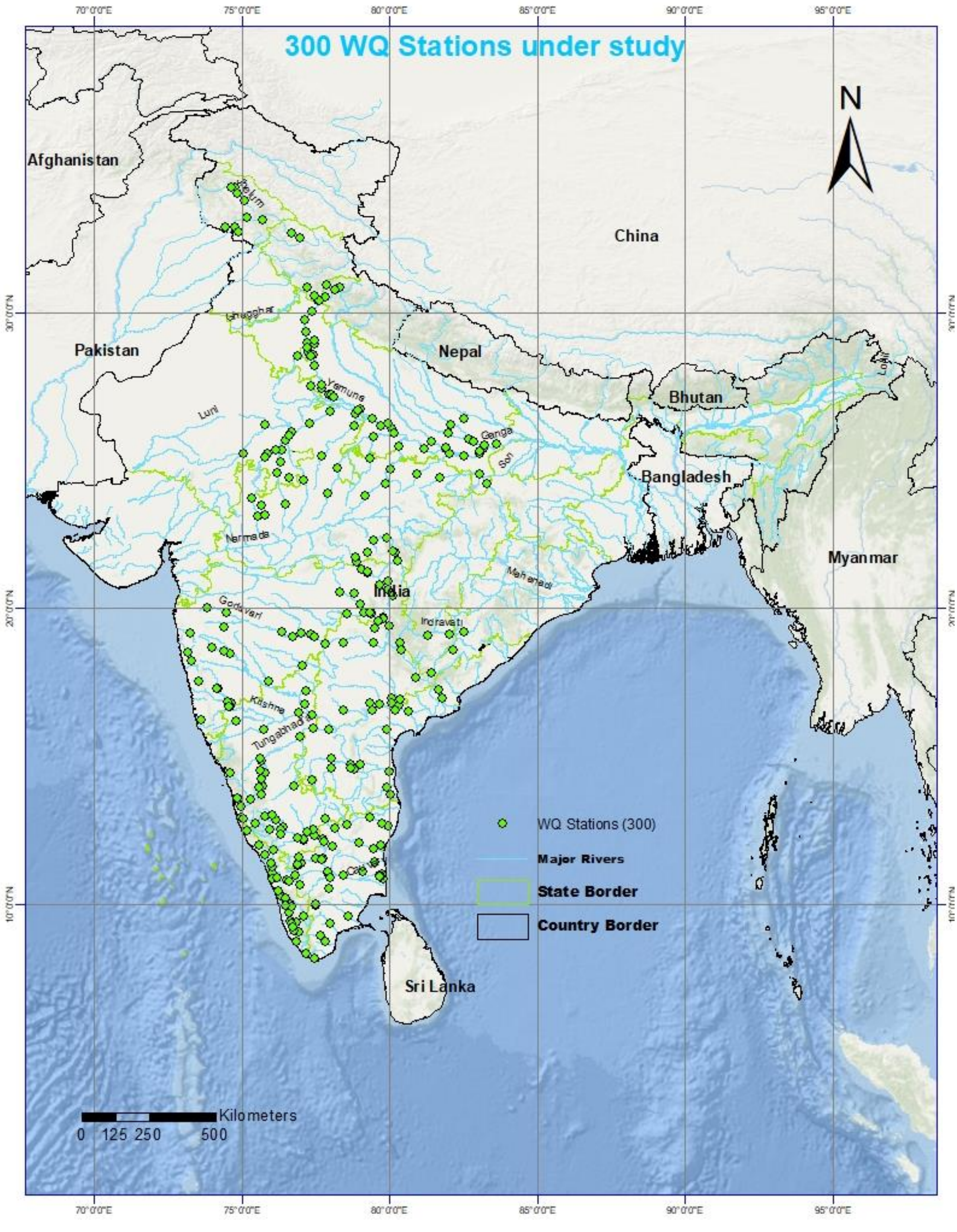

Figure 7: 300 Water quality stations monitored

The details of the 300 monitoring are enclosed as Annexure-I. The details of 10 basins considered for the study has been given below.

1. ***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 Tamilnadu. 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, Tamilnadu, Puducherry and some parts of Kerala. The Cauvery basin is fan shaped in Karnataka and leaf shaped in Tamilnadu. The major tributaries are Harangi, Hemavati, Kabini, Bhavani, Lakshmanthirtha, Noyyal, and Arkavati.

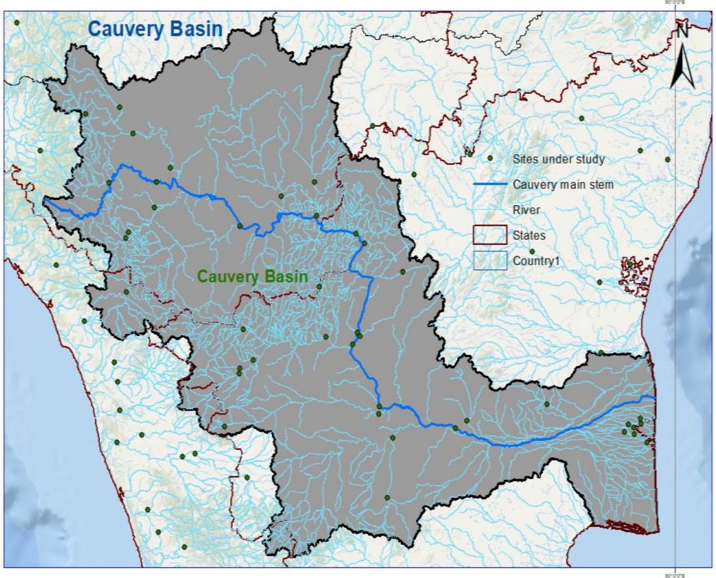

Figure 8: Cauvery Basin

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

2-3. East Flowing Rivers between Pennar & 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, Tamilnadu 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.

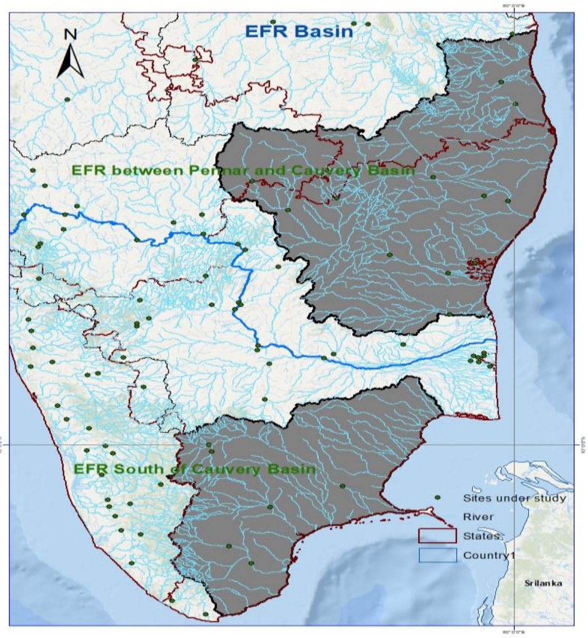

Figure 9: EFR Basin

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

4-5. ***Ganga Basin & Yamuna 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 head-streams, namely Bhagirathi, Alaknanda, Mandkini, Dhauliganga and Pindar. Of those, the two major head-streams 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 Hima-laya excluding Sone and Damo-dar rivers originating from the Amarkantak hills of Maikal range and Khamarpat hill on Chota Nagpur Plateau, respectively.

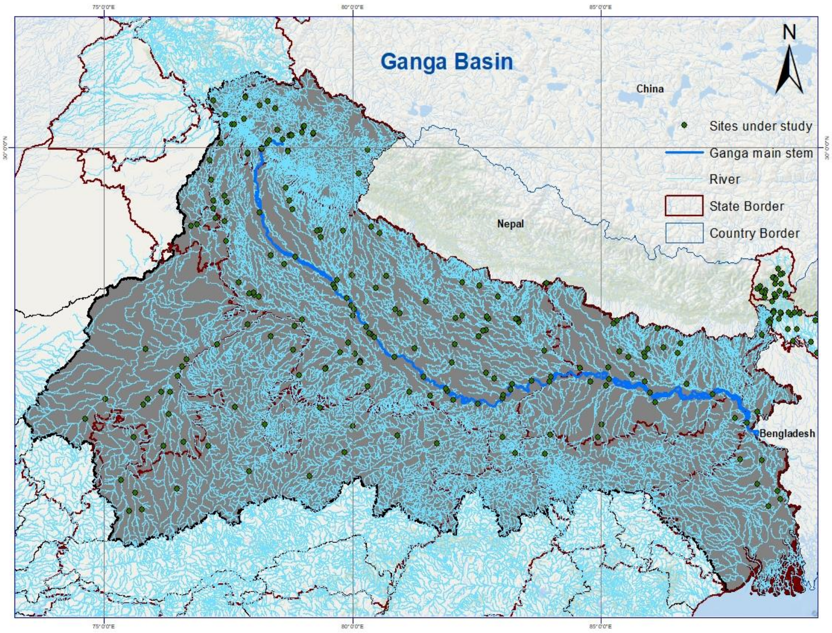

Figure 10: Ganga Basin

Alaknanda 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.

6. ***Indus(upto) Border 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

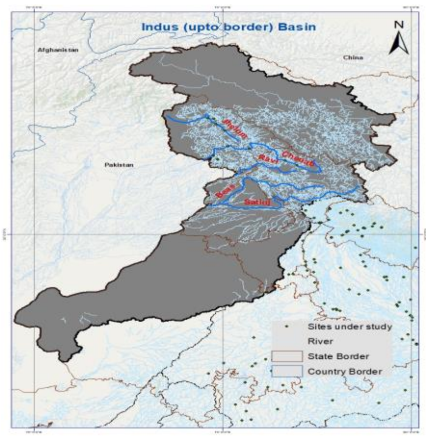

Figure 11: Indus Basin

Indian part of the basin consistts of five major tributaries: Satluj, 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.

7. ***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.

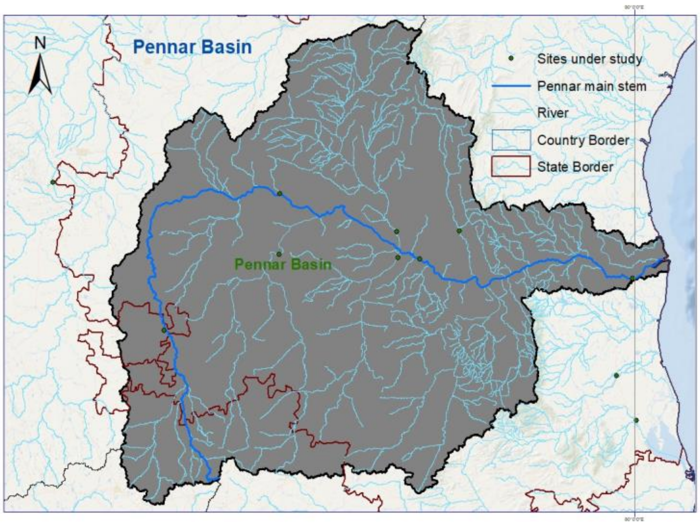

Figure 12: Pennar Basin

The Pennar drains an area of 55,213 Sqs.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.

8. ***West Flowing rivers south of Tapi Basin***

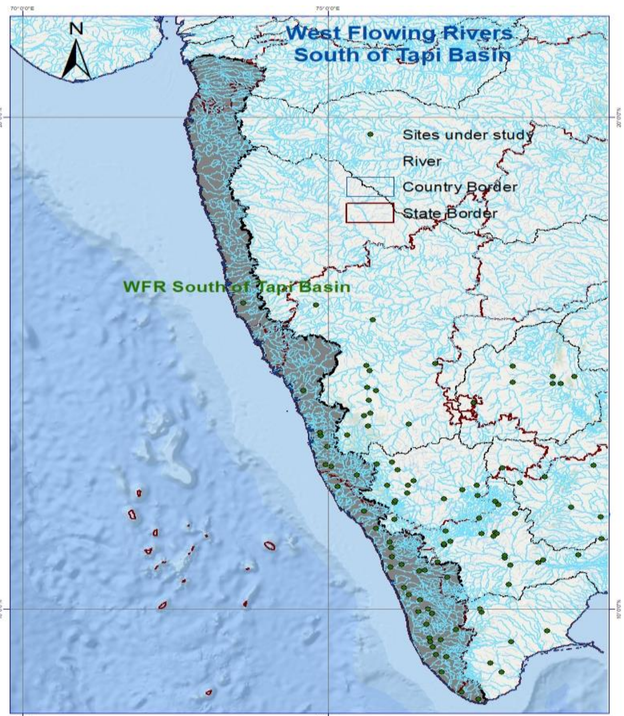

Figure 13: WFR South of Tapi Basin

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. Maps showing these basins are presented as Plates - I to III. 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.

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

9. *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 730 21’ to 810 09’ and North latitudes 130 07’ to 190 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 1337m just North of Mahabaleswar, about 64 km from the Arabian Sea and flows from West to East through the States of Maharashtra, Karnataka, Telangana and Andhra Pradesh before it joins the Bay of Bengal at downstream of Vijayawada.

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

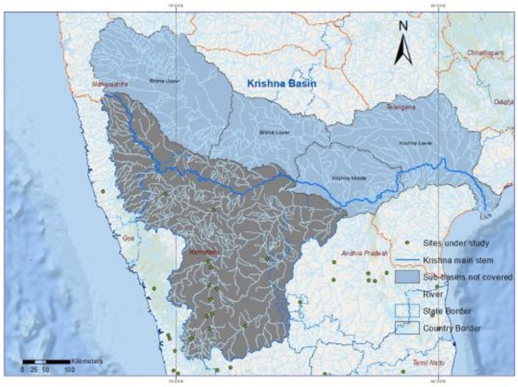

Figure 14: Krishna Basin

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.

10. *Godavari Basin*

The Godavari basin extends over states of Maharashtra, Andhra Pradesh, Chhattisgarh and Odisha in addition to smaller parts in Madhya Pradesh, Karnataka and Union territory of Puducherry having a total area of 3,12,812 Sq.km with a maximum length and width of about 995 km and 583 km.

It lies between 73°24′ to 83°4′ east longitudes and 16°19′ to 22°34′ north latitudes and accounts for nearly 9.5% of the total geographical area of the country. The basin is bounded by Satmala hills, the Ajanta range and the Mahadeo hills on the north, by the Eastern Ghats on the south and the east and by the Western Ghats on the west.

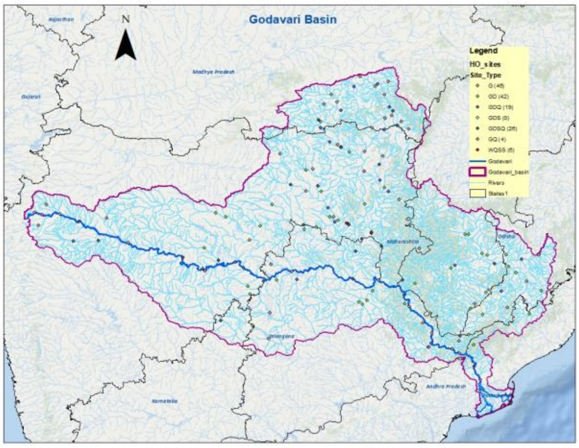

Figure 15: Godavari Basin

The Godavari River rises from Trimbakeshwar in the Nashik district of Maharashtra about 80 km from the Arabian Sea at an elevation of 1,067 m. The total length of Godavari from its origin to outfall into the Bay of Bengal is 1,465 km. Its principal tributaries joining from right are the Pravara and the Manjra whereas the Purna, the Penganga, the Wardha, the Wainganga, the Indravati and the Kolab joins from left.

Water quality samples collected from 12 water quality stations i.e. Bhadrachalam, Dhalegaon, GR Bridge, Kopergaon, Mancherial, Nanded, Nashik, Perur, Polavaram, Rajahmundry, Saloora and Yelli are being considered for the study.

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. The-

se 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 5946 samples were collected during January, 2023 to December, 2023 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 16: 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 300 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 212 out of 300 monitored stations while at 55 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	5911	5901	10	0.16
2	Cadmium (Cd)	3	5940	5939	1	0.02
3	Chromium (Cr)	50	5730	5643	87	1.52
4	Copper (Cu)	50	5940	5937	3	0.05
5	Iron (Fe)	1000	5768	5476	292	5.06
6	Lead (Pb)	10	5890	5814	76	1.29
7	Mercury (Hg)	1	5897	5869	28	0.47
8	Nickel (Ni)	20	5898	5881	17	0.29
9	Zinc (Zn)	5000	5946	5946	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 5911 river water samples, 10 samples from 03 water quality stations were found to have arsenic concentrations beyond the acceptable limit. The arsenic concentration varies from 0.000 to 17.59 μg/L. Maximum arsenic concentration (17.59 μg/L) was observed at Lalpur water quality monitoring station on Sengar River (a tributary of Yamuna) on 21.06.2023.

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 17 represents GIS map of WQ stations where Arsenic found above acceptable 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	Rind	Kora	12-06-2023	11.997	Uttar Pradesh	Fatehpur
			21-06-2023	11.874	Uttar Pradesh	Fatehpur
			01-07-2023	11.423	Uttar Pradesh	Fatehpur
			01-08-2023	11.332	Uttar Pradesh	Fatehpur
2	Sengar	Lalpur	12-06-2023	16.336	Uttar Pradesh	Kanpur Dehat
			21-06-2023	17.599	Uttar Pradesh	Kanpur Dehat
			21-10-2023	11.156	Uttar Pradesh	Kanpur Dehat
3	Yamuna	Vrindawan Bridge	03-10-2023	11.509	Uttar Pradesh	Mathura
			21-06-2023	11.585	Uttar Pradesh	Mathura
			21-10-2023	17.269	Uttar Pradesh	Mathura

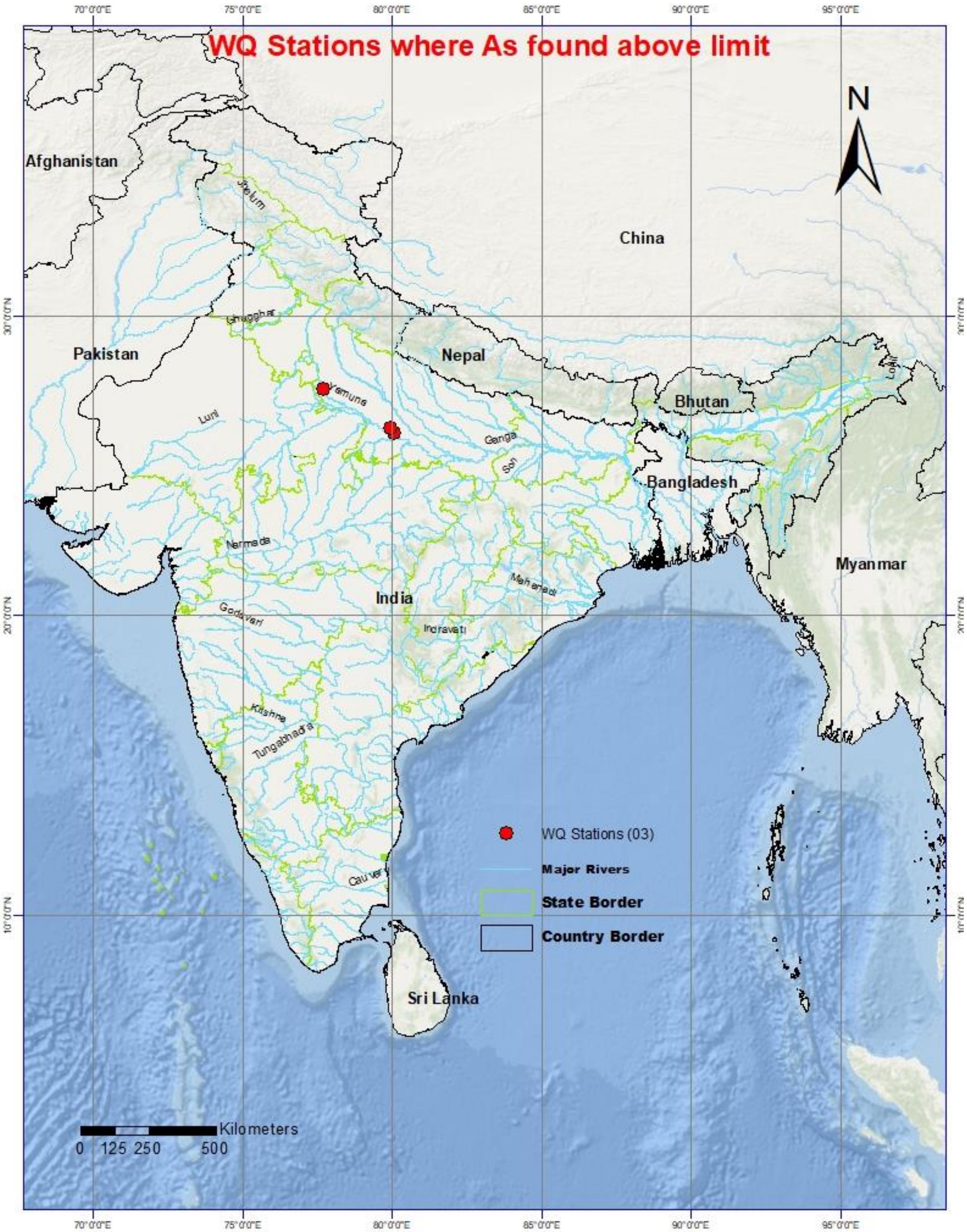

Figure 17: WQ stations where Arsenic found above acceptable limit

Comparison with 6th edition (period: January-December, 2023)

A comparison has been made between the current edition of the report and the 6th edition, which covers the period January - December 2022. 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 48 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.

In contrast, 2023 saw a decrease in both the number of samples exceeding the limit (10 out of 5911 samples) and the number of affected stations (3), with the highest concentration of 17.59 µg/L recorded at the Lalpur station on the Sengar River. These four stations belong to the Rind, Sengar and Yamuna River.

A GIS map depicting the stations where arsenic values were found above the acceptable limit during both study periods is shown as Figure 18.

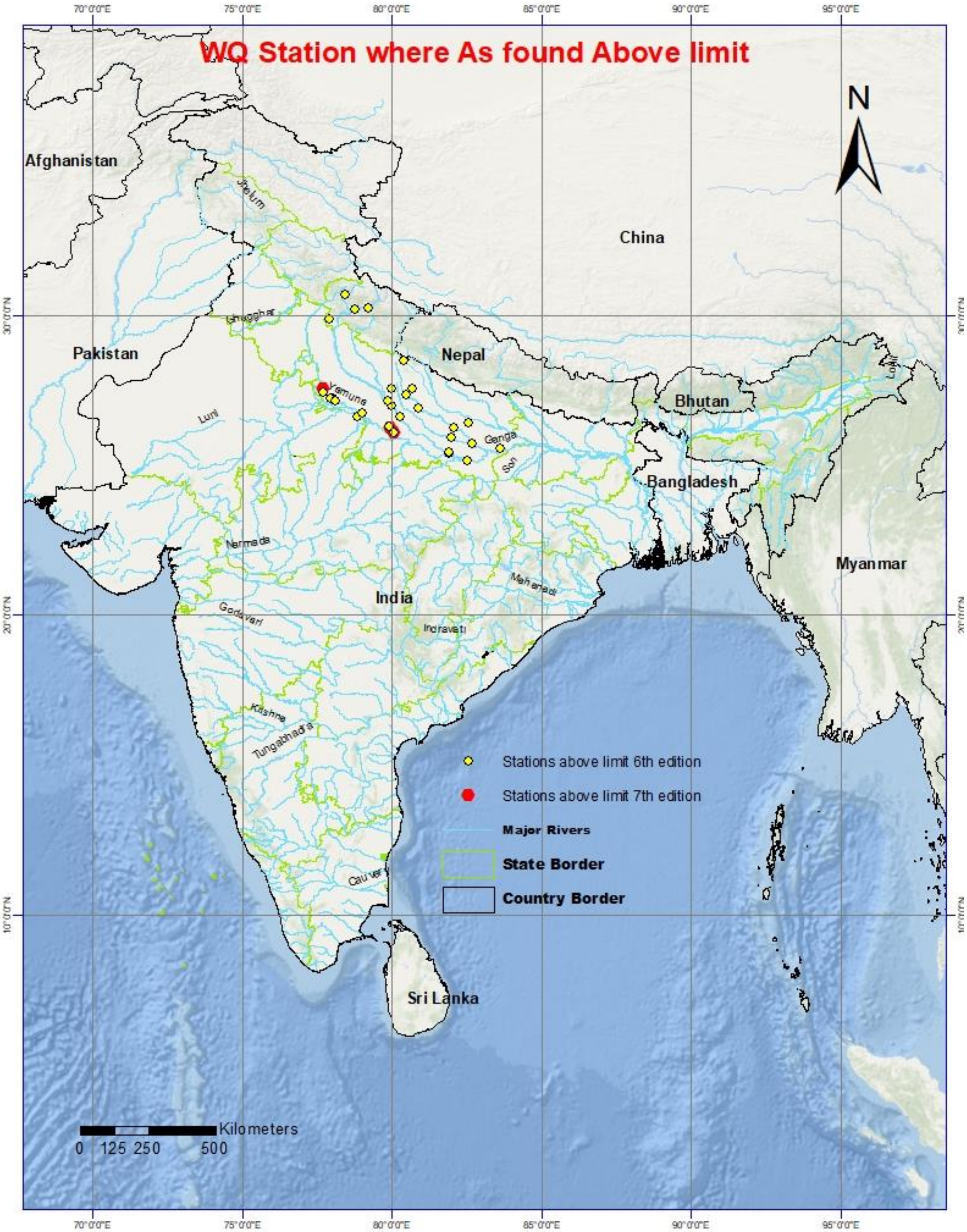

Figure 18: WQ stations where Arsenic found above acceptable limit (both study periods)

7.2 Cadmium (Cd)

BIS (Bureau of Indian Standard) 10500:2012 has recommended an acceptable limit of 3 µg/L of cadmium in drinking water. Out of total 5940 river water samples analysed, 1 samples from 1 water quality stations were found to have cadmium concentrations beyond the acceptable limit. The cadmium concentration varies from 0.000 to 10.59 µg/L. Maximum cadmium concentration (10.59 µg/L) was observed at Thevur water quality monitoring station on Sarabenga River on 01-02-2023.

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	Sarabenga	Thevur	01-02-2023	10.59	Tamil Nadu	Salem

The stations with above-limit cadmium values belong to Tamil Nadu. Figure 19 represents GIS map of WQ stations where Cadmium found above acceptable limit.

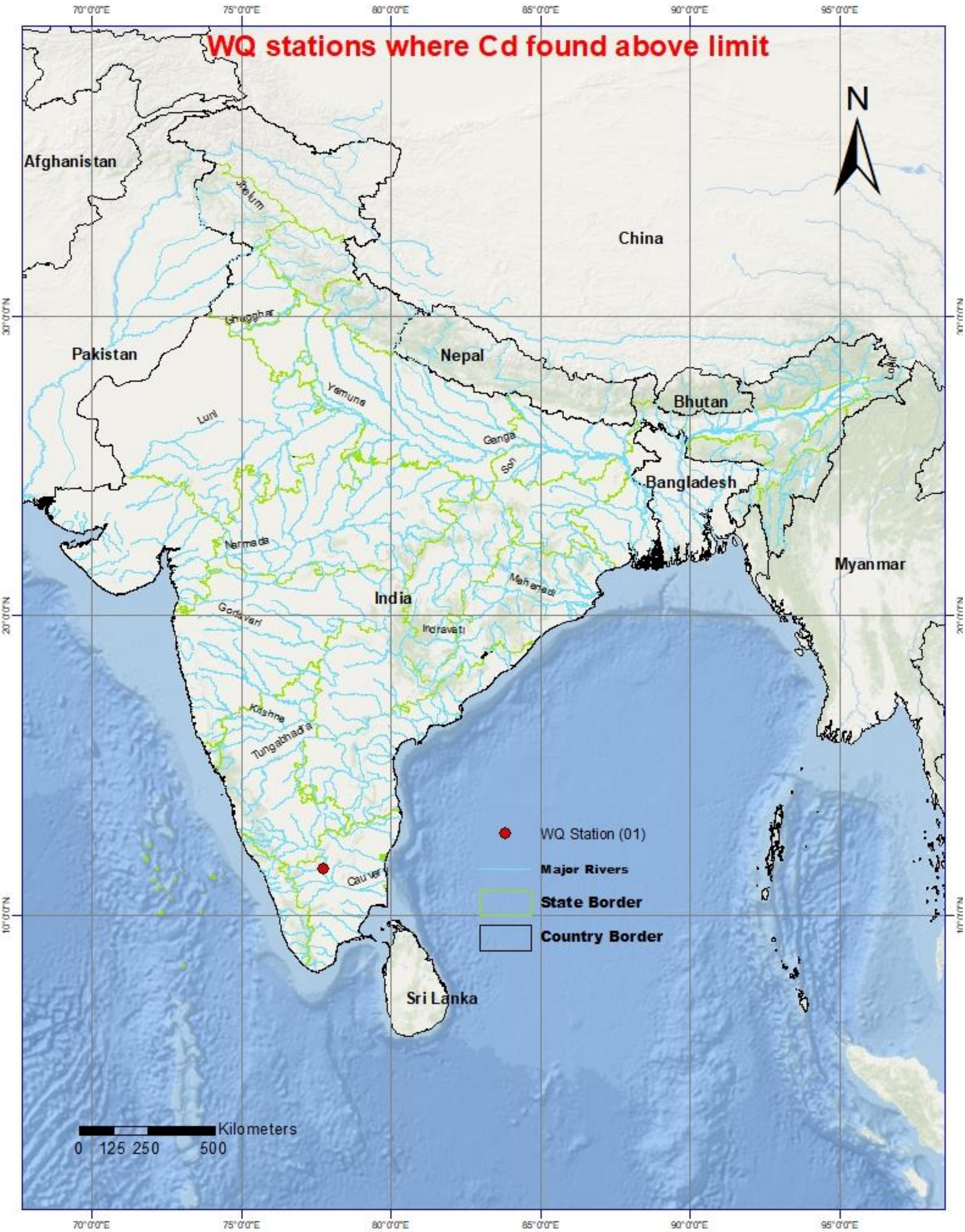

Figure 19: WQ stations where Cadmium found above acceptable limit

Comparison with 6th edition (period: January-December, 2023)

The data of cadmium found above limit in this report has been compared with the last edition of the report i.e., 6th edition, for the period January-December, 2022. During the 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. Ponnaiyar River showed two readings (5.073 µg/L and 3.647 µg/L), and Seetha River recorded a value of 3.623 µg/L.

In contrast, the data for 2023 is limited to the Sarabenga River in Tamil Nadu, where the Cd level at Thevur station reached a significantly higher value of 10.59 µg/L. The sharp increase in Cd concentration in 2023 at Sarabenga indicates a notable rise in contamination.

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. However, the no river is found to be the common river which experienced cadmium exceedance during both periods. The comparative analysis between the two periods indicates increase in cadmium exceedance, both in terms of the number of water quality stations and the diversity of rivers impacted during the period of 2023 compared to the preceding period (January- December 2022).

A GIS map depicting the stations where cadmium values were found above the acceptable limit during both study periods is shown as Figure 20.

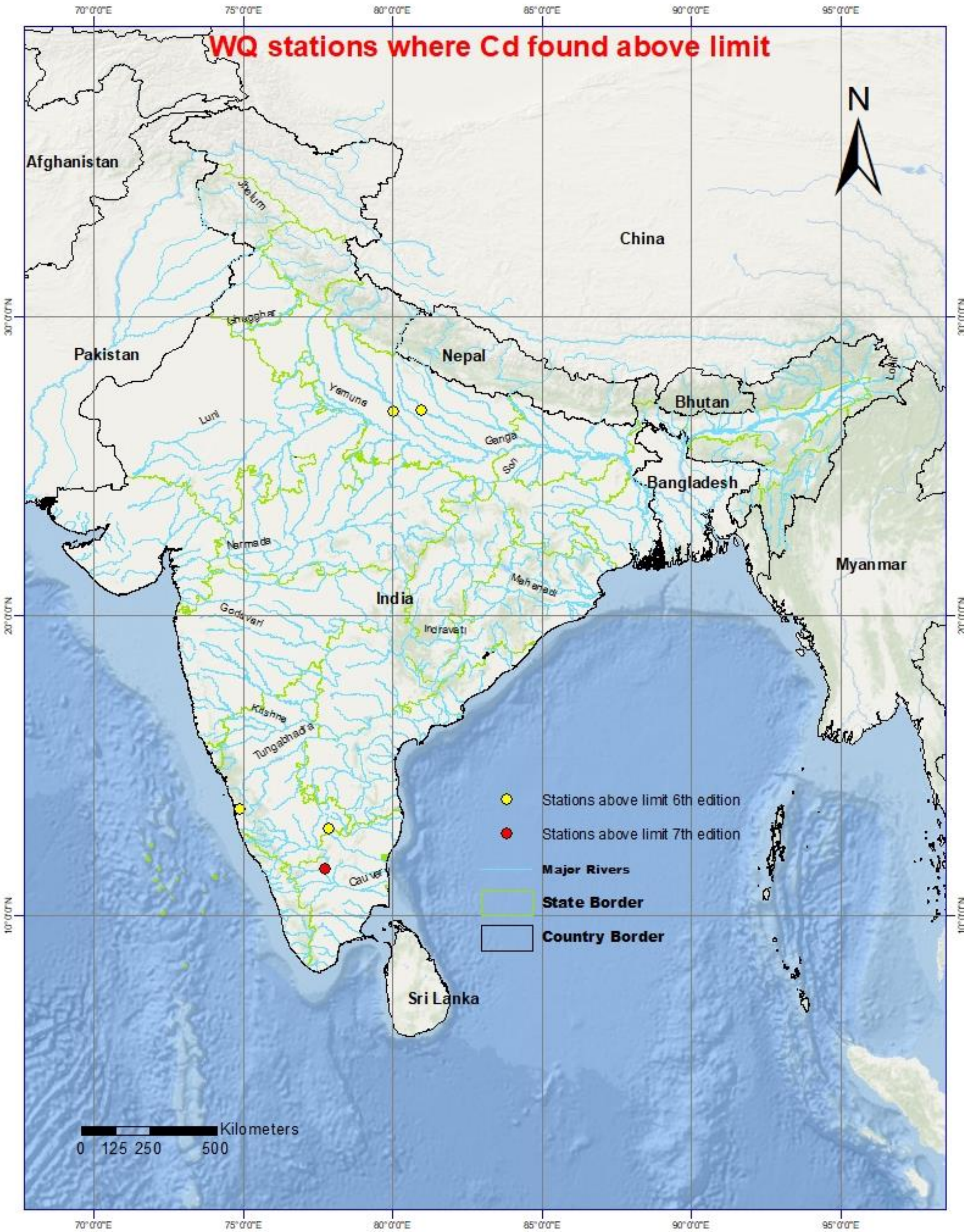

Figure 20: WQ stations where Cadmium found above acceptable limit (both study periods)

7.3 Chromium (Cr)

BIS (Bureau of Indian Standard) 10500:2012) has recommended an acceptable limit of 50 µg/L of chromium in drinking water. Out of total 5730 river water samples analysed, 87 samples from 27 water quality stations were found to have chromium concentrations beyond the acceptable limit. The chromium concentration varies from 0.000 to 84.61 µg/L. Maximum chromium concentration (84.61 µg/L) was observed at Biligundulu water quality monitoring station on Cauvery River on 12-06-2023.

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.

Sl. No.	River/tributary	Station	Date	Cr (µg/L)	State	District
1	Aliyar	Ambarampalayam	21-11-2023	69.632	Tamil Nadu	Coimbatore
			21-12-2023	80.441	Tamil Nadu	Coimbatore
2	Bhadra	Holehonnur	21-07-2023	72.350	Karnataka	Shimoga
3	Bhavani	Nellithurai	13-02-2023	63.230	Tamil Nadu	Coimbatore
		Savandapur	01-03-2023	77.480	Tamil Nadu	Erode
			21-04-2023	79.277	Tamil Nadu	Erode
			11-07-2023	79.823	Tamil Nadu	Erode
			01-11-2023	69.445	Tamil Nadu	Erode
			11-12-2023	73.656	Tamil Nadu	Erode
			21-12-2023	78.757	Tamil Nadu	Erode
4	Bhavani/Moyar	Thengumarahada	13-02-2023	65.646	Tamil Nadu	Nilgiris
			01-03-2023	69.244	Tamil Nadu	Nilgiris
			01-06-2023	70.867	Tamil Nadu	Nilgiris
			11-08-2023	71.936	Tamil Nadu	Nilgiris
			01-09-2023	80.087	Tamil Nadu	Nilgiris
			13-11-2023	83.727	Tamil Nadu	Nilgiris
			21-12-2023	61.775	Tamil Nadu	Nilgiris
5	Cauvery	Biligundulu	21-03-2023	74.287	Tamil Nadu	Krishnagiri
			01-05-2023	82.890	Tamil Nadu	Krishnagiri
			12-06-2023	84.618	Tamil Nadu	Krishnagiri
			21-07-2023	56.618	Tamil Nadu	Krishnagiri
			01-09-2023	56.018	Tamil Nadu	Krishnagiri
			01-11-2023	59.588	Tamil Nadu	Krishnagiri
		Kodumudi	11-07-2023	82.016	Tamil Nadu	Erode
			11-09-2023	80.468	Tamil Nadu	Erode
			11-10-2023	84.232	Tamil Nadu	Erode
			01-11-2023	60.259	Tamil Nadu	Erode
		Musiri	01-03-2023	56.921	Tamil Nadu	Thiruchirapalli
			21-07-2023	67.625	Tamil Nadu	Thiruchirapalli
			11-08-2023	70.917	Tamil Nadu	Thiruchirapalli

Sl. No.	River/tributary	Station	Date	Cr (µg/L)	State	District
			21-09-2023	60.632	Tamil Nadu	Thiruchirapalli
			01-12-2023	61.711	Tamil Nadu	Thiruchirapalli
		Urachikottai	27-03-2023	83.920	Tamil Nadu	Erode
			13-06-2023	78.483	Tamil Nadu	Erode
			21-07-2023	56.293	Tamil Nadu	Erode
			03-10-2023	57.24	Tamil Nadu	Erode
6	Chittar	Sevanur	09-05-2023	77.378	Tamil Nadu	Erode
7	Gandhayar	Gandhavayal	01-03-2023	75.210	Tamil Nadu	Coimbatore
			18-03-2023	83.618	Tamil Nadu	Coimbatore
			01-06-2023	80.311	Tamil Nadu	Coimbatore
			12-06-2023	65.706	Tamil Nadu	Coimbatore
			13-11-2023	76.67	Tamil Nadu	Coimbatore
			01-12-2023	67.624	Tamil Nadu	Coimbatore
			21-12-2023	59.166	Tamil Nadu	Coimbatore
8	Gataprabha	Gokak	21-07-2023	82.207	Karnataka	Belgaum
			12-09-2023	56.535	Karnataka	Belgaum
9	Kallar	Odenthurai	11-01-2023	66.183	Tamil Nadu	Coimbatore
			01-05-2023	68.582	Tamil Nadu	Coimbatore
			03-10-2023	70.68	Tamil Nadu	Coimbatore
10	Kodaganar	Lakshmanapatti	01-12-2023	79.695	Tamil Nadu	Dindigul
			11-12-2023	66.159	Tamil Nadu	Dindigul
			21-12-2023	55.808	Tamil Nadu	Dindigul
11	Marudaiyar	Varanavasi	06-11-2023	61.895	Tamil Nadu	Perambalur
12	Noyyal	Elunuthimangalam	11-07-2023	73.186	Tamil Nadu	Erode
			11-12-2023	60.696	Tamil Nadu	Erode
13	Palar	Avaramkuppam	21-01-2023	80.442	Tamil Nadu	Vellore
14	Ponnaiyar	Gummanur	02-01-2023	62.069	Tamil Nadu	Dharmapuri
			01-02-2023	69.432	Tamil Nadu	Dharmapuri
			01-03-2023	65.489	Tamil Nadu	Dharmapuri
			13-03-2023	57.735	Tamil Nadu	Dharmapuri
			01-11-2023	56.495	Tamil Nadu	Dharmapuri
			11-12-2023	76.231	Tamil Nadu	Dharmapuri
		Singasadanapalli	21-02-2023	74.172	Tamil Nadu	Dharmapuri
			01-07-2023	73.575	Tamil Nadu	Dharmapuri
			11-08-2023	75.474	Tamil Nadu	Dharmapuri
			21-12-2023	69.481	Tamil Nadu	Dharmapuri
15	Sarabenga	Thevur	02-01-2023	67.855	Tamil Nadu	Salem
			21-02-2023	57.721	Tamil Nadu	Salem
16	Suruliyar	Theni	21-03-2023	78.470	Tamil Nadu	Theni
			01-04-2023	57.508	Tamil Nadu	Theni
			01-09-2023	82.784	Tamil Nadu	Theni
			01-11-2023	58.356	Tamil Nadu	Theni
			21-11-2023	68.74	Tamil Nadu	Theni
17	Tambraparani	Murappanadu	21-02-2023	77.423	Tamil Nadu	Tuticorin
			11-04-2023	57.806	Tamil Nadu	Tuticorin
			12-06-2023	75.55	Tamil Nadu	Tuticorin

Sl. No.	River/tributary	Station	Date	Cr (µg/L)	State	District
			26-06-2023	55.615	Tamil Nadu	Tuticorin
			21-08-2023	70.767	Tamil Nadu	Tuticorin
18	Thoppaiyar	Thoppur	13-03-2023	56.597	Tamil Nadu	Salem
			21-04-2023	58.600	Tamil Nadu	Salem
19	Tungabhadra	Harahalli	21-07-2023	68.055	Karnataka	Haveri
			22-08-2023	56.427	Karnataka	Haveri
			14-11-2023	74.440	Karnataka	Haveri
		Honnali	12-09-2023	61.669	Karnataka	Davanagere
			21-11-2023	66.580	Karnataka	Davanagere
20	Vaigai	Paramakudi	28-11-2023	75.248	Tamil Nadu	Ramanathapuram
21	Yamuna	Delhi R. Bridge	13-03-2023	69.378	Delhi	North Delhi

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

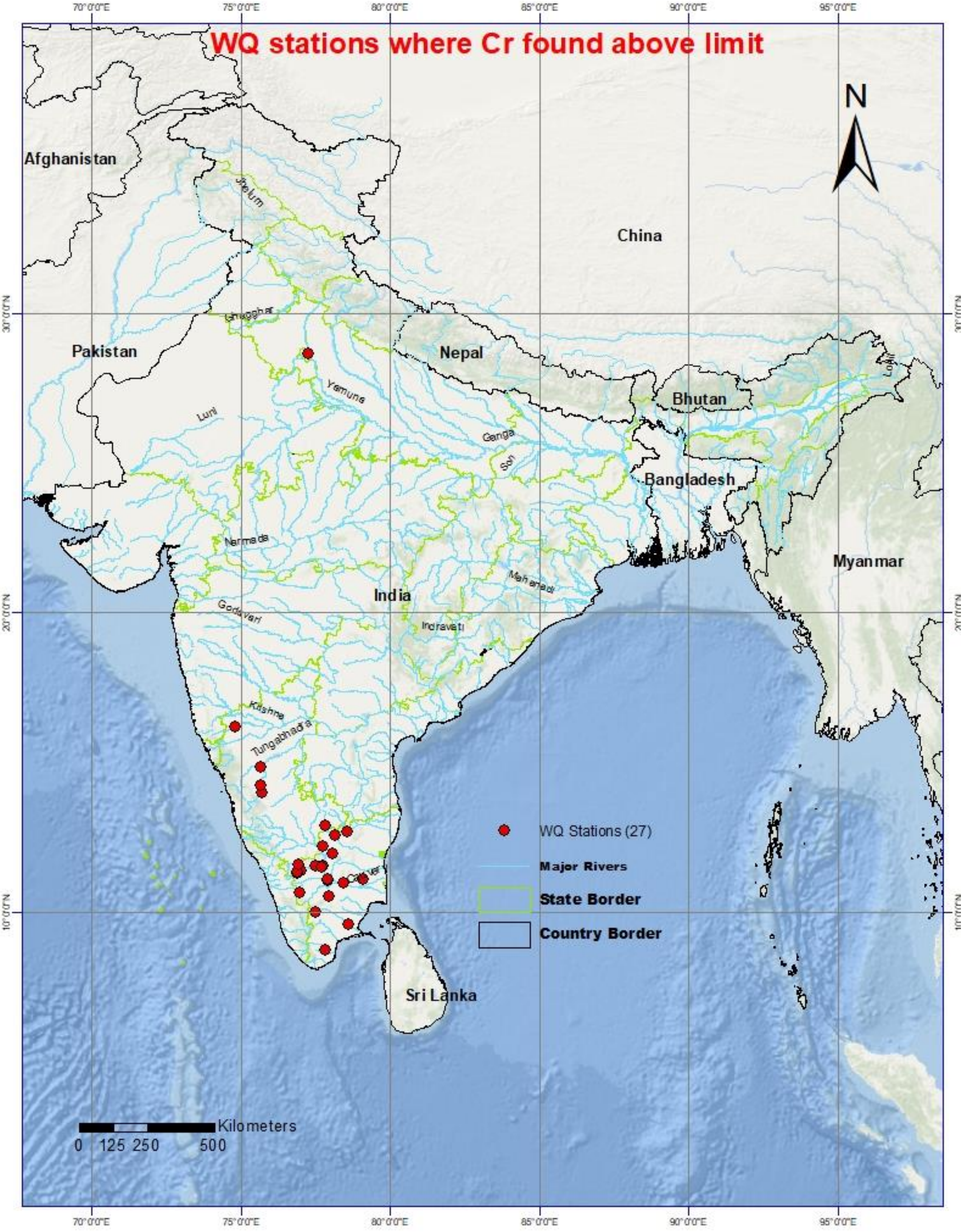

Figure 21: WQ stations where Chromium found above acceptable limit

Comparison with 6th edition (period: January-December, 2022)

In 2022, out of a total of 5,939 river water samples analyzed, 17 samples from 16 water quality stations exceeded the acceptable chromium limit of 50 µg/L, with concentrations ranging from 0.000 to 87.575 µg/L. 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 in 2022. The highest chromium concentration, 87.575 µg/L, was recorded at the Udaipur station on the Brahmaputra River on 21-12-2022.

In 2023, the number of samples exceeding the chromium limit significantly increased to 87 out of 5,730 river water samples analyzed, with concentrations ranging from 0.000 to 84.61 µg/L. The maximum chromium concentration of 84.61 µg/L was observed at the Biligundulu station on the Cauvery River on 12-06-2023. This comparison highlights a notable rise in both the number of stations exceeding the limit and the chromium concentrations in 2023 compared to 2022.

The Chromium concentration exceeded in 21 rivers i.e. Aliyar, Bhadra, Bhavani, Bhavani/Moyar, Cauvery, Chittar, Gandhayar, Gaprabha, Kallar, Kodaganar, Marudaiyar, Noyyal, Palar, Ponnaiyar, Sarabenga, Suruliyar, Tambraparani, Thoppaiyar, Tungabhadra, Vaigai, and Yamuna in 2023.

Common rivers in both years (2022 & 2023) include Cauvery, Tungabhadra, and Yamuna, indicating a continued and possibly worsening presence of chromium contamination in these river systems. Honnali is water quality station common in both years. There is one common water quality station with chromium exceedance in both reports. The Honnali water quality station at Tungabhadra River is the common water quality station. During December, 2020 chromium concentration observed was 139.66 µg/L and in September 2022, it was 78.271 µg/L, indicating a decreasing trend at water quality stations. The above-limit chromium concentrations at the common station are depicted in Figure 22.

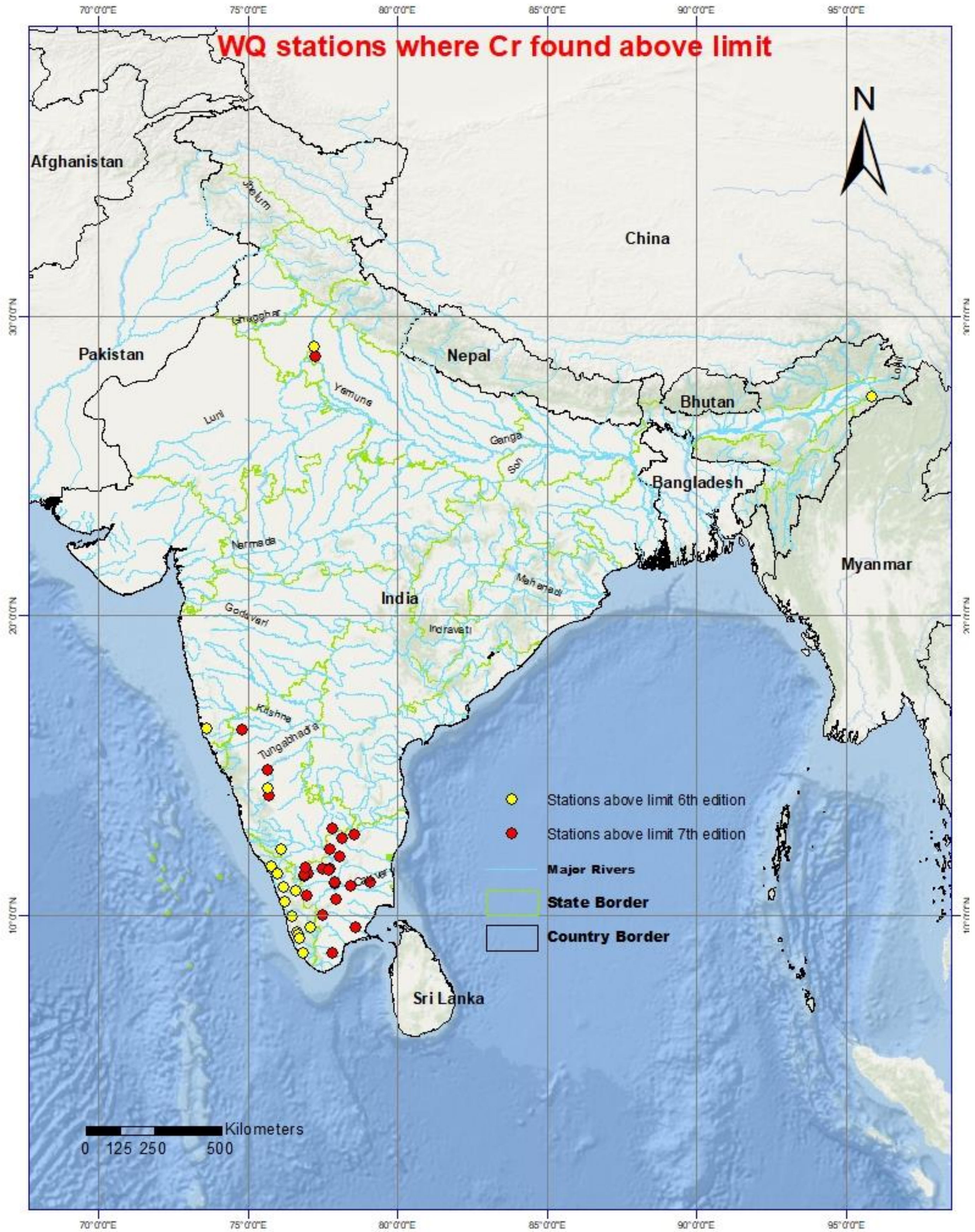

Figure 22: WQ stations where Chromium found above acceptable limit (both study periods)

7.4 Copper (Cu)

BIS (Bureau of Indian Standard) 10500:2012) has recommended an acceptable limit of 50 µg/L of copper in drinking water. Out of total 5940 river water samples analysed, 3 samples from 3 water quality stations were found to have copper concentrations beyond the acceptable limit. The copper concentration varies from 0.000 to 107.01 µg/L. Maximum copper concentration (107.01 µg/L) was observed at Nellithurai water quality monitoring station on Bhavani River on 13-02-2023.

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	Aliyar	Ambarampalayam	11-05-2023	66.37	Tamil Nadu	Coimbatore
2	Bhavani	Nellithurai	13-02-2023	107.01	Tamil Nadu	Coimbatore
3	Hindon	Noida	01-04-2023	102.81	Uttar Pradesh	Gautam Budh Nagar

Figure 23 represents a GIS map of WQ stations where Copper is found above acceptable limit.

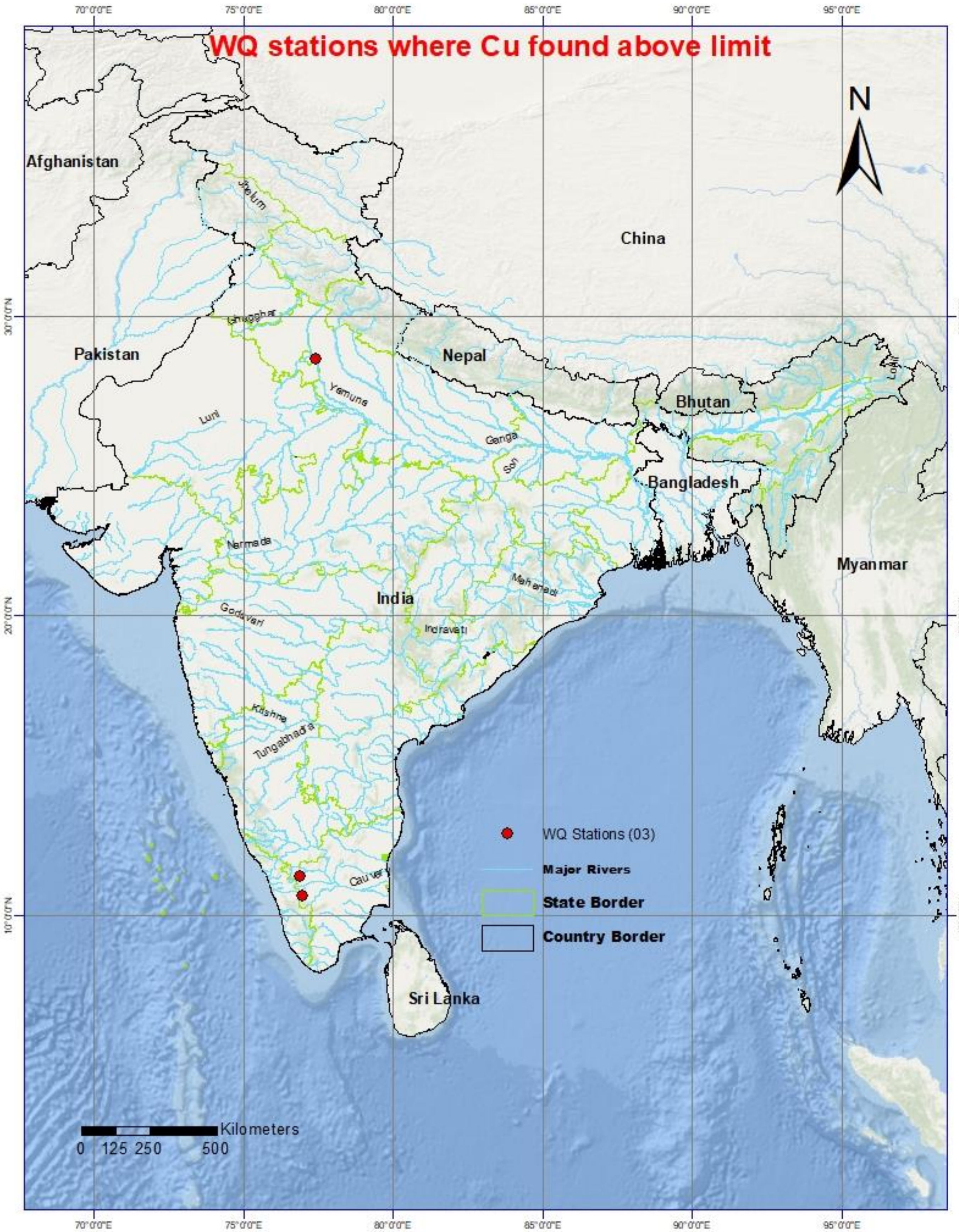

Figure 23: WQ stations where Copper found above acceptable limit

Comparison with 6th edition (period: January-December, 2022)

During the period from January-December, 2022, 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.

In 2023, among 5940 samples, only 3 samples from 3 stations exceeded the limit, indicating an improvement in compliance, though the maximum copper concentration increased to 107.01 µg/L, recorded at Nellithurai on the Bhavani River. This indicates that no station is common in between the previous study period and the 2022 period.

Figure 24 indicates a decrease in both the number of stations and rivers exceeding the acceptable limits of copper during the current study period.

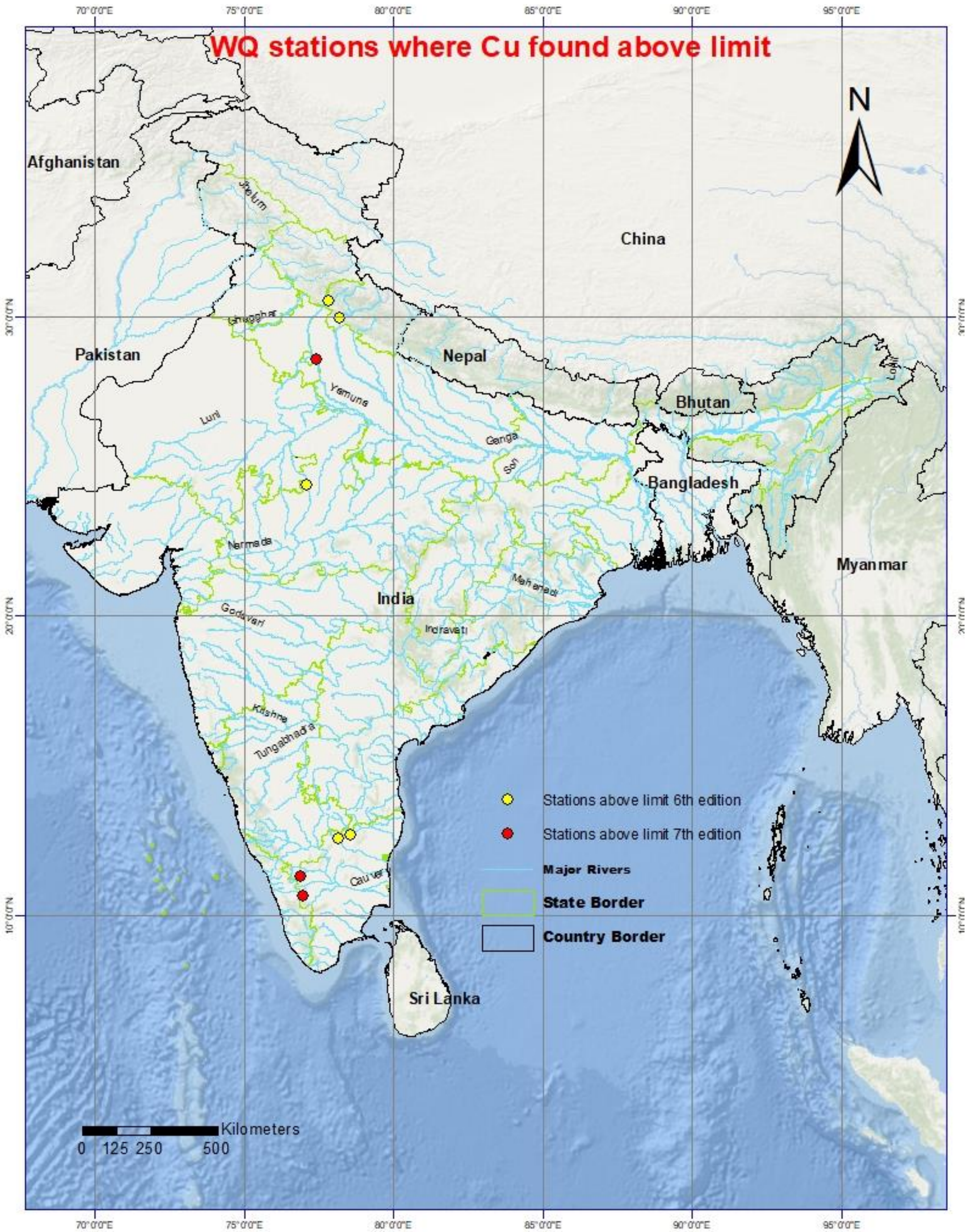

Figure 24: WQ stations where Copper found above acceptable limit (both study periods)

7.5 Iron (Fe)

BIS has recommended the acceptable limit of 1.0 mg/L (1000 µg/L) for Iron. Out of total 5768 river water samples analysed, 292 samples from 63 water quality stations were found to have iron concentrations beyond the acceptable limit. The iron concentration varies from 0.000 to 5.99 mg/L. Maximum iron concentration (5.99 mg/L) was observed at Murappanadu water quality monitoring station on Tambraparani River on 02.11.2023.

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

S.No.	River/ Reservoir	Water Quality Stations (data as received)	Date of Sampling	Fe (µg/L)	State	District
1	Aghnanashni	Santegulli	11.01.2023	3510.84	Karnataka	Uthara Kannada
			01.02.2023	2226.95	Karnataka	Uthara Kannada
2	Aliyar	Ambarampalayam	01-06-2023	3747.83	Tamil Nadu	Coimbatore
			21-06-2023	4413.26	Tamil Nadu	Coimbatore
			01-07-2023	4395.99	Tamil Nadu	Coimbatore
			01-08-2023	2946.86	Tamil Nadu	Coimbatore
			11-08-2023	2155.52	Tamil Nadu	Coimbatore
			01-09-2023	1559.99	Tamil Nadu	Coimbatore
			11-09-2023	5110.81	Tamil Nadu	Coimbatore
			21-09-2023	3613.02	Tamil Nadu	Coimbatore
			03-10-2023	3147.73	Tamil Nadu	Coimbatore
			01-11-2023	5408.77	Tamil Nadu	Coimbatore
			13-11-2023	2912.06	Tamil Nadu	Coimbatore
			21-11-2023	1502.90	Tamil Nadu	Coimbatore
			11-12-2023	3424.02	Tamil Nadu	Coimbatore
			21-12-2023	3243.49	Tamil Nadu	Coimbatore
3	Amaravathi	Nallamaranpatti	02-01-2023	4502.88	Tamil Nadu	Karur
			11-01-2023	2419.20	Tamil Nadu	Karur
			21-12-2023	5800.80	Tamil Nadu	Karur
4	Arasalar	Porakudi	21-11-2023	1772.49	Tamil Nadu	Nagapattinam
5	Bhadra	Holehonnur	23-05-2023	3833.53	Karnataka	Shimoga
			21-07-2023	2362.50	Karnataka	Shimoga
		Lakkavalli	04-07-2023	2058.16	Karnataka	Chikamagaliur
			11-07-2023	3243.72	Karnataka	Chikamagaliur
			21-07-2023	2981.15	Karnataka	Chikamagaliur
6	Bhavani	Savandapur	13-02-2023	1798.42	Tamil Nadu	Erode
			22-05-2023	1930.77	Tamil Nadu	Erode
			01-07-2023	2979.58	Tamil Nadu	Erode
			11-07-2023	2306.58	Tamil Nadu	Erode
			21-07-2023	4722.85	Tamil Nadu	Erode
			01-08-2023	3085.85	Tamil Nadu	Erode
			11-08-2023	3949.92	Tamil Nadu	Erode
			01-09-2023	3146.05	Tamil Nadu	Erode
			11-09-2023	2182.90	Tamil Nadu	Erode
			21-10-2023	1967.08	Tamil Nadu	Erode
			01-11-2023	1753.06	Tamil Nadu	Erode
			21-11-2023	2615.48	Tamil Nadu	Erode

S.No.	River/ Reservoir	Water Quality Stations (data as received)	Date of Sampling	Fe (µg/L)	State	District
			11-12-2023	2673.56	Tamil Nadu	Erode
			21-12-2023	3038.74	Tamil Nadu	Erode
7	Bhavani/Moyar	Thengumarahada	01-07-2023	3321.13	Tamil Nadu	Nilgiris
			11-07-2023	2437.27	Tamil Nadu	Nilgiris
			21-07-2023	2169.89	Tamil Nadu	Nilgiris
			01-08-2023	5442.19	Tamil Nadu	Nilgiris
			11-08-2023	2436.66	Tamil Nadu	Nilgiris
			21-08-2023	1956.88	Tamil Nadu	Nilgiris
			01-09-2023	4096.30	Tamil Nadu	Nilgiris
			11-09-2023	5389.15	Tamil Nadu	Nilgiris
			21-09-2023	2547.92	Tamil Nadu	Nilgiris
			11-10-2023	1888.22	Tamil Nadu	Nilgiris
			21-10-2023	3045.59	Tamil Nadu	Nilgiris
			13-11-2023	2253.37	Tamil Nadu	Nilgiris
			01-12-2023	4100.82	Tamil Nadu	Nilgiris
			21-12-2023	2781.11	Tamil Nadu	Nilgiris
8	Cauvery	Biligundulu	02-01-2023	3119.34	Tamil Nadu	Krishnagiri
			21-03-2023	1795.96	Tamil Nadu	Krishnagiri
			22-05-2023	1661.30	Tamil Nadu	Krishnagiri
			01-06-2023	4013.20	Tamil Nadu	Krishnagiri
			01-07-2023	3084.56	Tamil Nadu	Krishnagiri
			11-07-2023	2937.62	Tamil Nadu	Krishnagiri
			21-07-2023	1547.08	Tamil Nadu	Krishnagiri
			01-08-2023	3137.05	Tamil Nadu	Krishnagiri
			21-08-2023	1535.81	Tamil Nadu	Krishnagiri
			01-09-2023	1832.14	Tamil Nadu	Krishnagiri
			11-09-2023	3328.66	Tamil Nadu	Krishnagiri
			21-09-2023	2842.15	Tamil Nadu	Krishnagiri
			01-11-2023	2646.52	Tamil Nadu	Krishnagiri
			13-11-2023	5394.09	Tamil Nadu	Krishnagiri
			21-11-2023	1840.70	Tamil Nadu	Krishnagiri
			01-12-2023	2014.13	Tamil Nadu	Krishnagiri
			11-12-2023	3932.70	Tamil Nadu	Krishnagiri
		Kodumudi	11-05-2023	2748.49	Tamil Nadu	Erode
			21-06-2023	1564.11	Tamil Nadu	Erode
			01-07-2023	2933.87	Tamil Nadu	Erode
			21-07-2023	1603.53	Tamil Nadu	Erode
			01-08-2023	4193.98	Tamil Nadu	Erode
			21-08-2023	2095.60	Tamil Nadu	Erode
			01-09-2023	2155.28	Tamil Nadu	Erode
			11-09-2023	3259.55	Tamil Nadu	Erode
			01-11-2023	2323.84	Tamil Nadu	Erode
			01-12-2023	5821.59	Tamil Nadu	Erode
			11-12-2023	1834.81	Tamil Nadu	Erode
			21-12-2023	4128.44	Tamil Nadu	Erode
		Kollegal	21-11-2023	2948.10	KARNATAKA	Chamarajanagar
		Kudige	04-07-2023	1829.65	KARNATAKA	Kodugu
			11-07-2023	1923.42	KARNATAKA	Kodugu
			21-07-2023	3718.85	KARNATAKA	Kodugu
			14-11-2023	2057.20	KARNATAKA	Kodugu
		Musiri	21-02-2023	2039.50	Tamil Nadu	Thiruchirapalli
			22-05-2023	2478.71	Tamil Nadu	Thiruchirapalli
			12-06-2023	2517.38	Tamil Nadu	Thiruchirapalli
			21-06-2023	5239.36	Tamil Nadu	Thiruchirapalli
			11-07-2023	5131.01	Tamil Nadu	Thiruchirapalli

S.No.	River/ Reservoir	Water Quality Stations (data as received)	Date of Sampling	Fe (µg/L)	State	District
			11-08-2023	3552.42	Tamil Nadu	Thiruchirapalli
			01-09-2023	1988.47	Tamil Nadu	Thiruchirapalli
			11-09-2023	3685.20	Tamil Nadu	Thiruchirapalli
			21-09-2023	4269.41	Tamil Nadu	Thiruchirapalli
			11-10-2023	1751.99	Tamil Nadu	Thiruchirapalli
			13-11-2023	2316.85	Tamil Nadu	Thiruchirapalli
			01-12-2023	3406.89	Tamil Nadu	Thiruchirapalli
			21-12-2023	5908.02	Tamil Nadu	Thiruchirapalli
		Urachikottai	11-01-2023	2080.61	Tamil Nadu	Erode
			21-01-2023	1586.38	Tamil Nadu	Erode
			21-06-2023	4113.82	Tamil Nadu	Erode
			01-07-2023	2096.29	Tamil Nadu	Erode
			21-07-2023	2915.60	Tamil Nadu	Erode
			21-08-2023	2505.31	Tamil Nadu	Erode
			01-09-2023	2465.13	Tamil Nadu	Erode
			11-09-2023	2300.06	Tamil Nadu	Erode
9	Chalakkudy	Arangaly	21-07-2023	1918.25	Kerala	Trichur
10	Chittar	AP Puram	05-12-2023	3063.77	Tamil Nadu	Tirunelveli
			22-12-2023	5582.83	Tamil Nadu	Tirunelveli
		Sevanur	02-01-2023	1588.40	Tamil Nadu	Erode
			09-11-2023	1897.35	Tamil Nadu	Erode
11	Gad	Belne Bridge	21-07-2023	4531.19	Maharashtra	Sindhudurg
			11-08-2023	1973.73	Maharashtra	Sindhudurg
12	Gandhayar	Gandhavayal	21-01-2023	3659.52	Tamil Nadu	Coimbatore
			11-05-2023	2647.45	Tamil Nadu	Coimbatore
			11-07-2023	1900.70	Tamil Nadu	Coimbatore
			21-09-2023	1627.77	Tamil Nadu	Coimbatore
			01-11-2023	2950.81	Tamil Nadu	Coimbatore
			13-11-2023	1793.28	Tamil Nadu	Coimbatore
			01-12-2023	2750.10	Tamil Nadu	Coimbatore
			21-12-2023	3805.57	Tamil Nadu	Coimbatore
13	Godavari	Bhadrachalam	01-08-2023	1534.14	Telangana	Khammam
			11-09-2023	1595.51	Telangana	Khammam
		Perur	10-08-2023	1549.48	Telangana	Khammam
			25-09-2023	1531.69	Telangana	Khammam
14	Hemavathy	Sakleshpur	11-05-2023	2949.88	Karnataka	Hassan
			23-05-2023	4139.36	Karnataka	Hassan
			04-07-2023	2368.91	Karnataka	Hassan
			11-07-2023	1722.90	Karnataka	Hassan
			01-08-2023	2696.09	Karnataka	Hassan
			11-08-2023	2155.76	Karnataka	Hassan
15	Hindon	Noida	01-04-2023	5077.94	Uttar Pradesh	Gautam Budh Nagar
			03-10-2023	1972.11	Uttar Pradesh	Gautam Budh Nagar
			21-06-2023	1691.37	Uttar Pradesh	Gautam Budh Nagar
16	Indravathi	Nowrangpur	13-11-2023	2166.35	Odisha	Nowrangpur
17	Iruvazhinjipuzha	Thotathinkadavu	11.01.2023	1592.77	Kerala	Kozhikode
			12-06-2023	1534.66	Kerala	Kozhikode
			11-08-2023	1874.08	Kerala	Kozhikode
18	Kabini	Muthanakera	11-05-2023	2297.25	KERALA	Wyanad
			23-05-2023	3813.59	KERALA	Wyanad
			01-06-2023	1526.50	KERALA	Wyanad
			11-07-2023	1510.70	KERALA	Wyanad
			01-08-2023	1538.14	KERALA	Wyanad
			11-08-2023	1846.89	KERALA	Wyanad
			22-08-2023	1671.95	KERALA	Wyanad

S.No.	River/ Reservoir	Water Quality Stations (data as received)	Date of Sampling	Fe (µg/L)	State	District
		T N Pura	11-05-2023	1913.31	Karnataka	Mysore
			21-11-2023	1892.16	Karnataka	Mysore
19	Kadalundi	Karathode	01-11-2023	1644.29	Kerala	Malappuram
20	Kaliyar	Kalampur	11.01.2023	1702.25	Kerala	Ernakulam
			01.02.2023	2325.24	Kerala	Ernakulam
21	Kallada	Pattazhy	11.01.2023	2294.28	Kerala	Kollam
			01.03.2023	2359.36	Kerala	Kollam
22	Kallar	Odenthurai	21-06-2023	2009.93	Tamil Nadu	Coimbatore
			01-07-2023	3843.14	Tamil Nadu	Coimbatore
			11-07-2023	1538.92	Tamil Nadu	Coimbatore
			21-07-2023	2130.96	Tamil Nadu	Coimbatore
			04-09-2023	5119.08	Tamil Nadu	Coimbatore
			11-09-2023	1655.84	Tamil Nadu	Coimbatore
			21-10-2023	1964.14	Tamil Nadu	Coimbatore
			13-11-2023	5201.63	Tamil Nadu	Coimbatore
			21-11-2023	1575.26	Tamil Nadu	Coimbatore
			01-12-2023	3124.76	Tamil Nadu	Coimbatore
			11-12-2023	2611.07	Tamil Nadu	Coimbatore
			21-12-2023	1796.89	Tamil Nadu	Coimbatore
23	Kannadipuzha	Pudur	11.01.2023	1992.31	Kerala	Palakkad
24	Kodaganar	Lakshmanapatti	22-09-2023	5496.08	Tamil Nadu	Dindigul
			21-10-2023	2838.50	Tamil Nadu	Dindigul
			01-11-2023	1665.01	Tamil Nadu	Dindigul
			13-11-2023	2660.36	Tamil Nadu	Dindigul
			11-12-2023	5884.04	Tamil Nadu	Dindigul
			21-12-2023	1856.41	Tamil Nadu	Dindigul
25	Kumudvathi	Kuppelur	01-08-2023	2957.56	Karnataka	Haveri
26	Kutiyadi	Kuttiyadi	01.02.2023	2062.52	Kerala	Kozhikode
			11.04.2023	2018.26	Kerala	Kozhikode
27	Laxmanathirtha	K M Vadi	11-07-2023	5797.19	Karnataka	Mysore
			21-07-2023	1571.92	Karnataka	Mysore
			01-08-2023	2066.62	Karnataka	Mysore
28	Marudaiyar	Varanavasi	30-08-2023	1557.26	Tamil Nadu	Perambalur
			13-09-2023	2692.94	Tamil Nadu	Perambalur
			06-11-2023	2084.66	Tamil Nadu	Perambalur
29	Meenachil	Kidangoor	01.02.2023	1724.01	Kerala	Kottayam
30	Muvattupuzha	Ramamangalam	11.01.2023	2944.04	Kerala	Ernakulam
			01.02.2023	2113.00	Kerala	Ernakulam
31	Nandalar	Nallathur	14-11-2023	1563.72	Pondicherry	Karaikal
32	Noyyal	Alandurai	21-07-2023	3844.86	Tamil Nadu	Coimbatore
			03-10-2023	5664.97	Tamil Nadu	Coimbatore
		Elunuthimangalam	02-01-2023	1878.60	Tamil Nadu	Erode
			01-06-2023	1645.16	Tamil Nadu	Erode
			21-06-2023	1528.79	Tamil Nadu	Erode
			01-07-2023	4049.93	Tamil Nadu	Erode
			11-07-2023	2422.68	Tamil Nadu	Erode
			01-09-2023	3287.99	Tamil Nadu	Erode
			11-10-2023	1849.03	Tamil Nadu	Erode
			01-11-2023	5060.38	Tamil Nadu	Erode
			11-12-2023	3034.95	Tamil Nadu	Erode
			21-12-2023	4731.08	Tamil Nadu	Erode
33	Palar	Avaramkuppam	02-01-2023	2466.17	Tamil Nadu	Vellore
34	Pampa	Madamon	11.01.2023	2135.10	Kerala	Pathanamthitta
			01.05.2023	1565.19	Kerala	Pathanamthitta
		Malakkara	01.05.2023	2174.78	Kerala	Pathanamthitta

S.No.	River/ Reservoir	Water Quality Stations (data as received)	Date of Sampling	Fe (µg/L)	State	District
35	Payaswani	Erinjipuzha	01.02.2023	1505.36	kerala	Kasargod
36	Ponnaiyar	Gummanur	01-06-2023	2269.54	Tamil Nadu	Dharmapuri
			21-06-2023	1663.37	Tamil Nadu	Dharmapuri
			01-07-2023	3870.23	Tamil Nadu	Dharmapuri
			11-07-2023	2549.87	Tamil Nadu	Dharmapuri
			21-07-2023	1874.55	Tamil Nadu	Dharmapuri
			11-08-2023	2654.56	Tamil Nadu	Dharmapuri
			01-09-2023	1621.09	Tamil Nadu	Dharmapuri
			11-09-2023	4493.35	Tamil Nadu	Dharmapuri
			11-10-2023	2121.95	Tamil Nadu	Dharmapuri
			01-11-2023	4305.54	Tamil Nadu	Dharmapuri
			13-11-2023	3093.82	Tamil Nadu	Dharmapuri
			21-11-2023	3176.69	Tamil Nadu	Dharmapuri
			11-12-2023	3687.79	Tamil Nadu	Dharmapuri
			21-12-2023	4718.21	Tamil Nadu	Dharmapuri
		Singasadanapalli	02-01-2023	3109.50	Tamil Nadu	Dharmapuri
			01-06-2023	4088.92	Tamil Nadu	Dharmapuri
			01-07-2023	2349.78	Tamil Nadu	Dharmapuri
			11-07-2023	2524.78	Tamil Nadu	Dharmapuri
			21-07-2023	2411.64	Tamil Nadu	Dharmapuri
			01-08-2023	3353.77	Tamil Nadu	Dharmapuri
			11-08-2023	4668.62	Tamil Nadu	Dharmapuri
			01-09-2023	2033.18	Tamil Nadu	Dharmapuri
			11-09-2023	4354.51	Tamil Nadu	Dharmapuri
			21-09-2023	3806.69	Tamil Nadu	Dharmapuri
			13-11-2023	4571.55	Tamil Nadu	Dharmapuri
			21-12-2023	2823.22	Tamil Nadu	Dharmapuri
37	Rind	Kora	11-07-2023	2396.78	Uttar Pradesh	Fatehpur
			21-07-2023	2236.85	Uttar Pradesh	Fatehpur
38	Sarabenga	Thevur	06-11-2023	2632.27	Tamil Nadu	Salem
			13-11-2023	3362.80	Tamil Nadu	Salem
			21-12-2023	5858.98	Tamil Nadu	Salem
39	Sindh	Pachawali	01-07-2023	1626.56	Madhya Pradesh	Shivpuri
40	Suruliyar	Theni	01-03-2023	1744.48	Tamil Nadu	Theni
			21-04-2023	2056.15	Tamil Nadu	Theni
			02-06-2023	2177.36	Tamil Nadu	Theni
			12-06-2023	4063.18	Tamil Nadu	Theni
			04-07-2023	1815.03	Tamil Nadu	Theni
			21-07-2023	3659.22	Tamil Nadu	Theni
			11-08-2023	4302.30	Tamil Nadu	Theni
			21-08-2023	3284.12	Tamil Nadu	Theni
			01-09-2023	2428.98	Tamil Nadu	Theni
			13-09-2023	3108.00	Tamil Nadu	Theni
			21-09-2023	2701.72	Tamil Nadu	Theni
			03-10-2023	2618.16	Tamil Nadu	Theni
			21-10-2023	2439.92	Tamil Nadu	Theni
			21-11-2023	1779.32	Tamil Nadu	Theni
			01-12-2023	4065.00	Tamil Nadu	Theni
			11-12-2023	1920.79	Tamil Nadu	Theni
			21-12-2023	5711.33	Tamil Nadu	Theni
41	Suvarnavathy	Bendarahalli	23-05-2023	1714.27	Karnataka	Chamarajanagar
			11-07-2023	3996.81	Karnataka	Chamarajanagar
			21-07-2023	4213.09	Karnataka	Chamarajanagar
42	Tambraparani	Murappanadu	01-06-2023	1766.12	Tamil Nadu	Tuticorin
			21-07-2023	3256.26	Tamil Nadu	Tuticorin

S.No.	River/ Reservoir	Water Quality Stations (data as received)	Date of Sampling	Fe (µg/L)	State	District
			11-08-2023	1883.71	Tamil Nadu	Tuticorin
			21-08-2023	1664.05	Tamil Nadu	Tuticorin
			01-09-2023	1706.79	Tamil Nadu	Tuticorin
			21-09-2023	3170.01	Tamil Nadu	Tuticorin
			03-10-2023	3823.17	Tamil Nadu	Tuticorin
			11-10-2023	1973.64	Tamil Nadu	Tuticorin
			02-11-2023	5995.14	Tamil Nadu	Tuticorin
			21-11-2023	4284.68	Tamil Nadu	Tuticorin
			01-12-2023	3832.83	Tamil Nadu	Tuticorin
			11-12-2023	5040.16	Tamil Nadu	Tuticorin
43	Tunga	Hariharapura	04-07-2023	3986.23	Karnataka	Chikamagaliur
			11-07-2023	2466.86	Karnataka	Chikamagaliur
			21-07-2023	2894.80	Karnataka	Chikamagaliur
44	Tungabhadra	Harahalli	11-07-2023	2302.95	Karnataka	Haveri
			21-07-2023	2002.85	Karnataka	Haveri
		Honnali	11-07-2023	1951.07	Karnataka	Davanagere
			21-07-2023	4554.45	Karnataka	Davanagere
45	Vaigai	Ambasamudram	13-11-2023	2415.24	Tamil Nadu	Theni
			21-11-2023	3648.16	Tamil Nadu	Theni
			11-12-2023	3791.60	Tamil Nadu	Theni
			21-12-2023	5468.39	Tamil Nadu	Theni
		Paramakudi	28-11-2023	2856.96	Tamil Nadu	Ramanathapuram
			01-12-2023	2327.10	Tamil Nadu	Ramanathapuram
			21-12-2023	2888.89	Tamil Nadu	Ramanathapuram
46	Vaippar	Irrukkankudi	12-06-2023	2483.09	Tamil Nadu	Virudhunagar
			13-11-2023	2641.95	Tamil Nadu	Virudhunagar
			01-12-2023	1520.52	Tamil Nadu	Virudhunagar
			21-12-2023	4283.91	Tamil Nadu	Virudhunagar
47	Valapatnam	Perumannu	01.02.2023	1629.40	Kerala	Cannanore
			11.04.2023	1931.65	Kerala	Cannanore
48	Varada	Marol	21-07-2023	4327.57	Karnataka	Haveri
			01-08-2023	2413.55	Karnataka	Haveri
			11-08-2023	2850.68	Karnataka	Haveri
49	Yagachi	Thimmanahalli	11-05-2023	4518.58	Karnataka	Hassan
			23-05-2023	2148.55	Karnataka	Hassan

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 25 depicts the GIS map of WQ stations where Iron is found to be above limit.

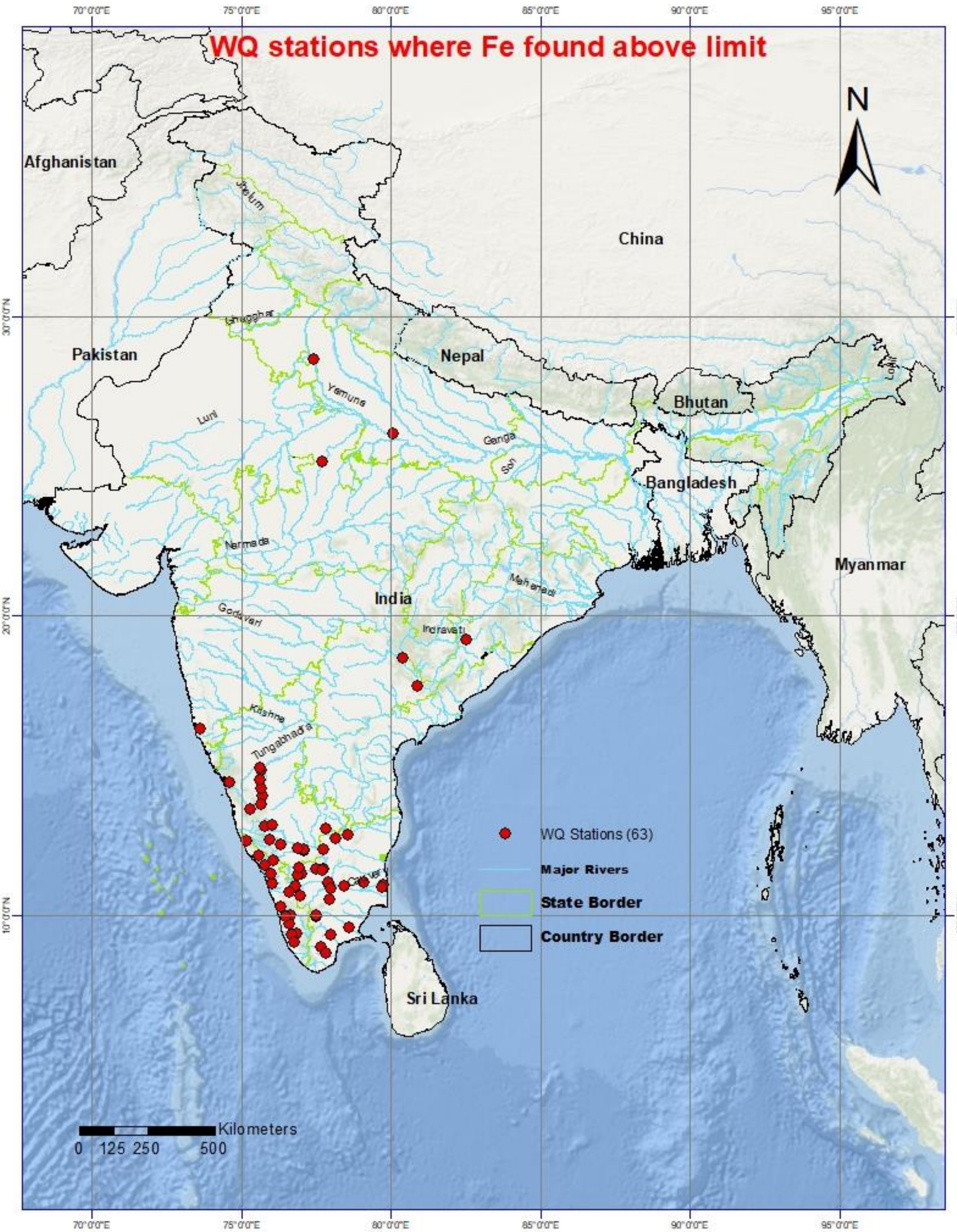

Figure 25: WQ stations where Iron found above acceptable limit

Comparison with 6th edition (period: January-December, 2022)

In the 6th edition, 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.

During the 2023 total 5768 river water samples analysed, 292 samples from 63 water quality stations were found to have iron concentrations beyond the acceptable limit. However, 5.06 % of the total samples analysed are found to exceed the limit (292 samples out of 5768). These samples were collected from 292 water quality monitoring stations across 49 rivers. The iron concentration varies from 0.000 to 5.99 mg/L. Maximum iron concentration (5.99 mg/L) was observed at Murappanadu water quality monitoring station on Tambraparani River on 02.11.2023.

These findings indicate a higher percentage of samples exceeding the limit in 2023 but a reduction in peak contamination levels compared to 2022.

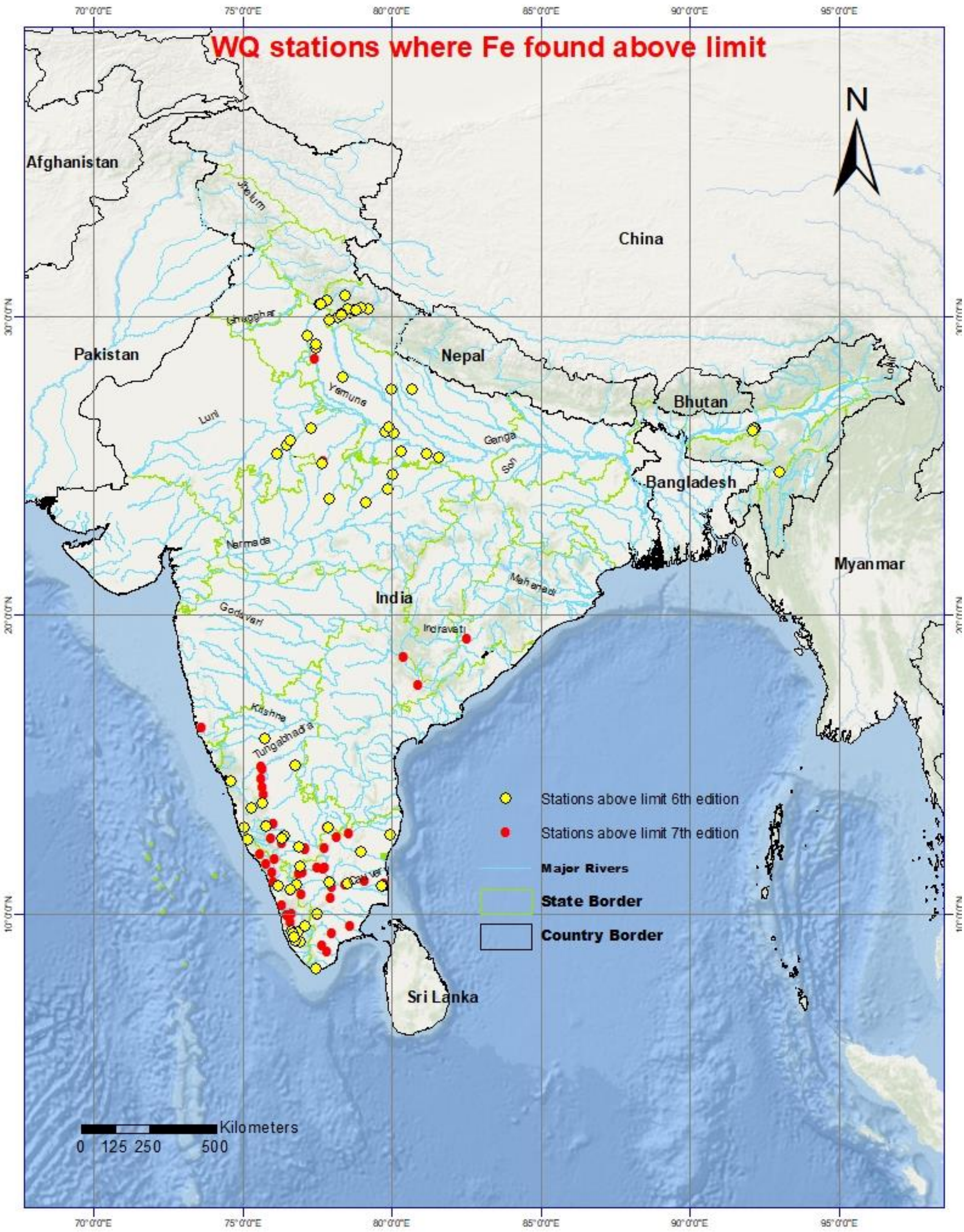

Figure 26: WQ stations where Iron found above acceptable limit (both study periods)

7.6 Lead (Pb)

Bureau of Indian Standard (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 5890 river water samples analysed, 76 samples from 23 water quality stations were found to have lead concentrations beyond the acceptable limit. The lead concentration varies from 0.000 to 75.51 µg/L. Maximum lead concentration (75.51 µg/L) was observed at Kudige water quality monitoring station on Cauvery River on 14-11-2023.

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	Aliyar	Ambarampalayam	21-03-2023	13.831	Tamil Nadu	Coimbatore
			11-12-2023	20.264	Tamil Nadu	Coimbatore
2	Arkavathy	Koggedoddi	12-01-2023	23.147	Karnataka	Ramanagara
			21-02-2023	23.146	Karnataka	Ramanagara
			11-05-2023	12.943	Karnataka	Ramanagara
		T Bekuppe	03-01-2023	14.114	Karnataka	Ramanagara
			12-09-2023	34.689	Karnataka	Ramanagara
			14-11-2023	16.331	Karnataka	Ramanagara
3	Bhadra	Holehonnur	01-06-2023	22.327	Karnataka	Shimoga
			21-07-2023	25.641	Karnataka	Shimoga
4	Bhavani	Savandapur	21-01-2023	11.198	Tamil Nadu	Erode
			01-09-2023	12.711	Tamil Nadu	Erode
			11-09-2023	11.137	Tamil Nadu	Erode
5	Bhavani/Moyar	Thengumarahada	01-04-2023	12.667	Tamil Nadu	Nilgiris
			11-08-2023	22.292	Tamil Nadu	Nilgiris
			11-12-2023	17.257	Tamil Nadu	Nilgiris
6	Cauvery	Kudige	24-01-2023	18.316	Karnataka	Kodugu
			01-02-2023	21.502	Karnataka	Kodugu
			14-02-2023	18.308	Karnataka	Kodugu
			11-05-2023	40.296	Karnataka	Kodugu
			22-08-2023	12.648	Karnataka	Kodugu
			01-11-2023	74.717	Karnataka	Kodugu
			14-11-2023	75.514	Karnataka	Kodugu
7	Gandhayar	Gandhavayal	21-09-2023	15.949	Tamil Nadu	Coimbatore
			11-12-2023	19.498	Tamil Nadu	Coimbatore
8	Ganga/Yamuna	Kalindi Kunj	13-03-2023	20.427	Delhi	East Delhi
9	Hemavathy	Sakleshpur	12-09-2023	12.845	Karnataka	Hassan
			01-11-2023	31.47	Karnataka	Hassan
			14-11-2023	46.463	Karnataka	Hassan
			21-11-2023	17.790	Karnataka	Hassan
10	Jhelum	Ram Munshi Bagh	01-04-2023	33.613	Jammu & Kashmir	Srinagar
			21-12-2023	11.149	Jammu & Kashmir	Srinagar
			21-06-2023	11.17	Jammu & Kashmir	Srinagar

Sl. No.	River/tributary	Station	Date	Pb (µg/L)	State	District
11	Kallada	Pattazhy	11.04.2023	12.910	Kerala	Kollam
			01-12-2023	15.126	Kerala	Kollam
12	Kannadipuzha	Pudur	21-06-2023	52.876	Kerala	Palakkad
			01-07-2023	49.661	Kerala	Palakkad
			11-07-2023	50.666	Kerala	Palakkad
			45128	51.63	Kerala	Palakkad
			01-08-2023	49.538	Kerala	Palakkad
			11-08-2023	47.671	Kerala	Palakkad
			01-09-2023	46.399	Kerala	Palakkad
			11-09-2023	54.893	Kerala	Palakkad
			21-09-2023	48.193	Kerala	Palakkad
			03-10-2023	73.428	Kerala	Palakkad
			11-10-2023	57.385	Kerala	Palakkad
			21-10-2023	60.497	Kerala	Palakkad
			01-11-2023	59.551	Kerala	Palakkad
			11-11-2023	67.403	Kerala	Palakkad
			21-11-2023	57.21	Kerala	Palakkad
13	Karuvannur	Palakkadavu	03-10-2023	49.503	Kerala	Thrissur
14	Ponnaiyar	Gummanur	21-01-2023	16.213	Tamil Nadu	Dharmapuri
			11-09-2023	15.093	Tamil Nadu	Dharmapuri
		Singasadanapalli	01-04-2023	13.333	Tamil Nadu	Dharmapuri
			21-04-2023	11.276	Tamil Nadu	Dharmapuri
			11-09-2023	18.334	Tamil Nadu	Dharmapuri
			21-09-2023	15.601	Tamil Nadu	Dharmapuri
			01-12-2023	13.649	Tamil Nadu	Dharmapuri
			11-12-2023	18.975	Tamil Nadu	Dharmapuri
15	Sarabenga	Thevur	01-02-2023	16.219	Tamil Nadu	Salem
			11-12-2023	15.155	Tamil Nadu	Salem
16	Shimsha	T.K. Halli	03-01-2023	13.655	Karnataka	Mandya
			01-11-2023	23.725	Karnataka	Mandya
			14-11-2023	21.789	Karnataka	Mandya
17	Suruliyar	Theni	21-01-2023	14.465	Tamil Nadu	Theni
			13-02-2023	14.937	Tamil Nadu	Theni
			01-09-2023	11.745	Tamil Nadu	Theni
			01-12-2023	11.665	Tamil Nadu	Theni
18	Tungabhadra	Harahalli	24-01-2023	24.606	Karnataka	Haveri
			14-02-2023	14.111	Karnataka	Haveri
			21-07-2023	26.636	Karnataka	Haveri
			14-11-2023	22.699	Karnataka	Haveri
19	Vaigai	Ambasamudram	01-12-2023	12.012	Tamil Nadu	Theni
		Paramakudi	21-01-2023	12.722	Tamil Nadu	Ramanathapuram
			01-12-2023	15.240	Tamil Nadu	Ramanathapuram
20	Yamuna	Delhi Railway Bridge	21-07-2023	12.129	Delhi	North Delhi

A GIS map of WQ stations where lead is found above acceptable limit is depicted in Figure 27.

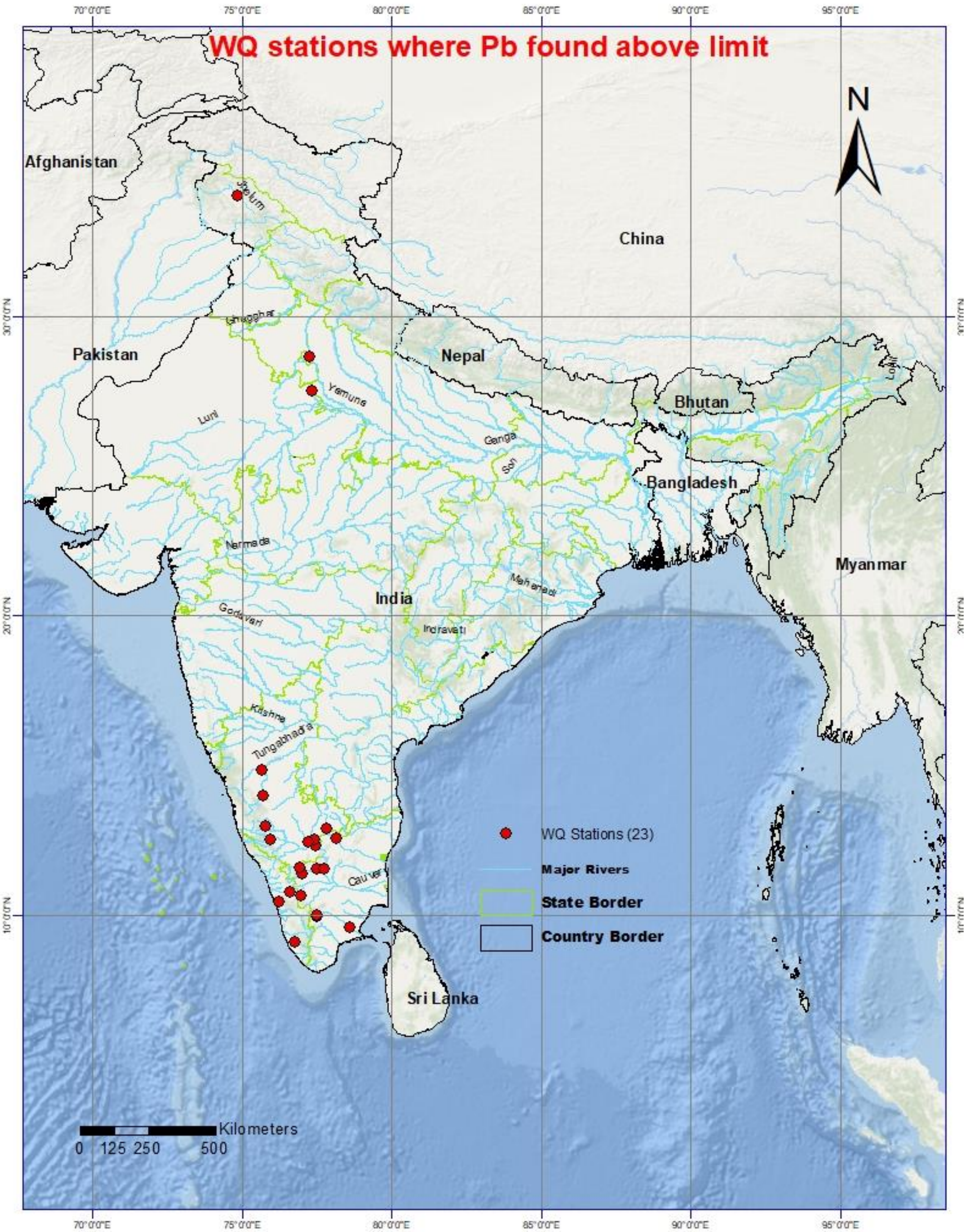

Figure 27: WQ stations where Lead found above acceptable limit

Comparison with 6th edition (period: January-December, 2022)

During the period from January-December, 2022 a 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.

Subsequently, during the 2023 period, out of total 5890 river water samples analysed, 76 samples from 23 water quality stations were found to have lead concentrations beyond the acceptable limit. The lead concentration varies from 0.000 to 75.51 µg/L. Maximum lead concentration (75.51 µg/L) was observed at Kudige water quality monitoring station on Cauvery River on 14-11-2023. These findings indicate an increase in both the number of samples exceeding the limit and the peak contamination level in 2023 compared to 2022. In 2022, 37 samples from 30 water quality stations across 25 rivers surpassed the acceptable limit, while in 2023, 76 samples exceeded the limit, but they were recorded at fewer stations—23 stations across 20 rivers.

Figure 30 represents the GIS map of stations affected with Pb in both reports.

A graphical representation of the above-limit values at the common stations is given as Figure 28.

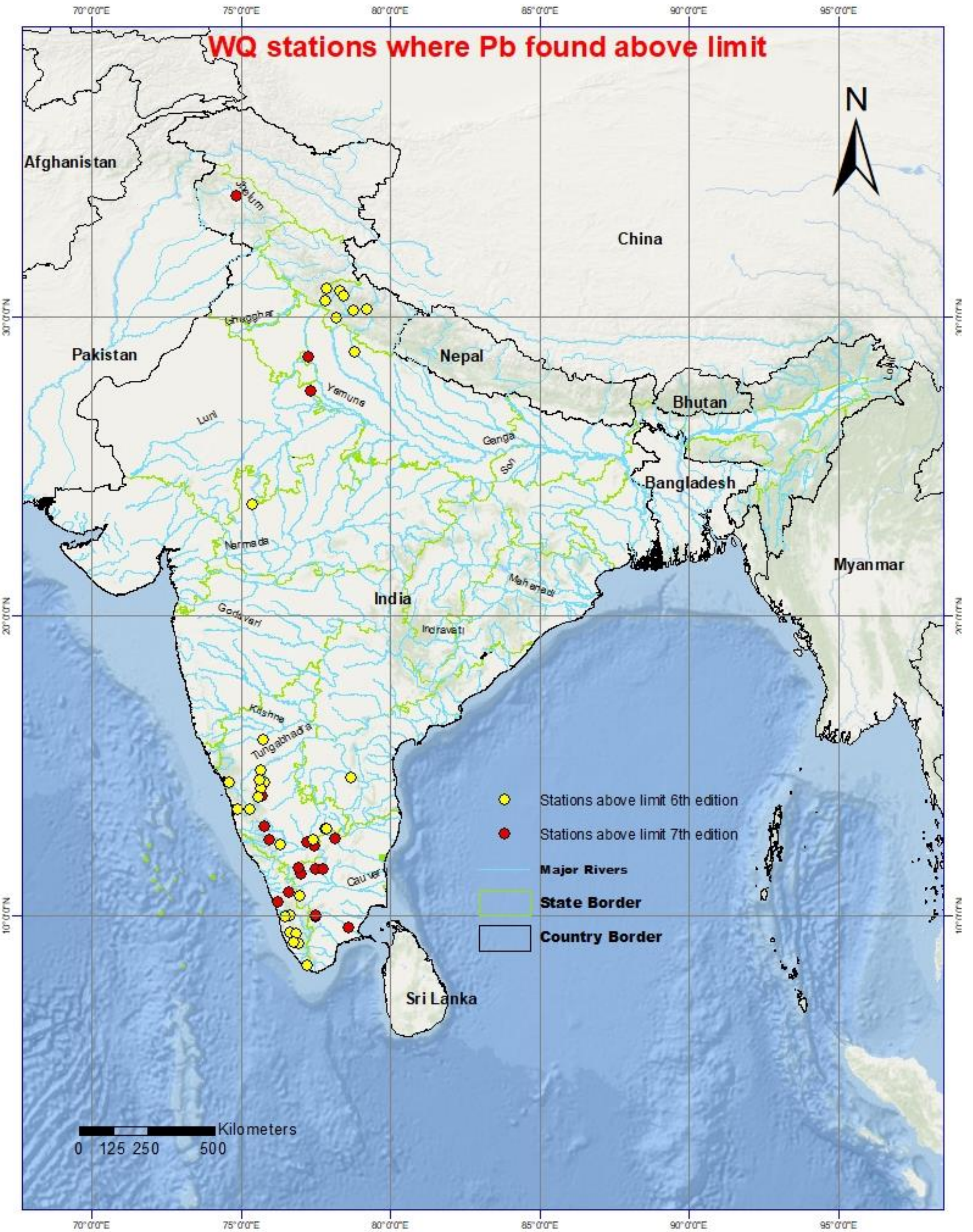

Figure 28: WQ stations where Lead found above acceptable limit (both study periods)

7.7 Mercury (Hg)

BIS (Bureau of Indian Standard) 10500:2012) has recommended an acceptable limit of 1 µg/L of mercury in drinking water. Out of total 5897 river water samples analysed, 28 samples from 14 water quality stations were found to have mercury concentrations beyond the acceptable limit. The mercury concentration varies from 0.000 to 4.79 µg/L. Maximum mercury concentration (4.79 µg/L) was observed at Rajahmundry water quality monitoring station on Godavari River on 20-10-2023.

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	Chandrabhaga	Patansaongi	01-09-2023	2.940	Maharashtra	Nagpur
2	Godavari	Dhalegaon	20-10-2023	3.665	Maharashtra	Parbhani
		Nanded	22-12-2023	4.431	Maharashtra	Nanded
		Nashik	01-08-2023	3.182	Maharashtra	Nasik
			10-08-2023	3.277	Maharashtra	Nasik
			11-09-2023	3.150	Maharashtra	Nasik
			25-09-2023	3.056	Maharashtra	Nasik
			20-10-2023	2.713	Maharashtra	Nasik
			01-11-2023	4.200	Maharashtra	Nasik
			11-12-2023	4.009	Maharashtra	Nasik
		Perur	20-10-2023	4.470	Telangana	Khammam
			21-11-2023	3.447	Telangana	Khammam
		Rajahmundry	21-08-2023	2.993	Andhra Pradesh	East Godavari
			25-09-2023	2.693	Andhra Pradesh	East Godavari
			03-10-2023	2.613	Andhra Pradesh	East Godavari
			20-10-2023	4.790	Andhra Pradesh	East Godavari
			13-11-2023	4.694	Andhra Pradesh	East Godavari
3	Hindon	Galeta	12-06-2023	3.68	Uttar Pradesh	Meerut
4	Krishna	Wadenapally	13-11-2023	4.082	Telangana	Nalgonda
5	Pravara	Pratappur	10-08-2023	1.523	Maharashtra	Ahmednagar
			11-09-2023	1.538	Maharashtra	Ahmednagar
			25-09-2023	1.492	Maharashtra	Ahmednagar
6	Purna	Purna	20-10-2023	3.483	Maharashtra	Parbhani
			01-11-2023	2.051	Maharashtra	Parbhani
7	Sabri	Saradaput	20-10-2023	2.528	Odisha	Malkangiri
8	Wardha	Sakmur	01-09-2023	2.676	Maharashtra	Chandrapur
9	Wyra	Madhira	01-11-2023	2.655	Telangana	Khammam
10	Yamuna	Jawahar Bridge, Agra	12-01-2023	1.529	Uttar Pradesh	Agra

Figure 29 represents GIS map of WQ stations where mercury is found above acceptable limit.

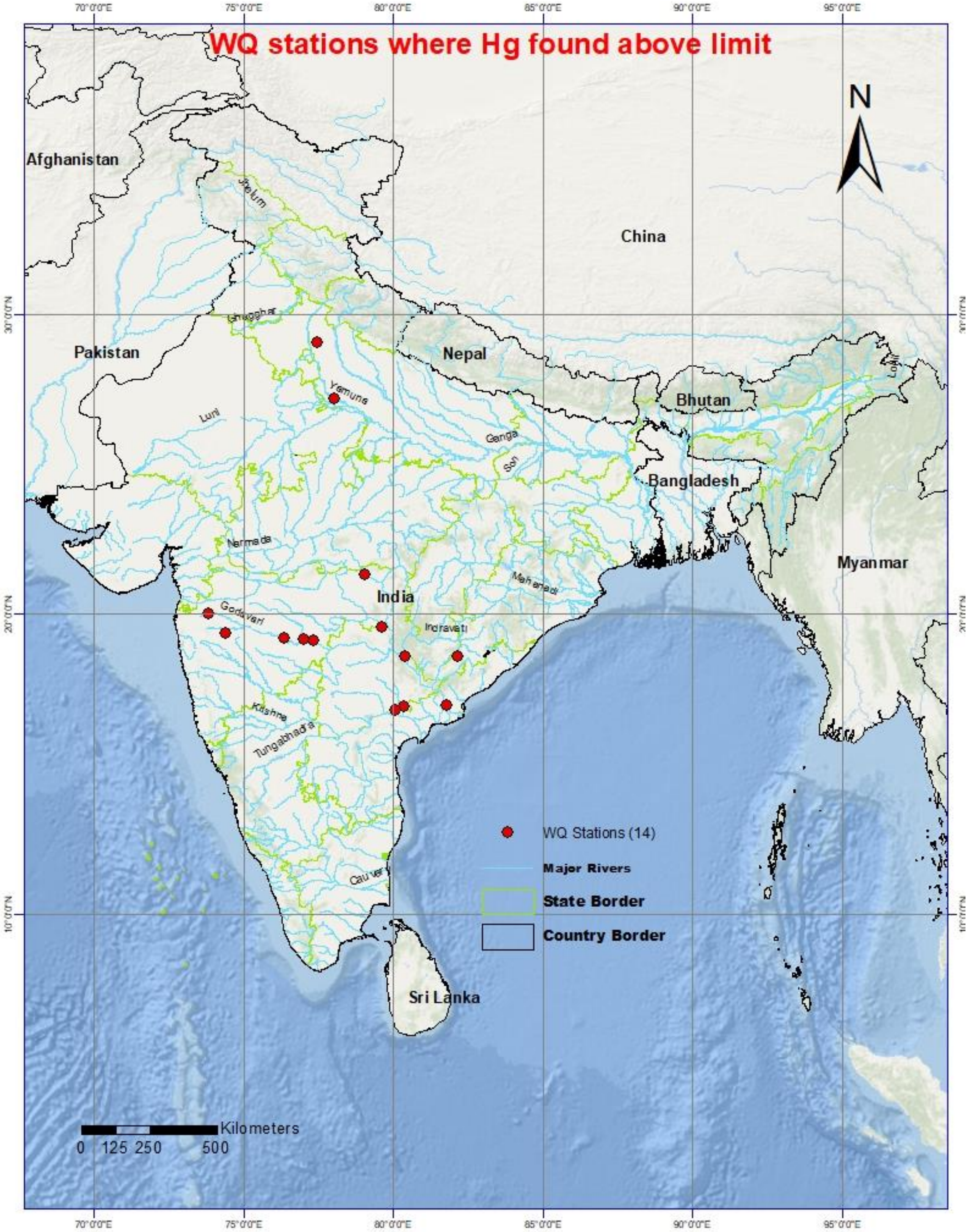

Figure 29: WQ stations where Mercury found above acceptable limit

Comparison with 6th edition (period: January-December, 2022)

In 2022, out of 5941 analyzed river water samples, 18 samples from 18 water quality stations were found to have mercury concentrations beyond the acceptable limit. The mercury concentration ranged from 0.000 to 8.903 µg/L, with the maximum concentration of 8.903 µg/L recorded at the Palla U/S Delhi station on the Yamuna River on 01.05.2022.

In 2023, out of 5897 analyzed samples, 28 samples from 14 water quality stations were found to exceed the acceptable limit. The mercury concentration ranged from 0.000 to 4.79 µg/L, with the maximum concentration of 4.79 µg/L observed at the Rajahmundry station on the Godavari River on 20.10.2023.

The data reveals an increase in the number of samples and stations with mercury levels beyond the acceptable limit in 2023 compared to 2022. However, the maximum mercury concentration observed in 2023 (4.79 µg/L) was significantly lower than in 2022 (8.903 µg/L). This indicates a broader distribution of contamination in 2023 but with reduced peak levels.

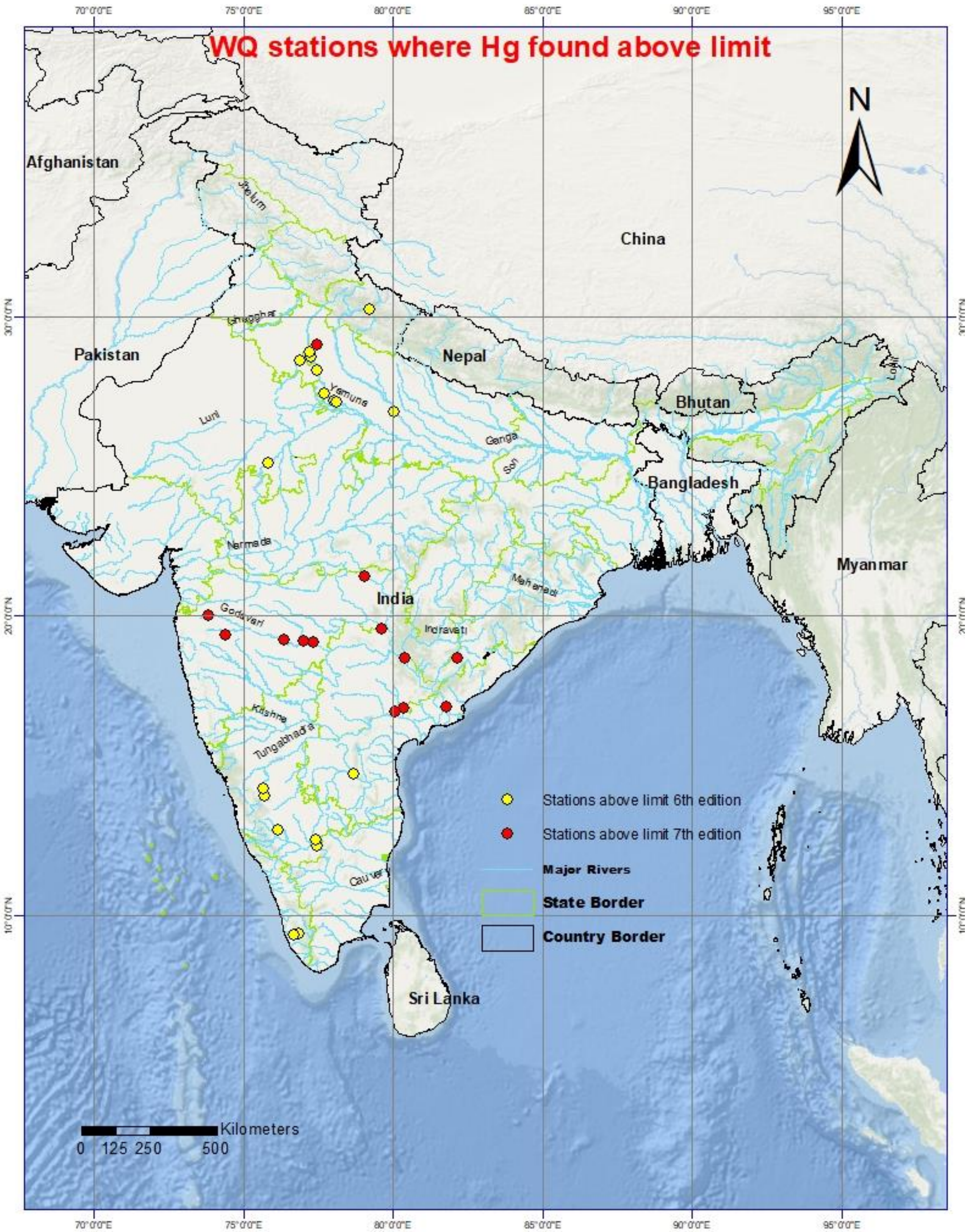

Figure 30: WQ stations where Mercury found above acceptable limit (both study periods)

7.8 Nickel (Ni)

BIS (Bureau of Indian Standard) 10500:2012) has recommended an acceptable limit of 20 µg/L of nickel in drinking water. Out of total 5898 river water samples analysed, 17 samples from 06 water quality stations were found to have nickel concentrations beyond the acceptable limit.The nickel concentration varies from 0.000 to 66.64 µg/L. Maximum nickel concentration (66.64 µg/L) was observed at Musiri water quality monitoring station on Cauvery River on 11-05-2023.

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	Bhavani/Moyar	Thengumarahada	11-05-2023	23.666	Tamil Nadu	Nilgiris
			21-11-2023	41.743	Tamil Nadu	Nilgiris
			11-12-2023	61.043	Tamil Nadu	Nilgiris
2	Cauvery	Biligundulu	13-02-2023	25.242	Tamil Nadu	Krishnagiri
			11-05-2023	43.576	Tamil Nadu	Krishnagiri
			21-12-2023	28.871	Tamil Nadu	Krishnagiri
3	Cauvery	Musiri	01-02-2023	23.167	Tamil Nadu	Thiruchirapalli
			11-05-2023	66.642	Tamil Nadu	Thiruchirapalli
			11-12-2023	34.428	Tamil Nadu	Thiruchirapalli
4	Gandhayar	Gandhavayal	21-11-2023	35.188	Tamil Nadu	Coimbatore
			11-12-2023	56.161	Tamil Nadu	Coimbatore
5	Ponnaiyar	Gummanur	13-03-2023	24.604	Tamil Nadu	Dharmapuri
			11-09-2023	33.57	Tamil Nadu	Dharmapuri
6	Ponnaiyar	Singasadanapalli	02-01-2023	43.943	Tamil Nadu	Dharmapuri
			01-05-2023	46.755	Tamil Nadu	Dharmapuri
			03-10-2023	41.307	Tamil Nadu	Dharmapuri
			11-12-2023	42.041	Tamil Nadu	Dharmapuri

One states, namely Tamil Nadu is found to be affected by the issue of Nickel contamination. Figure 32 represents the GIS map of WQ stations with nickel values above limit.

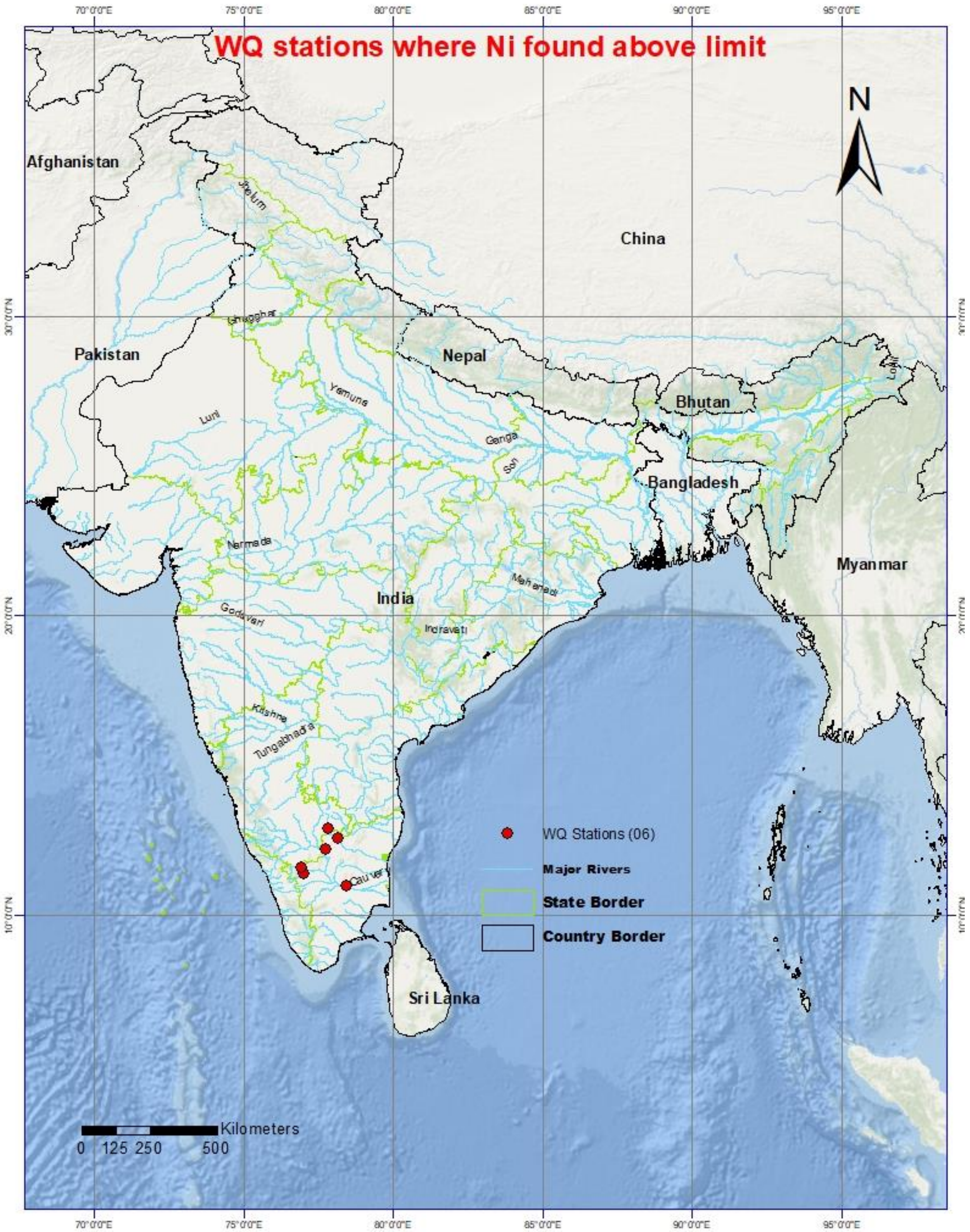

Figure 31: WQ stations where Nickel found above acceptable limit

Comparison with 6th edition (period: January-December, 2022)

The comprehensive analysis of water quality during two distinct periods: January-December,2022 and subsequently January-December,2023 has provided valuable insights into nickel concentrations in Indian rivers. The comparison between 2022 and 2023 data from the 6th edition of the report reveals notable changes in nickel contamination levels in river water samples. In 2022, out of 5942 analyzed samples, 22 samples from 11 water quality stations across 11 rivers exceeded the acceptable nickel concentration limit, with the maximum concentration recorded at 69.01 µg/L at the Madamon station on the Pamba River. In contrast, 2023 saw a slight decrease, with 17 out of 5898 samples exceeding the limit, identified at only 6 stations across 4 rivers. The maximum concentration in 2023 was lower, at 66.64 µg/L, observed at the Musiri station on the Cauvery River. These findings indicate a reduction in the number of stations and rivers affected and a slight decrease in the peak nickel concentration.

The GIS map in Figure 32 illustrates the stations which have exceeded the Ni limit in both the current and previous reports.

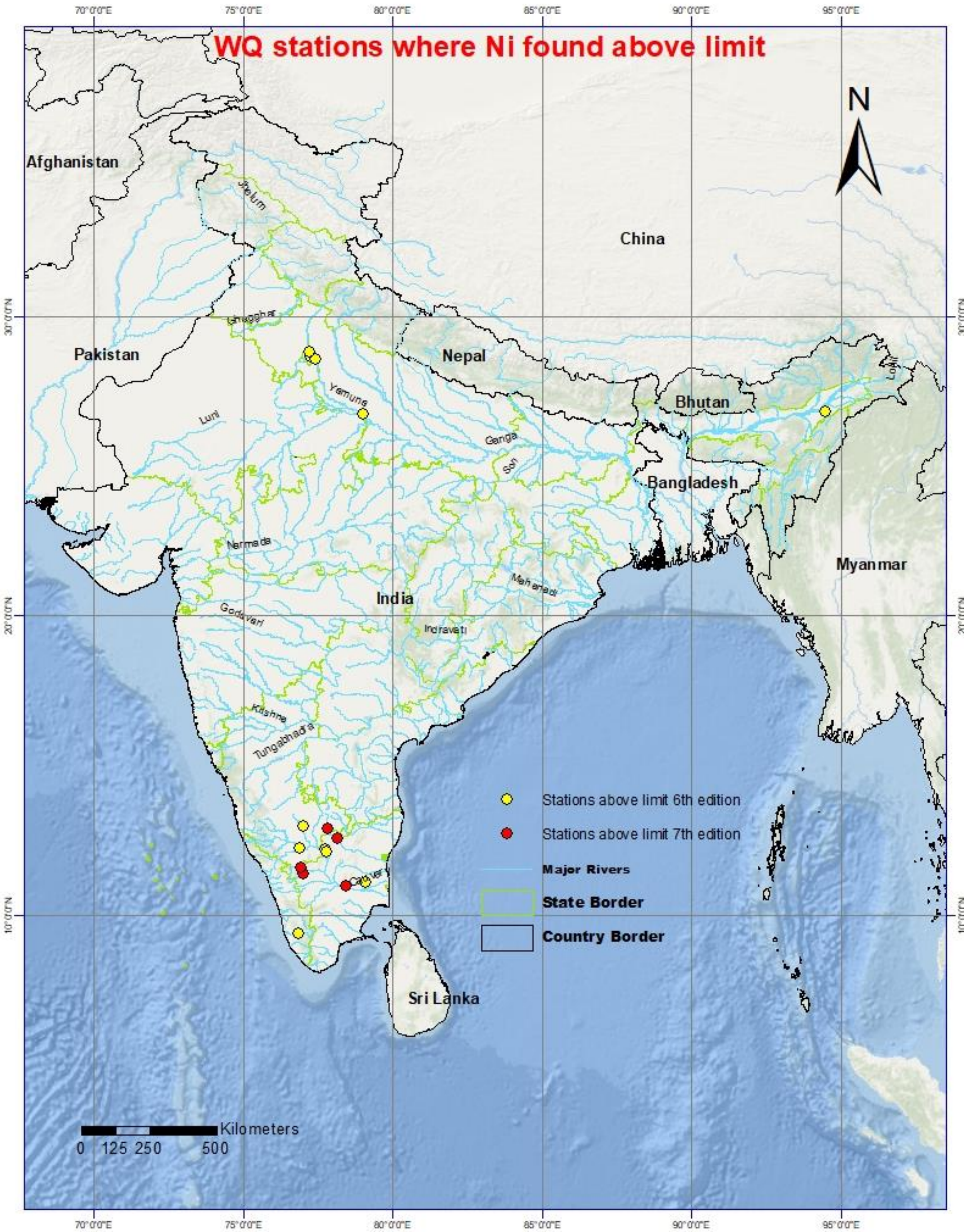

Figure 32: WQ stations where Nickel found above acceptable limit (both study periods)

7.9 Zinc (Zn)

BIS (Bureau of Indian Standard) 10500:2012) has recommended acceptable limit of 5 mg/L (5000 µg/L) of Zinc in drinking water. Out of total 5946 river water samples analysed, no sample is found to have zinc concentration beyond the acceptable limit. The zinc concentration varies from 0.000 to 4990 µg/L. Maximum zinc concentration (4990 µg/L) was observed at Hariharapura water quality monitoring station on Tunga River on 22.08.2023.

Out of total 5940 river water samples analysed; no sample is found to have zinc concentration beyond the acceptable limit. Maximum zinc concentration (950.535 µg/L) was observed at Haridwar (Ganga River). The data indicates that while zinc concentrations remained within acceptable limits in both years, the maximum recorded concentration was significantly higher in 2023 compared to 2022.

8.CONCLUSION

The analysis results of 9 metals analysed in samples collected from 300 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 212 monitored stations while at 55 stations, at only one metal was found to be beyond the acceptable limits prescribed by BIS (10500:2012).
- The results underscore the pervasive nature of water pollution, 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 10 samples from 03 stations among the 5911 samples analysed.
- Similarly, cadmium surpassed the acceptable limit of 3 µg/L in 1 sample from 1 station.
- Chromium, copper, and nickel also presented challenges, exceeding their respective limits in 27, 03, and 06 stations across various rivers.
- The significant concern arises with iron, where 292 samples from 63 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 76 samples from 23 stations.
- Mercury breached the acceptable limit of 1 µg/L in 28 samples from 14 stations, emphasizing the widespread presence of this toxic element.
- Biligundulu (Cauvery River), Harahalli (Tungabhadra River), Holehonnur (Bhadra River), Musiri (Cauvery River), Paramakudi (Vaigai River), Savandapur (Bhavani River), Theni (Suruliyar River) 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 analysis of 300 water quality (WQ) stations revealed that a total of 88 stations exhibited one or more metals exceeding the acceptable limits. The overall summary of the results of metal contamination across the 300 stations is as follows:

Table 20: Overall Statistics of Analysis

Sl. No	Parameters	No. of Stations where metal found above acceptable limit
1	Arsenic only	**02**
2	Cadmium only	**00**
3	Chromium only	**02**
4	Copper only	**00**
5	Iron only	**32**
6	Lead only	**06**
7	Mercury only	**13**
8	Nickel only	**00**
9	Zinc only	**00**
10	Two or More metals	**33**
Total WQ stations where one or more metals found above acceptable limits		**88**
Total WQ Stations where all toxic metals found within acceptable limits		**212**
Total WQ Stations under study		**300**

Table 21: Overall Status of 88 stations where one or more metals found above acceptable limits

No. of stations where 4 metals found to be above limit	**06**
No. of stations where 3 metals found to be above limit	**07**
No. of stations where 2 metals found to be above limit	**20**
No. of stations where only 1 metal found to be above limit	**55**

The analysis of the 88 water quality stations where one or more metals were found above the acceptable limits reveals the following distribution:

- Table 22 above show that there is six (06) stations where four metals were found to exceed the limit, seven (07) stations where three metals were above the limit, and twenty (20) stations where two metals exceeded the limit.
- It is evident from the tables that, out of 88 stations where one or more metals are found above acceptable limits, 55 stations have only 1 metal which exceeds the limit. Among these 88 stations, 32 stations have only Iron exceeding the limit. This means that, only Iron metal is found to breach the limit at 36% of the 88 stations affected.
- However, it is important to note that there are 212 WQ stations (70.66%) where all the toxic metals are found within acceptable limits.

The analysis of water quality (WQ) stations across various basins reveals significant variations in the presence of metals above the acceptable limits. Out of the total 300 WQ stations studied across the basins, a substantial proportion of these stations showed metal concentrations exceeding the permissible 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	Cauvery	39	30
2 & 3	East Flowing Rivers between Pennar and Cauvery Basin and East Flowing Rivers South of Cauvery Basin	18	09
4	Ganga & Yamuna	90	09
5	Godavari	53	12
6	Indus	11	01
7	Krishna	42	11
8	Pennar	08	00
9	West Flowing rivers south of Tapi Basin	39	16

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. Cauvery Basin exhibited the highest frequency of elevated metal concentrations, with 30 out of 39 WQ stations (approximately 77%) showing one or more metals above acceptable limits. Ganga and Yamuna Basin basin has the highest number of WQ stations monitored, with 90 stations showed a relatively lower incidence of metals exceeding acceptable limits, with only 9 out of 90 stations (10%) reporting such contamination. In Godavari & Krishna Basin, 12 out of 53 stations (approximately 23%) and 11 stations out of 42 (26%) had metal levels above acceptable limits.

The high level of metal contamination 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.

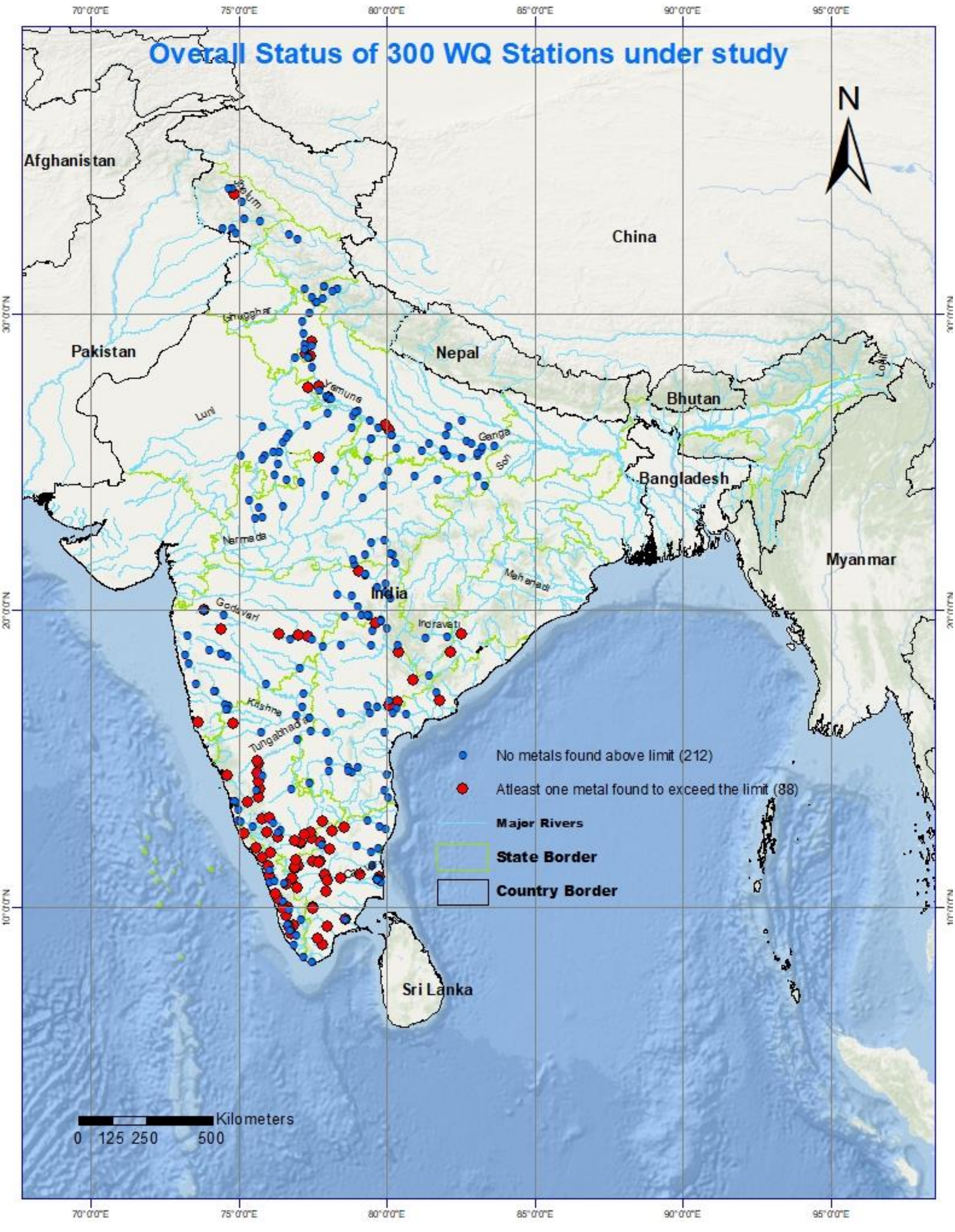

Figure 33: Overall status of 300 stations under study

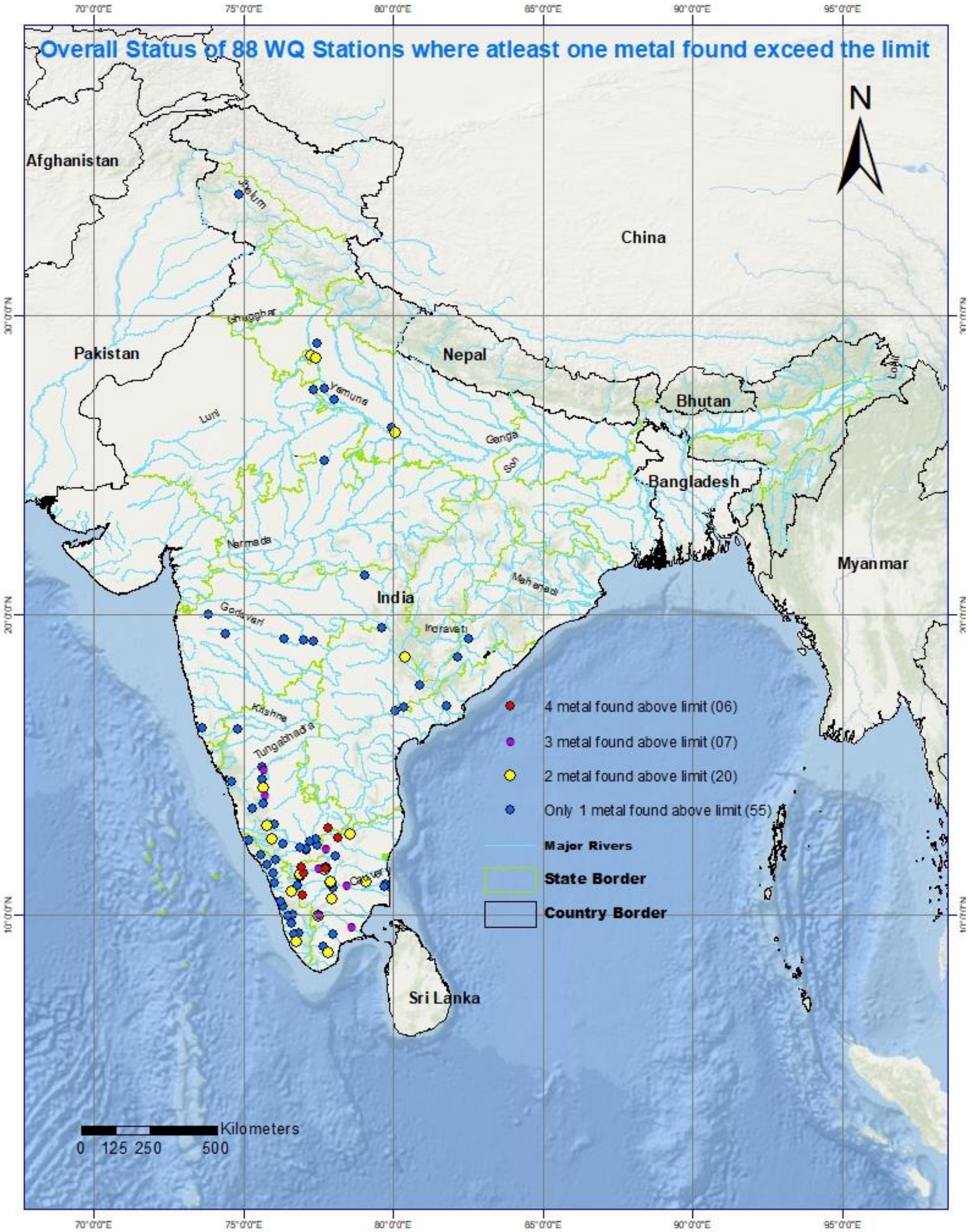

Figure 34: Overall status of 222 stations where at least one metal is found above the limit

Comparison with 6th edition

The analysis results of trace and toxic metal concentrations in river water samples for the years 2022 and 2023 have been compared to assess compliance with the acceptable limits specified by BIS: 10500, 2012.

Table 23: Comparison of Metal-wise Analysis Result

		Analysis result (2022)					Analysis result (2023)			
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	5911	5901	10	0.16
2	Cadmium (Cd)	3	5942	5937	05	0.08	5940	5939	1	0.02
3	Chromium (Cr)	50	5939	5922	17	0.29	5730	5643	87	1.52
4	Copper (Cu)	50	5941	5936	05	0.08	5940	5937	3	0.05
5	Iron (Fe)	1000	5980	5867	113	1.89	5768	5476	292	5.06
6	Lead (Pb)	10	5942	5905	37	0.62	5890	5814	76	1.29
7	Mercury (Hg)	1	5941	5923	18	0.30	5897	5869	28	0.47
8	Nickel (Ni)	20	5942	5931	11	0.19	5898	5881	17	0.29
9	Zinc (Zn)	5000	5940	5940	00	0.00	5946	5946	0	0.00

Table 24: Overall comparison of 2 reports

WQ stations	Year 2023	Year 2022	WQ Samples	Year 2023	Year 2022
No of stations where no metal found above acceptable limit	212	187	No of samples where no metal found above acceptable limit	5495	5748
No of stations where at least one metal found above acceptable limit	88	141	No of samples where at least one metal found above acceptable limit	451	232
Total Stations under study	300	328	Total Samples under study	5946	5980

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 300 Water Quality Monitoring Stations

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
1	A.B. Road Xing	No metals found above limit	Madhya Pradesh	Guna	Yamuna Basin	Parwati	24.366	77.099
2	A.P.M.(ASHTI)	No metals found above limit	Maharashtra	Gadchiroli	Godavari	Wainganga	19.668	79.789
3	Addoor	No metals found above limit	Karnataka	Dakshina Kannada	WFR South of Tapi	Gurupur	12.929	74.954
4	Akbarpur	No metals found above limit	Uttar Pradesh	Ambedkar Nagar	Ganga	Chhoti Sarju	26.433	82.533
5	Akhnoor	No metals found above limit	Jammu & Kashmir	Jammu	Indus	Chenab	32.901	74.759
6	Akkihebbal	No metals found above limit	Karnataka	Mandya	Cauvery	Hemavathy	12.599	76.400
7	Aklera	No metals found above limit	Rajasthan	Jhalawar	Yamuna Basin	Parwan	24.430	76.604
8	Alandurai	Fe	Tamil Nadu	Coimbatore	Cauvery	Noyyal	10.954	76.786
9	Alladupalli	No metals found above limit	Andhra Pradesh	Kadapa	Pennar	Kunderu	14.717	78.669
10	Allahabad	No metals found above limit	Uttar Pradesh	Allahabad	Ganga	Ganga	25.403	81.911
11	Ambarampalayam	Pb,Cr, Fe, Cu	Tamil Nadu	Coimbatore	WFR South of Tapi	Aliyar	10.630	76.946
12	Ambasamudram	Pb, Fe	Tamil Nadu	Theni	EFR South of Cauvery	Vaigai	9.926	77.512
13	AP Puram	Fe	Tamil Nadu	Tirunelveli	EFR South of Cauvery	Chittar	8.901	77.649
14	Arangaly	Fe	Kerala	Trichur	WFR South of Tapi	Chalakkudy	10.281	76.315
15	Arcot	No metals found above limit	Tamil Nadu	Vellore	EFR between Pennar-Cauvery	Palar	12.914	79.333
16	Arjunwad	No metals found above limit	Maharashtra	Kolhapur	Krishna	Krishna	16.781	74.633
17	Ashramam	No metals found above limit	Tamil Nadu	Kanyakumari	WFR South of Tapi	Pazhayar	8.159	77.460
18	Asthi	No metals found above limit	Maharashtra	Gadchiroli	Godavari	Wainganga	19.685	79.789
19	Auraiya	No metals found above limit	Uttar Pradesh	Auraiya	Ganga	Yamuna	26.427	79.418
20	Avaramkuppam	Fe, Cr	Tamil Nadu	Vellore	EFR between Pennar-	Palar	12.684	78.539

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
					Cauvery			
21	Avershe	No metals found above limit	Karnataka	Udupi	WFR South of Tapi	Seetha	13.521	74.880
22	Ayilam	No metals found above limit	Kerala	Thiruvananthapuram	WFR South of Tapi	Vamanapuram	8.715	76.850
23	B.P.M. (BAMNI)	No metals found above limit	Maharashtra	Chandrapur	Godavari	Wardha	19.840	79.360
24	Badalapur	No metals found above limit	Maharashtra	Thane	WFR South of Tapi	Ulhas	19.162	73.254
25	Baghpat	No metals found above limit	Uttar Pradesh	Baghpat	Yamuna Basin	Yamuna	28.988	77.203
26	Bakhari	No metals found above limit	Madhya Pradesh	Seoni	Godavari	Wainganga	22.325	79.468
27	Baleni	No metals found above limit	Uttar Pradesh	Baghpat	Yamuna Basin	Hindon	28.959	77.470
28	Baluaghat	No metals found above limit	Uttar Pradesh	Varanasi	Ganga	Ganga	25.421	83.184
29	Bamni	No metals found above limit	Maharashtra	Chandrapur	Godavari	Wardha	19.814	79.379
30	Banda	No metals found above limit	Uttar Pradesh	Banda	Ganga	Ken	25.483	80.313
31	Bantwal	No metals found above limit	Karnataka	Dakshina Kannada	WFR South of Tapi	Nethravathi	12.881	75.041
32	Baranwada	No metals found above limit	Rajasthan	Sawai-Madhopur	Yamuna Basin	Banas	26.000	76.667
33	Barod	No metals found above limit	Rajasthan	Kota	Yamuna Basin	Kalisindh	25.383	76.334
34	Basoda	No metals found above limit	Uttar Pradesh	Vidisha	Ganga	Betwa	23.887	77.920
35	Bawapuram	No metals found above limit	Andhra Pradesh	Kurnool	Krishna	Tungabhadra	15.883	77.957
36	Belne Bridge	Fe	Maharashtra	Sindhudurg	Krishna	Gad	16.221	73.595
37	Bendarahalli	Fe	Karnataka	Chamarajanagar	Cauvery	Suvarnavathy	12.129	77.083
38	Bhadana	No metals found above limit	Rajasthan	Kota	Yamuna Basin	Chambal	25.240	75.880
39	Bhadrachalam	Fe	Telangana	Khammam	Godavari	Godavari	17.668	80.877
40	Bhatpalli	No metals found above limit	Telangana	Adilabad	Godavari	Peddavagu	19.332	79.503
41	Bhind	No metals found above limit	Madhya Pradesh	Bhind	Ganga	Kunwari	26.608	78.857
42	Bigod	No metals found above limit	Rajasthan	Bhilwara	Yamuna Basin	Banas	25.251	75.035
43	Biligundulu	Cr, Fe, Ni	Tamil Nadu	Krishnagiri	Cauvery	Cauvery	12.182	77.724

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
44	Byaladahalli	No metals found above limit	Karnataka	Davanagere	Krishna	Haridra	14.434	75.780
45	Chengalpet	No metals found above limit	Tamil Nadu	Kancheepuram	EFR between Pennar-Cauvery	Palar	12.650	79.947
46	Chennur	No metals found above limit	Andhra Pradesh	Kadapa	Pennar	Pennar	14.572	78.800
47	Chhapriyal (Bar-doh)	No metals found above limit	Jammu & Kashmir	Jammu	Indus	Manawar Tawi	32.915	74.424
48	Chilla Village	No metals found above limit	Delhi	East Delhi	Yamuna Basin	Hindon Cut	28.588	77.299
49	Chindnar	No metals found above limit	Chhattisgarh	Dantewara	Godavari	Indravathi	19.079	81.301
50	Cholachagudda	No metals found above limit	Karnataka	Bagalkot	Krishna	Malaprabha	15.879	75.721
51	Chopan	No metals found above limit	Uttar Pradesh	Sonebhadra	Ganga	Sone	24.533	83.050
52	Chunchanakatte	No metals found above limit	Karnataka	Mysore	Cauvery	Cauvery	12.511	76.303
53	D/S (ASHTI)	No metals found above limit	Maharashtra	Gadchiroli	Godavari	Wainganga	19.668	79.786
54	Dameracherla	No metals found above limit	Telangana	Nalgonda	Krishna	Musi	16.739	79.670
55	Daund	No metals found above limit	Maharashtra	Pune	Krishna	Bhima	18.474	74.576
56	Delhi Railway Bridge	Cr, Pb	Delhi	North Delhi	Yamuna Basin	Yamuna	28.663	77.249
57	Deosugar	No metals found above limit	Karnataka	Raichur	Krishna	Musi	16.382	77.357
58	Dhalegaon	Hg	Maharashtra	Parbhani	Godavari	Godavari	19.220	76.363
59	Dhamkund	No metals found above limit	Jammu & Kashmir	Ramban	Indus	Chenab	33.243	75.146
60	Dhansa	No metals found above limit	Haryana	Jhjjar	Yamuna Basin	Sahibi	28.534	76.871
61	Dhareri	No metals found above limit	Madhya Pradesh	Ujjain	Yamuna Basin	Chambal	23.133	75.515
62	Dholpur	No metals found above limit	Rajasthan	Dholpur	Ganga	Chambal	26.666	77.967
63	Duddhi	No metals found above limit	Uttar Pradesh	Sonebhadra	Ganga	Kanhar	24.227	83.275
64	Elunuthimangalam	Cr, Fe	Tamil Nadu	Erode	Cauvery	Noyyal	11.032	77.888
65	Erinjipuzha	Fe	kerala	Kasargod	WFR South of Tapi	Payaswani	12.479	75.147
66	Etawah	No metals found above limit	Uttar Pradesh	Etawah	Ganga	Yamuna	26.750	78.983

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
67	Fatehpora(Prang)	No metals found above limit	Jammu & Kashmir	Gandarbal	Indus	Sindh Nallah	34.258	74.778
68	Gaisabad	No metals found above limit	Madhya Pradesh	Damoh	Ganga	Bearma	24.243	79.844
69	Galeta	Hg	Uttar Pradesh	Meerut	Yamuna Basin	Hindon	29.082	77.437
70	Gandhavayal	Pb, Ni, Fe, Cr	Tamil Nadu	Coimbatore	Cauvery	Gandhayar	11.374	76.992
71	Gandlapet	No metals found above limit	Telangana	Nizamabad	Godavari	Peddavagu	18.829	78.437
72	Ganguwala	No metals found above limit	Himachal Pradesh	Sirmaur	Yamuna Basin	Bata	30.436	77.578
73	Garhakota	No metals found above limit	Madhya Pradesh	Sagar	Ganga	Sonar	23.829	79.167
74	Garrauli	No metals found above limit	Madhya Pradesh	Chhatarpur	Ganga	Dhasan	25.081	79.344
75	Ghazipur	No metals found above limit	Uttar Pradesh	Ghazipur	Ganga	Ganga	25.586	83.607
76	Gokak	Cr	Karnataka	Belgaum	Krishna	Gataprabha	16.181	74.801
77	Gokul Barrage	No metals found above limit	Uttar Pradesh	Mathura	Yamuna Basin	Yamuna	27.443	77.714
78	Gopurajapuram	No metals found above limit	Tamil Nadu	Nagapattinam	Cauvery	Puravidlayar	10.850	79.790
79	GR Bridge	No metals found above limit	Maharashtra	Parbhani	Godavari	Godavari	19.022	76.729
80	Gudam Bridge	No metals found above limit	Maharashtra	Gadchiroli	Godavari	Pranhita	19.417	79.972
81	Gummanur	Pb, Fe, Ni, Cr	Tamil Nadu	Dharmapuri	EFR between Pennar-Cauvery	Ponnaiyar	12.555	78.139
82	Haladi	No metals found above limit	Karnataka	Udupi	WFR South of Tapi	Halady	13.582	74.858
83	Halia	No metals found above limit	Telangana	Nalgonda	Krishna	Halia	16.790	79.339
84	Hamirpur	No metals found above limit	Uttar Pradesh	Hamirpur	Ganga	Yamuna	25.960	80.154
85	Harahalli	Pb, Cr, Fe	Karnataka	Haveri	Krishna	Tungabhadra	14.831	75.675
86	Hariharapura	Fe	Karnataka	Chikamagaliur	Krishna	Tunga	13.522	75.304
87	Haripur	No metals found above limit	Uttarakhand	Dehradun	Yamuna Basin	Tons	30.537	77.826
88	HIVRA	No metals found above limit	Maharashtra	Wardha	Godavari	Wardha	20.547	78.325
89	Hogenakkal	No metals found above limit	Tamil Nadu	Dharmapuri	Cauvery	Chinnar	12.121	77.786

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
90	Holehonnur	Pb, Cr, Fe	Karnataka	Shimoga	Krishna	Bhadra	13.976	75.685
91	Honnali	Cr, Fe	Karnataka	Davanagere	Krishna	Tungabhadra	14.237	75.663
92	Hoovinahole	No metals found above limit	Karnataka	Chitradurga	Krishna	Swarnamukhi	13.983	76.749
93	Huvinhedgi	No metals found above limit	Karnataka	Raichur	Krishna	Krishna	16.491	76.923
94	Irrukkankudi	Fe	Tamil Nadu	Virudhunagar	EFR South of Cauvery	Vaippar	9.324	77.990
95	Jagdalpur	No metals found above limit	Chhattisgarh	Bastar	Godavari	Indravathi	19.108	82.023
96	Jaunpur	No metals found above limit	Uttar Pradesh	Jaunpur	Ganga	Gomti	25.744	82.690
97	Jawahar Bridge, Agra	Hg	Uttar Pradesh	Agra	Ganga	Yamuna	27.204	78.035
98	Jhalawar	No metals found above limit	Rajasthan	Jhalawar	Yamuna Basin	Kalisindh	24.591	76.188
99	Jhansi Mirjapur Highway Road Bridge	No metals found above limit	Uttar Pradesh	Hamirpur	Ganga	Betwa	25.944	80.155
100	K M Vadi	Fe	Karnataka	Mysore	Cauvery	Laxmanathirtha	12.347	76.292
101	K.T.(SATRAPUR)	No metals found above limit	Maharashtra	Nagpur	Godavari	Kanhan	21.226	79.231
102	Kailash Mandir, Near Benpur Village	No metals found above limit	Uttar Pradesh	Agra	Ganga	Yamuna	27.236	77.931
103	Kalampur	Fe	Kerala	Ernakulam	WFR South of Tapi	Kaliyar	9.991	76.632
104	Kalanaur	No metals found above limit	Uttar Pradesh	Saharanpur	Yamuna Basin	Yamuna	30.068	77.354
105	Kalindi Kunj	Pb	Delhi	East Delhi	Yamuna Basin	Ganga/Yamuna	27.543	77.309
106	kallooppara	No metals found above limit	Kerala	pathanamthitta	WFR South of Tapi	Manimala	9.404	76.650

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
107	Kalpi	No metals found above limit	Uttar Pradesh	Jalaun	Ganga	Yamuna	26.200	79.700
108	Kamalapuram	No metals found above limit	Andhra Pradesh	Kadapa	Pennar	Papagani	14.581	78.678
109	Karad	No metals found above limit	Maharashtra	Satara	Krishna	Krishna	17.294	74.190
110	Karathode	Fe	Kerala	Malappuram	WFR South of Tapi	Kadalundi	11.057	76.039
111	Karnal	No metals found above limit	Haryana	Karnal	Yamuna Basin	Yamuna	29.762	77.132
112	Keesara	No metals found above limit	Andhra Pradesh	Krishna	Krishna	Munneru	16.716	80.316
113	Keolari	No metals found above limit	Madhya Pradesh	Seoni	Godavari	Wainganga	22.381	79.900
114	Khatoli	No metals found above limit	Rajasthan	Kota	Yamuna Basin	Parwati	25.683	76.483
115	Kidangoor	Fe	Kerala	Kottayam	WFR South of Tapi	Meenachil	9.676	76.606
116	Kodumudi	Cr, Fe	Tamil Nadu	Erode	Cauvery	Cauvery	11.081	77.890
117	Koggedoddi	Pb	Karnataka	Ramanagara	Cauvery	Arkavathy	12.296	77.441
118	Kokiwada	No metals found above limit	Madhya Pradesh	Chhindwara	Godavari	Pench	21.898	79.234
119	Kollegal	Fe	Karnataka	Chamarajanagar	Cauvery	Cauvery	12.189	77.102
120	Konta	No metals found above limit	Chhattisgarh	Dantewara	Godavari	Sabri	17.799	81.393
121	Kopergaon	No metals found above limit	Maharashtra	Ahmednagar	Godavari	Godavari	19.878	74.481
122	Kora	As, Fe	Uttar Pradesh	Fatehpur	Ganga	Rind	26.106	80.051

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
123	Kota Hanging Bridge U/S	No metals found above limit	Rajasthan	Kota	Yamuna Basin	Chambal	25.140	75.795
124	Kudalaiyathur	No metals found above limit	Tamil Nadu	Cuddalore	EFR between Pennar-Cauvery	Vellar	11.422	79.472
125	Kudige	Pb, Fe	Karnataka	Kodugu	Cauvery	Cauvery	12.502	75.961
126	Kuldahbridge	No metals found above limit	Madhya Pradesh	Sidhi	Ganga	Sone	24.410	81.704
127	Kumarapalayam	No metals found above limit	Pondicherry	Pondicherry	EFR between Pennar-Cauvery	Varahanadhi	11.983	79.681
128	Kumbidi	No metals found above limit	Kerala	Palakkad	WFR South of Tapi	Bharatapuzha	10.854	76.020
129	Kumhari	No metals found above limit	Madhya Pradesh	Balaghat	Godavari	Wainganga	21.884	80.175
130	Kuniyil	No metals found above limit	Kerala	Malappuram	WFR South of Tapi	Chaliyar	11.239	76.023
131	Kuppelur	Fe	Karnataka	Haveri	Krishna	Kumudvathi	14.500	75.634
132	Kurundwad	No metals found above limit	Maharashtra	Kolhapur	Krishna	Krishna	16.684	74.603
133	Kuthnaur	No metals found above limit	Uttarakhand	Uttarkashi	Yamuna Basin	Yamuna	30.874	78.303
134	Kuttiyadi	Fe	Kerala	Kozhikode	WFR South of Tapi	Kutiyadi	11.638	75.776
135	Kuzhithurai	No metals found above limit	Tamil Nadu	Kanyakumari	WFR South of Tapi	Thamarabarani	8.305	77.186
136	Lakkavalli	Fe	Karnataka	Chikamagaliur	Krishna	Bhadra	13.707	75.645
137	Lakshmanapatti	Cr, Fe	Tamil Nadu	Dindigul	Cauvery	Kodaganar	10.498	77.946
138	Lalpur	As	Uttar Pradesh	Kanpur Dehat	Ganga	Sengar	26.271	79.950

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
139	Lodhikheda	No metals found above limit	Madhya Pradesh	Chhindwara	Godavari	Jam	21.579	78.866
140	M.H. Halli	No metals found above limit	Karnataka	Hassan	Cauvery	Hemavathy	12.820	76.141
141	Madamon	Fe	Kerala	Pathanamthitta	WFR South of Tapi	Pampa	9.364	76.838
142	Madhira	Hg	Telangana	Khammam	Krishna	Wyra	16.918	80.356
143	Madla	No metals found above limit	Madhya Pradesh	Panna	Ganga	Ken	24.733	80.007
144	Magaral	No metals found above limit	Tamil Nadu	Kancheepuram	EFR between Pennar-Cauvery	Cheyyar	12.708	79.750
145	Magardhara	No metals found above limit	Maharashtra	Balaghat	Godavari	Wainganga	21.956	80.109
146	Mahidpur	No metals found above limit	Madhya Pradesh	Ujjain	Yamuna Basin	Shipra	23.481	75.636
147	Maighat	No metals found above limit	Uttar Pradesh	Jaunpur	Ganga	Gomti	25.644	82.847
148	Malakkara	Fe	Kerala	Pathanamthitta	WFR South of Tapi	Pampa	9.333	76.663
149	Malkhed	No metals found above limit	Karnataka	Gulbarga	Krishna	Bhima	17.203	77.157
150	Manakkad	No metals found above limit	Kerala	Idukki	WFR South of Tapi	Thodupuzha	9.910	76.687
151	Mancherial	No metals found above limit	Telangana	Adilabad	Godavari	Godavari	18.836	79.445
152	Mandawara	No metals found above limit	Rajasthan	Kota	Yamuna Basin	Chambal	25.385	76.152
153	Manderial	No metals found above limit	Rajasthan	Karauli	Yamuna Basin	Chambal	26.273	77.275
154	Mangaon	No metals found above limit	Maharashtra	Raigad	WFR South of Tapi	Kal	18.232	73.283
155	Mankara	No metals found above limit	Kerala	Palakkad	WFR South of Tapi	Bharatapuzha	10.781	76.513
156	Mantralayam	No metals found above limit	Andhra Pradesh	Kurnool	Krishna	Tungabhadra	15.948	77.426
157	Marella	No metals found above limit	Andhra Pradesh	Prakasam	Krishna	Gundakamma	15.883	79.910
158	Marol	Fe	Karnataka	Haveri	Krishna	Varada	14.939	75.618
159	Mawi	No metals found above limit	Uttar Pradesh	Muzaffar Nagar	Yamuna Basin	Yamuna	29.383	77.155
160	Meja Road	No metals found above limit	Uttar Pradesh	Allahabad	Ganga	Tons	25.233	82.038
161	Menangudi	No metals found above limit	Tamil Nadu	Tiruvarur	Cauvery	Noolar	10.949	79.704
162	Mirzapur	No metals found above limit	Uttar Pradesh	Mirzapur	Ganga	Ganga	25.157	82.530
163	Mohana	No metals found above limit	Uttar Pradesh	Jalaun	Ganga	Betwa	25.824	79.463

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
164	Mohna	No metals found above limit	Haryana	Faridabad	Yamuna Basin	Yamuna	28.224	77.456
165	Mungoli	No metals found above limit	Maharashtra	Yavatmal	Godavari	Penganga	19.864	79.125
166	Munugodu	No metals found above limit	Andhra Pradesh	Guntur	Krishna	Edduvagu	16.555	80.206
167	Muradpur	No metals found above limit	Maharashtra	Ratnagiri	WFR South of Tapi	Vashishti	17.539	73.522
168	Murappanadu	Cr, Fe	Tamil Nadu	Tuticorin	EFR South of Cauvery	Tambraparani	8.714	77.835
169	Musiri	Cr, Fe, Ni	Tamil Nadu	Thiruchirapalli	Cauvery	Cauvery	10.943	78.435
170	Muthanakera	Fe	Kerala	Wyanad	Cauvery	Kabini	11.808	76.084
171	Nagalamadike	No metals found above limit	Karnataka	Tumkur	Pennar	Pennar	14.189	77.372
172	Nagothane	No metals found above limit	Maharashtra	Raigad	WFR South of Tapi	Amba	18.519	73.156
173	Naidupet	No metals found above limit	Andhra Pradesh	Nellore	EFR between Pennar-Cauvery	Swarnamukhi	13.947	79.897
174	Nallamaranpatti	Fe	Tamil Nadu	Karur	Cauvery	Amaravathi	10.881	77.985
175	Nallathur	Fe	Pondicherry	Karaikal	Cauvery	Nandalar	11.002	79.752
176	Nanded	Hg	Maharashtra	Nanded	Godavari	Godavari	19.142	77.320
177	Nandgaon	No metals found above limit	Maharashtra	Wardha	Godavari	Wunna	20.526	78.810
178	Nandipalli	No metals found above limit	Andhra Pradesh	Kadapa	Pennar	Sagileru	14.721	79.019
179	Nashik	Hg	Maharashtra	Nasik	Godavari	Godavari	20.002	73.803
180	Naugaon	No metals found above limit	Uttarakhand	Uttarkashi	Yamuna Basin	Yamuna	30.792	78.138
181	Neeleswaram	No metals found above limit	Kerala	Ernakulam	WFR South of Tapi	Periyar	10.181	76.469
182	Nellipally	No metals found above limit	Kerala	Kollam	WFR South of Tapi	Kallada	9.028	76.925
183	Nellithurai	Cr, Cu	Tamil Nadu	Coimbatore	Cauvery	Bhavani	11.288	76.891
184	Nellore	No metals found above limit	Andhra Pradesh	Nellore	Pennar	Pennar	14.470	79.989
185	Noida	Fe, Cu	Uttar Pradesh	Gautam Budh Nagar	Yamuna Basin	Hindon	28.602	77.424
186	Nowrangpur	Fe	Odisha	Nowrangpur	Godavari	Indravathi	19.198	82.512
187	Odenthurai	Cr, Fe	Tamil Nadu	Coimbatore	Cauvery	Kallar	11.322	76.893
188	Okhla Barrage	No metals found above limit	Delhi	South Delhi	Yamuna Basin	Yamuna	28.545	77.312
189	Orai Rath marg	No metals found above limit	Uttar Pradesh	Jalaun	Ganga	Betwa	25.811	79.461

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
	Road Bride, Chikasi							
190	P.G.BRIDGE	No metals found above limit	Maharashtra	Yavatmal	Godavari	Penganga	19.821	78.561
191	Pachawali	Fe	Madhya Pradesh	Shivpuri	Ganga	Sindh	25.179	77.687
192	Pachegaon	No metals found above limit	Maharashtra	Ahmednagar	Godavari	Pravara	20.002	73.803
193	Palakkadavu	Pb	Kerala	Thrissur	WFR South of Tapi	Karuvannur	10.425	76.238
194	Paleru Bridge	No metals found above limit	Andhra Pradesh	Krishna	Krishna	Krishna	16.949	80.048
195	Pali	No metals found above limit	Rajasthan	Sawai-Madhopur	Yamuna Basin	Chambal	25.863	76.577
196	Palla	No metals found above limit	Delhi	North West Delhi	Yamuna Basin	Yamuna	28.845	77.213
197	Paramakudi	Pb, Cr, Fe	Tamil Nadu	Ramanathapuram	EFR South of Cauvery	Vaigai	9.553	78.586
198	Pargaon	No metals found above limit	Maharashtra	Pune	Krishna	Bhima	18.572	74.392
199	Patala	No metals found above limit	Maharashtra	Chandrapur	Godavari	Wardha	20.127	79.001
200	Patansaongi	Hg	Maharashtra	Nagpur	Godavari	Chandrabhaga	21.321	79.024
201	Pathagudem	No metals found above limit	Chhattisgarh	Dantewara	Godavari	Indravathi	18.853	80.349
202	Pattazhy	Pb, Fe	Kerala	Kollam	WFR South of Tapi	Kallada	9.073	76.761
203	Pauni	No metals found above limit	Maharashtra	Bhandara	Godavari	Wainganga	20.795	79.649
204	Peralam	No metals found above limit	Tamil Nadu	Tiruvarur	Cauvery	Vanjiyar	10.969	79.662
205	Perumannu	Fe	Kerala	Cannanore	WFR South of Tapi	Valapatnam	11.982	75.584
206	Perur	Fe, Hg	Telangana	Khammam	Godavari	Godavari	18.587	80.396
207	Phulgaon	No metals found above limit	Maharashtra	Pune	Krishna	Bhima	18.667	74.002
208	Poanta	No metals found above limit	Himachal Pradesh	Simaur	Yamuna Basin	Yamuna	30.434	77.623
209	Poiyaghat, Agra	No metals found above limit	Uttar Pradesh	Agra	Ganga	Yamuna	27.254	78.023
210	Polavaram	No metals found above limit	Andhra Pradesh	West Godavari	Godavari	Godavari	17.252	81.656
211	Porakudi	Fe	Tamil Nadu	Nagapattinam	Cauvery	Arasalar	10.904	79.707
212	Pratapgarh	No metals found above limit	Uttar Pradesh	Pratapgarh	Ganga	Sai	25.935	82.002
213	Pratappur	Hg	Maharashtra	Ahmednagar	Godavari	Pravara	19.358	74.384
214	Premnagar	No metals found above limit	Jammu & Kashmir	Doda	Indus	Chenab	33.155	75.704

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
215	Pudur	Pb, Fe	Kerala	Palakkad	WFR South of Tapi	Kannadipuzha	10.775	76.583
216	Pulamanthole	No metals found above limit	Kerala	Palakkad	WFR South of Tapi	Pulanthodu	10.899	76.197
217	Pulikukku	No metals found above limit	Karnataka	Dakshina Kannada	WFR South of Tapi	Kumaradhara	12.711	75.469
218	Purna	Hg	Maharashtra	Parbhani	Godavari	Purna	19.176	77.013
219	Rahu	No metals found above limit	Maharashtra	Pune	Krishna	Mula-Mutha	18.568	74.381
220	Rajahmundry	Hg	Andhra Pradesh	East Godavari	Godavari	Godavari	16.966	81.783
221	Rajapur	No metals found above limit	Uttar Pradesh	Chitrakoot	Ganga	Yamuna	25.390	81.154
222	Rajegaon	No metals found above limit	Madhya Pradesh	Balaghat	Godavari	Bagh	21.624	80.253
223	Rajghat	No metals found above limit	Uttar Pradesh	Lalitpur	Ganga	Betwa	24.768	78.236
224	Ram Munshi Bagh	Pb	Jammu & Kashmir	Srinagar	Indus	Jhelum	34.069	74.839
225	Ramakona	No metals found above limit	Madhya Pradesh	Chhindwara	Godavari	Kanhan	21.719	78.824
226	Ramamangalam	Fe	Kerala	Ernakulam	WFR South of Tapi	Muvattupuzha	9.944	76.478
227	Renuka ji	No metals found above limit	Uttarakhand	Sirmaur	Yamuna Basin	Giri	30.604	77.441
228	Safapora	No metals found above limit	Jammu & Kashmir	Baramula	Indus	Jhelum	34.246	74.632
229	Sahijana	No metals found above limit	Uttar Pradesh	Hamirpur	Ganga	Betwa	25.950	80.148
230	Saidpur	No metals found above limit	Uttar Pradesh	Ghazipur	Ganga	Ganga	25.534	83.221
231	Saigaon	No metals found above limit	Karnataka	Bidar	Godavari	Manjera	18.076	77.053
232	Sakhara	No metals found above limit	Maharashtra	Gadchiroli	Godavari	Wainganga	20.621	79.937
233	Sakleshpur	Pb, Fe	Karnataka	Hassan	Cauvery	Hemavathy	12.944	75.794
234	Sakmur	Hg	Maharashtra	Chandrapur	Godavari	Wardha	19.559	79.612
235	Salebardi	No metals found above limit	Maharashtra	Bhandara	Godavari	Chulband	20.913	79.927
236	Saloora	No metals found above limit	Telangana	Nizamabad	Godavari	Godavari	18.792	77.834
237	Samdoli	No metals found above limit	Maharashtra	Sangali	Krishna	Warana	16.856	74.496
238	Sangam	No metals found above limit	Jammu & Kashmir	Anantnag	Indus	Kinnersani	33.833	75.066

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
239	Sangod	No metals found above limit	Rajasthan	Kota	Yamuna Basin	Parwan	24.960	76.301
240	Santegulli	Fe	Karnataka	Uthara Kannada	WFR South of Tapi	Aghnanashni	14.435	74.587
241	Saradaput	Hg	Odisha	Malkangiri	Godavari	Sabri	18.613	82.143
242	Sarangpur	No metals found above limit	Madhya Pradesh	Rajgarh	Yamuna Basin	Kalisindh	23.550	76.467
243	Satna	No metals found above limit	Madhya Pradesh	Satna	Ganga	Tons	24.562	80.908
244	Satrapur	No metals found above limit	Maharashtra	Nagpur	Godavari	Kanhan	21.217	79.233
245	Savandapur	Pb, Cr, Fe	Tamil Nadu	Erode	Cauvery	Bhavani	11.522	77.510
246	Seondha	No metals found above limit	Madhya Pradesh	Datia	Ganga	Sindh	26.172	78.804
247	Sevanur	Cr, Fe	Tamil Nadu	Erode	Cauvery	Chittar	11.552	77.732
248	Shahzadpur	No metals found above limit	Uttar Pradesh	Kaushambi	Ganga	Ganga	25.667	81.430
249	Shastri bridge	No metals found above limit	Uttar Pradesh	Allahabad	Ganga	Ganga	25.437	81.889
250	Shimoga	No metals found above limit	Karnataka	Shimoga	Krishna	Tunga	13.927	75.585
251	Sidhra, Jammu	No metals found above limit	Jammu & Kashmir	Jammu	Indus	Tawi	32.763	74.884
252	Singasadanapalli	Pb, Cr, Fe, Ni	Tamil Nadu	Dharmapuri	EFR between Pennar-Cauvery	Ponnaiyar	12.870	77.836
253	Singavaram	No metals found above limit	Andhra Pradesh	Anantapur	Pennar	Chitravathi	14.598	78.013
254	Suddakallu	No metals found above limit	Telangana	Mahaboob Nagar	Krishna	Dindi	16.567	78.417
255	Sultanpur	No metals found above limit	Uttar Pradesh	Sultanpur	Ganga	Gomti	26.226	82.068
256	Sulurpet	No metals found above limit	Andhra Pradesh	Nellore	EFR between Pennar-Cauvery	Kalingi	13.708	80.010
257	T Bekuppe	Pb	Karnataka	Ramanagara	Cauvery	Arkavathy	12.507	77.428
258	T N Pura	Fe	Karnataka	Mysore	Cauvery	Kabini	12.230	76.894

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
259	T.K. Halli	Pb	Karnataka	Mandya	Cauvery	Shimsha	12.412	77.193
260	T.Ramapuram	No metals found above limit	Karnataka	Bellary	Krishna	Hagari	15.661	76.963
261	Tadipatri	No metals found above limit	Andhra Pradesh	Anantapur	Pennar	Pennar	14.922	78.016
262	Tal	No metals found above limit	Madhya Pradesh	Ratlam	Yamuna Basin	Chambal	23.723	75.347
263	Tandalaiputhur	No metals found above limit	Tamil Nadu	Thiruchirapalli	Cauvery	Ayyar	9.553	78.586
264	Tandi	No metals found above limit	Himachal Pradesh	Lahoul & Spiti	Indus	Chenab	32.550	76.980
265	Terwad	No metals found above limit	Maharashtra	Kolhapur	Krishna	Panchganga	16.674	74.574
266	Thengudi	No metals found above limit	Tamil Nadu	Tiruvarur	Cauvery	Thirumalairajanar	10.916	79.639
267	Thengumarahada	Pb, Cr, Fe, Ni	Tamil Nadu	Nilgiris	Cauvery	Bhavani/Moyar	11.573	76.919
268	Theni	Pb, Cr, Fe	Tamil Nadu	Theni	EFR South of Cauvery	Suruliyar	10.001	77.485
269	Thevur	Pb, Cd, Cr, Fe	Tamil Nadu	Salem	Cauvery	Sarabenga	11.527	77.751
270	Thimmanahalli	Fe	Karnataka	Hassan	Cauvery	Yagachi	12.985	76.038
271	Thoppur	Cr	Tamil Nadu	Salem	Cauvery	Thoppaiyar	11.938	78.057
272	Thotathinkadavu	Fe	Kerala	Kozhikode	WFR South of Tapi	Iruvazhinjipuzha	11.362	76.002
273	Thumpamon	No metals found above limit	Kerala	Pathanamthitta	WFR South of Tapi	Achankovil	9.225	76.715
274	Tonk	No metals found above limit	Rajasthan	Tonk	Yamuna Basin	Banas	26.206	75.776
275	Tuini	No metals found above limit	Uttarakhand	Dehradun	Yamuna Basin	Tons	30.940	77.847
276	Tuini (P)	No metals found above limit	Himachal Pradesh	Dehradun	Yamuna Basin	Pabar	30.955	77.853
277	U/S (BAMNI)	No metals found above limit	Maharashtra	Chandrapur	Godavari	Wardha	19.850	79.340
278	U/S (SATRAPUR)	No metals found above limit	Maharashtra	Nagpur	Godavari	Kanhan	21.226	79.231
279	Udaipur	No metals found above limit	Himachal Pradesh	Lahoul & Spiti	Indus	Chenab	32.721	76.663
280	Udi	No metals found above limit	Uttar Pradesh	Etawah	Ganga	Chambal	26.696	78.938
281	Ujjain	No metals found above limit	Madhya Pradesh	Ujjain	Yamuna Basin	Shipra	23.168	75.771
282	Urachikottai	Cr, Fe	Tamil Nadu	Erode	Cauvery	Cauvery	11.478	77.700

S.No.	Water Quality Stations(data as received)	Metal Found Above Limit	State	District	Basin	River/ Reservoir	Latitude	Longitude
283	V S Bridge	No metals found above limit	Uttar Pradesh	Varanasi	Ganga	Ganga	25.255	83.025
284	Vandiperiyar	No metals found above limit	Kerala	Idukki	WFR South of Tapi	Periyar	9.573	77.091
285	Varanasi	No metals found above limit	Uttar Pradesh	Varanasi	Ganga	Ganga	25.324	83.038
286	Varanavasi	Cr, Fe	Tamil Nadu	Perambalur	Cauvery	Marudaiyar	11.093	79.085
287	Vazhavachanur	No metals found above limit	Tamil Nadu	Thiruvannamalai	EFR between Pennar-Cauvery	Ponnaiyar	12.066	78.978
288	Veligonda	No metals found above limit	Telangana	Nalgonda	Krishna	Musi	16.571	79.421
289	Vijayawada	No metals found above limit	Andhra Pradesh	Krishna	Krishna	Krishna	16.501	80.625
290	Villupuram	No metals found above limit	Tamil Nadu	Villupuram	EFR between Pennar-Cauvery	Ponnaiyar	11.871	79.459
291	Vrindawan Bridge	As	Uttar Pradesh	Mathura	Yamuna Basin	Yamuna	27.566	77.708
292	Wadakbal	No metals found above limit	Maharashtra	Solapur	Krishna	Sina	17.533	75.885
293	Wadenapally	Hg	Telangana	Nalgonda	Krishna	Krishna	16.794	80.069
294	Wairagarh	No metals found above limit	Maharashtra	Gadchiroli	Godavari	Wainganga	20.422	80.092
295	Warunji	No metals found above limit	Maharashtra	Satara	Krishna	Koyna	17.272	74.165
296	Yadgir	No metals found above limit	Karnataka	Gulbarga	Krishna	Bhima	16.738	77.125
297	Yamuna Expess-way Road Bridge, Etamadpur	No metals found above limit	Uttar Pradesh	Agra	Ganga	Yamuna	27.179	78.119
298	Yashwant Nagar	No metals found above limit	Himachal Pradesh	Simaur	Yamuna Basin	Giri	30.882	77.209
299	Yelli	No metals found above limit	Maharashtra	Nanded	Godavari	Godavari	19.044	77.456
300	Yennehole	No metals found above limit	Karnataka	Udupi	WFR South of Tapi	Swarna	13.294	74.981

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