Accumulation of Trace Metals in the Water of Godavari River with Special Reference to Agricultural Runoff Near Balegaon Dam Nanded (M.S)

Mahesh R. Mupade[1], Dr. Jayprakash M. Patwari[2]

[1]Netaji Subhashchandra Bose Arts, Commerce and Science College, Swami Ramanand Teerth Marathwada University, Nanded, Maharashtra 431606

[2]Maharashtra Udayagiri Mahavidyalaya, Udgir, Somnathpur, Maharashtra 413517

Abstract: ***The Godavari River, a vital water resource in India, faces increasing pollution levels, particularly from trace metal contamination. This study assessed the variation of trace metals across ten locations along the river to understand the distribution and potential sources of contamination. Water samples were collected and analyzed for pH, electrical conductivity (EC), total dissolved solids (TDS), and concentrations of various trace metals, including manganese, zinc, copper, calcium, and selenium. The results indicated slightly alkaline pH levels, moderate EC and TDS values, and significant spatial variations in trace metal concentrations. Notably, elevated manganese and selenium levels were observed in certain areas, potentially indicating localized contamination. While some metals remained within safe limits, others, like manganese, could pose risks to the ecosystem. The findings highlight the need for ongoing monitoring and management of trace metal contamination in the Godavari River. Further research, including source identification and multi-year studies, is essential for developing effective water quality management strategies to ensure the long-term health of the river and its surrounding ecosystem. This study provides valuable insights into the current state of trace metal pollution in the Godavari River and emphasizes the importance of addressing this issue to protect both aquatic life and human health in the region.***

Keywords: Godavari River, Agricultural Runoff, Trace Metals, Water Quality, QGIS

1. Introduction

The Godavari River, one of the most significant rivers in India, flows through a diverse region and supports a wide range of activities such as agriculture, drinking water supply, and industrial use. It plays a vital role in maintaining ecological balance and providing resources for millions of people living in its basin [1]. However, like many other rivers across the country, the Godavari faces severe challenges due to anthropogenic influences, with pollution from industrial discharge, untreated sewage, and agricultural runoff being some of the most notable contributors. Among these, agricultural runoff is particularly alarming as it introduces a wide array of contaminants into water bodies, including nutrients, pesticides, fertilizers, and trace metals [2]. These pollutants, especially trace metals, can accumulate in the river water, leading to significant health risks for humans and aquatic life. The effects of trace metals in the water, such as lead (Pb), arsenic (As), cadmium (Cd), copper (Cu), and mercury (Hg), can be long-lasting as these metals persist in the environment without breaking down, leading to bioaccumulation and biomagnification in aquatic organisms [3]. The Godavari River in the vicinity of the Balegaon Dam, located in the Nanded district of Maharashtra, is facing growing concerns about water quality due to the increasing agricultural runoff in the region. The Balegaon Dam is an essential water resource for the region, providing irrigation and drinking water to local communities [4]. The agricultural land surrounding the dam primarily supports crops like sugarcane, cotton, and paddy, all of which require large amounts of water and fertilizers [5]. The extensive use of chemical fertilizers and pesticides in these agricultural practices contributes to the contamination of the river system [6] [7]. These chemicals often contain trace metals, which can leach into the river via surface runoff or irrigation systems. As a result, metals like copper, zinc, cadmium, and lead, found in fertilizers and pesticides, enter the river and accumulate in its water, sediments, and aquatic organisms. The accumulation of trace metals in river systems poses a significant threat to both the environment and public health [8]. Trace metals, unlike organic pollutants, do not degrade or break down over time, which makes them persistent pollutants in aquatic ecosystems. When these metals enter the river, they can accumulate in riverbed sediments and bioaccumulate in aquatic organisms like fish and plankton [9]. As these organisms are consumed by higher trophic levels in the food chain, these metals can concentrate and magnify in the bodies of larger aquatic species, including fish that humans consume [10]. This process of biomagnification is particularly concerning because humans, especially those relying on river-based fish for sustenance, can be exposed to harmful levels of trace metals, which may cause serious health issues, such as kidney damage, developmental problems, neurological disorders, and cancer [11].

The Godavari River is also the primary source of drinking water for several villages along its course, making the quality of the river's water even more critical [12]. In regions like Nanded, where agriculture is the dominant economic activity, the increased use of chemical fertilizers and pesticides not only contributes to water contamination but also affects groundwater quality, which many local communities rely on for drinking [13]. The presence of trace metals in drinking water can lead to long-term health problems, especially in rural areas where water treatment infrastructure is inadequate or non-existent. Thus, contamination from agricultural runoff, specifically trace metals, is not only an environmental issue but also a public health concern. In addition to its direct impact on water quality, the accumulation of trace metals has a profound effect on the river's ecosystem [14]. Aquatic organisms that are exposed to these metals can suffer from growth inhibition, reproductive failure, and death. Fish species, which are an important food source for both wildlife and humans, are especially vulnerable to the toxic effects of trace metals. The presence of metals like mercury and cadmium in fish has been linked to reproductive failure, reduced fertility, and even death, thereby disrupting the balance of the ecosystem [3][14]. Furthermore, the metal contamination can also affect the soil quality along the river, leading to further degradation of agricultural land, which is essential for sustaining local communities. Given the severity of the issue, it is crucial to assess the extent of trace metal contamination in the Godavari River, particularly near the Balegaon Dam, where agricultural runoff is a major contributing factor [11]. While several studies have explored pollution in the Godavari River, there is limited research on the specific impact of agricultural runoff on the accumulation of trace metals in this region. This research aims to fill this gap by providing a comprehensive analysis of the concentration levels of trace metals in the water and sediments of the Godavari River near the Balegaon Dam. The study will also explore the sources of contamination, specifically the role of agricultural runoff in the introduction of these metals into the river system [15].

The primary aim of this study is to assess the accumulation of trace metals in the water of the Godavari River near the Balegaon Dam, focusing on the impact of agricultural runoff. The study will investigate the concentration levels of metals such as cadmium, lead, arsenic, copper, and mercury in the river water and sediments to understand the extent of contamination and its potential effects on the river's ecosystem and human health. To achieve this, the study will address the following research objectives:

- To analyze trace metal concentrations in the water and sediments of the Godavari River near Balegaon Dam to evaluate the extent of contamination.
- To assess the impact of agricultural runoff on trace metal contamination, highlighting the contribution of farming activities to pollution levels in the river.

2. Related Work

Kandrakunta Babu et al. (2023) investigated heavy metal contamination in agricultural soils of the Godavari River basin near Rajahmundry. Using PERI, contamination factor, and Pearson's correlation, they identified moderate contamination of Ni, Fe, Cu, Zn, and considerable Cd contamination in specific sites. High coefficient variations indicated uneven accumulation. The study attributed rising toxicity levels to excessive fertilizer use, posing ecological and crop-related risks due to metal buildup in soils. Jakir Hussain et al. (2017) conducted a comprehensive study on surface water quality in the Godavari River basin by analyzing eight heavy metals arsenic, cadmium, chromium, copper, iron, lead, nickel, and zinc using atomic absorption spectrophotometry. Their findings highlighted iron and zinc as the most abundant metals, while cadmium had the lowest concentration. Although most metal concentrations were within BIS (2012) permissible limits, elevated levels of copper and nickel were detected at several monitoring stations, rendering the water unsuitable for drinking in those areas. Specifically, 11 out of 18 sampling stations, including Rajegaon, Tekra, and Kumhari, showed contamination due to these metals. The temporal and spatial variation in copper and nickel levels was attributed to rapid urbanization and industrialization, indicating significant anthropogenic influence on water quality in the region. Srikanta Samanta et al. (2021) assessed heavy metal contamination in Godavari River water and sediments. While water remained mostly safe, moderate sediment contamination was observed at specific sites, mainly due to Cu, Mn, and Zn. Pollution indices indicated localized ecological risks. Source analysis revealed that Cu, Cr, and Zn stemmed from human activities, while Mn had both natural and anthropogenic origins.

Mane et al. (2011) conducted a study to determine the concentrations of trace elements—manganese and selenium—at three sampling sites (S1, S2, and S3) in the Manjara Dam. Using UV spectroscopic methods, they measured the concentrations over two years (2009–2010 and 2010–2011). The study found the highest concentration of manganese to be 0.1866 mg/L, and the lowest was 0.057 mg/L. Selenium concentrations ranged from a high of 0.022 mg/L to a low of 0.0092 mg/L. The results indicated significant seasonal variations in trace element concentrations throughout the study period, emphasizing the dynamic nature of water quality in the dam. Ghorade et al. (2015) examined heavy metal pollution in the Godavari River during 2011–2012, focusing on Fe, Cu, Cr, Zn, Pb, and Cd levels. The study highlighted the persistent nature of heavy metals and their harmful impact on freshwater ecosystems. Findings emphasized the role of anthropogenic activities in degrading water quality, posing threats to aquatic flora, fauna, and human health through contamination of critical water sources. Jakir Hussain et al. (2017) analyzed heavy metals in Godavari River basin surface water, detecting elevated levels of copper and nickel beyond BIS limits. Iron and zinc were most abundant, while cadmium was least. Seven out of 18 water quality stations were within permissible limits, but several sites were unsuitable for drinking. The study linked metal contamination to rapid population growth and industrialization, contributing to environmental degradation and declining water quality.

Pawale and Lokhande (2011) conducted a study on the concentration of heavy metals in two major drinking water reservoirs in Nanded district, Maharashtra—Vishnupuri and Barul reservoirs. The investigation focused on determining the concentrations of iron, copper, and manganese, which were analyzed using standard methods suggested by APHA (1995) and NEERI (1988). The results revealed that the Vishnupuri reservoir exhibited higher concentrations of these heavy metals compared to the Barul reservoir. The elevated levels of heavy metals in the Vishnupuri reservoir could potentially impact both human health and the aquatic ecosystem, highlighting the need for further monitoring and management of water quality in these reservoirs. Mayur P. Davne et al. (2021) analyzed heavy metal concentrations in Godavari River water, identifying site-specific variations.

The metals followed the concentration order: Ni > Pb > Cd > Zn > Cr. The study emphasized the growing concern over pollution from natural and anthropogenic sources, highlighting the urgent need to control practices contributing to rising metal levels, which pose risks to freshwater ecosystems and human health.

3. Method and Material

The study area is located around Balegaon Dam in Nanded, Maharashtra, where agricultural runoff is a known source of contamination. Water samples were collected from five different sites along the Godavari River: Badbaha, Balagaon, Manur, Izatgaon, and Hatni shown in below figure 1. The sampling was carried out in accordance with standard procedures, and the collected water samples were analyzed for various parameters, including pH, electrical conductivity, total dissolved solids (TDS), and the concentrations of several trace metals. The trace metals tested in the water samples included Zinc (Zn), Iron (Fe), Chromium (Cr), Copper (Cu), Manganese (Mn), and Selenium (Se). The laboratory analysis followed standard methods as per APHA (Part 3111-Part B) for trace metal testing. Additionally, the pH and TDS values were measured following the guidelines from IS 3025 (Parts 11, 16) given in below table 1.

To assess the impact of agricultural runoff, satellite imagery from Landsat or Sentinel-2 was utilized to analyze surrounding land use patterns. QGIS software was then employed to integrate the water quality data with satellite images for spatial analysis. The integration of both datasets allowed for the creation of buffer zones around agricultural fields to evaluate the impact of runoff on water quality at various sites. The geospatial analysis was performed by creating vector layers for the sampling points and agricultural fields. The raster data from satellite imagery was used to classify land use and assess the proximity of agricultural runoff sources to the river. Buffer zones were used to estimate the potential impact of agricultural runoff on trace metal accumulation in the river water.

Spatial interpolation techniques, such as Inverse Distance Weighting (IDW), were applied to estimate trace metal concentrations at unsampled locations, generating continuous spatial maps of contamination levels. This technique helped identify contamination hotspots along the river, particularly near agricultural areas. The results of this analysis were visualized using thematic maps in QGIS, which highlight the concentration of trace metals along the river, with particular emphasis on areas impacted by agricultural runoff. These visualizations provide a clear representation of how agricultural runoff contributes to trace metal contamination in the river water.

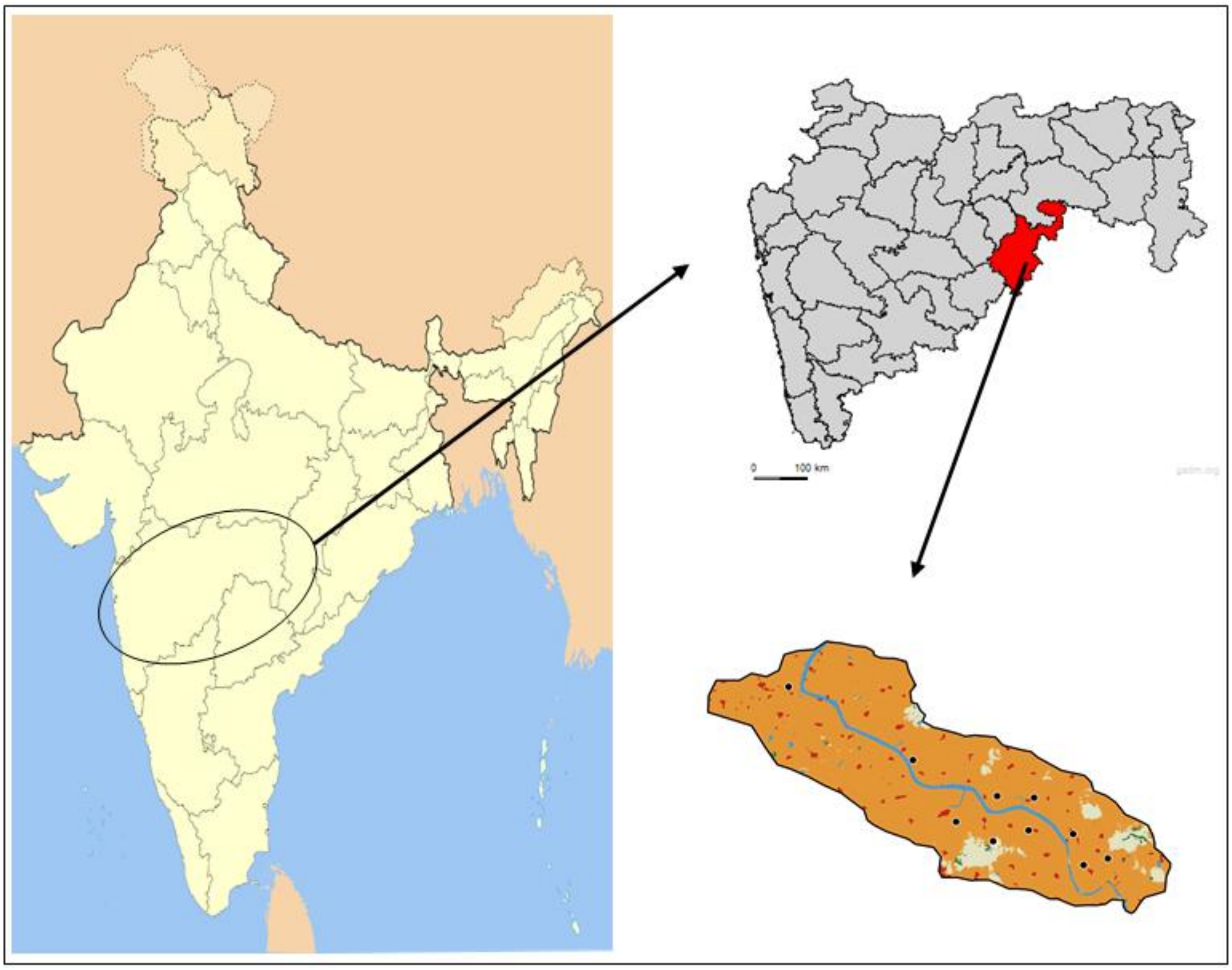


Figure 1. Study Area

Table 1: Analytical Methods for Trace Metal Measurement in Godavari River Water

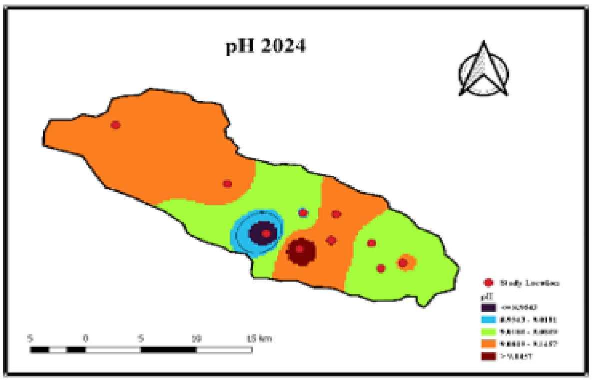
Test Parameter	Test Method	Unit of Measurement
pH	IS 3025 (Part 11)	--
Electrical Conductivity	APHA Part 2510-B	µS/cm
Total Dissolved Solids (TDS)	IS 3025 (Part 16)	mg/L
Total alkalinity (CaCO3)	IS 3025 (Part 23)	mg/L
Potassium (K+)	IS 3025 (Part 45)	mg/L
Calcium (Ca2+)	IS 3025 (Part 40)	mg/L
Magnesium (MG2+)	IS 3025 (Part 46)	mg/L
Nitrate (NO3)	APHA Part 4500-NO3 B	mg/L
Manganese (Mn)	APHA Part 3111-Part B	mg/L
Zinc (Zn)	APHA Part 3111-Part B	mg/L
Iron (Fe)	APHA Part 3111-Part B	mg/L
Chromium (Cr)	APHA Part 3111-Part B	mg/L
Selenium (Se)	APHA Part 3111-Part B	mg/L
Copper (Cu)	APHA Part 3111-Part B	mg/L

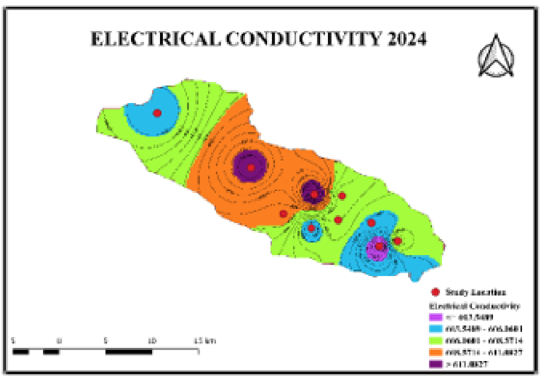
4. Result and Discussion

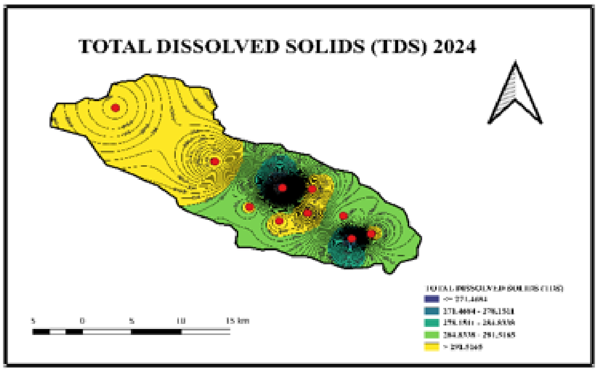
Table 2: Variation of Trace Metals in the Water of Godavari River at Various Locations

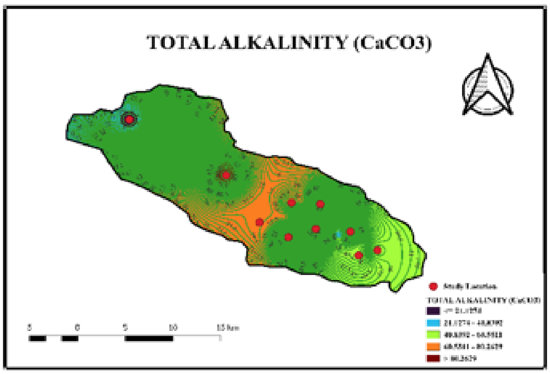
Sample	Izatgaon	Antaragaon	Rathi	Manur	Mahati	Barbada	Balegaon	Bhayegaon	Chinchpipri	Hatni
pH	9.15	9.21	9.01	9.15	9.03	8.89	9.04	9.13	9.11	9.09
EC	607	604.8	613.6	607	601	609	606	605.5	612	607.5
TDS	297.6	293.3	264.7	297.6	273.5	292.01	288.3	296.2	298.2	293.9
$CaCO_3$	1.4	95	80	100	45	75	37	20	87	51
K^+	1	6.7	2	2	3.1	4	6.1	6.2	2.3	3.1
Ca^{2+}	37.9	54.42	65.85	38.87	43.5	54.7	52.9	62.2	64.7	61.3
Mg^{2+}	28.92	16.5	28.3	25.92	22.7	23.9	18.3	20	22.9	16.8
NO_3^-	2.8	1.03	2	2.9	2.9	2.28	2.74	5.17	2.7	3.1
Mn	0.34	0.04	27.94	0.34	0.04	0.06	28.41	0.34	30.31	0.34
Zn	0.03	0.12	0.12	0.02	0.02	0.02	0.01	0.04	0.01	0.01
Fe	0.13	0.02	0.12	0.02	0.02	0.01	0.08	0.1	0.03	0.01
Cr	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.02	0.03	0.02
Se	0.02	0.26	0.02	0.02	0.073	0.05	0.26	0.02	0.02	0.5
Cu	0.28	0.35	0.28	0.26	0.35	0.23	0.28	0.28	0.34	0.23

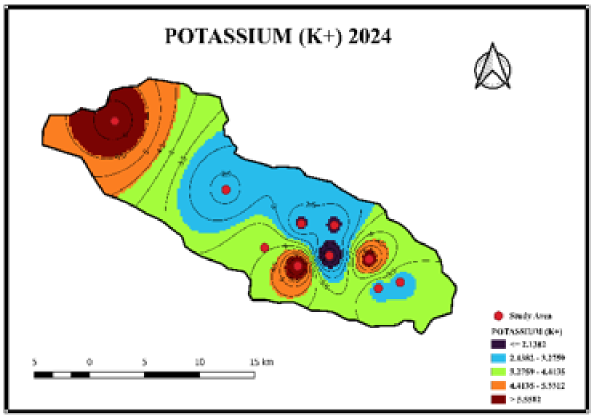
The pH values across the various sampling locations range from 8.89 to 9.21. The highest pH value of 9.21 was recorded at Antaragaon, indicating a slightly alkaline environment, while the lowest value of 8.89 was observed at Barbada. The elevated pH levels throughout the study area suggest relatively basic conditions, which could influence the solubility and mobility of trace metals in the water. The EC values varied from 601 to 613.6 µS/cm, with the highest value observed at Rathi. EC is often correlated with the presence of dissolved salts and ions in water, suggesting that the river water in these regions is moderately conductive. Correspondingly, TDS values ranged from 264.7 to 298.2 mg/L, with the highest levels at Chinchpipri. Higher TDS can be indicative of elevated ion concentrations, potentially affecting aquatic life and water quality shown in above table 2.

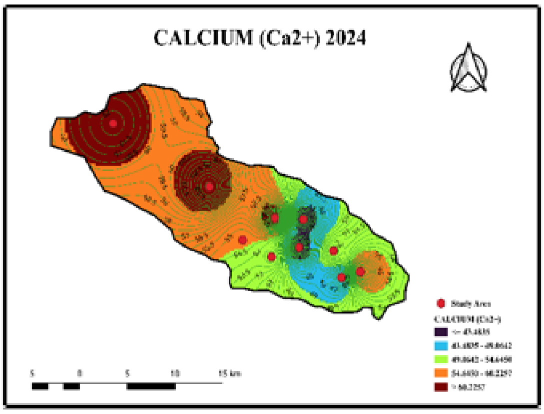


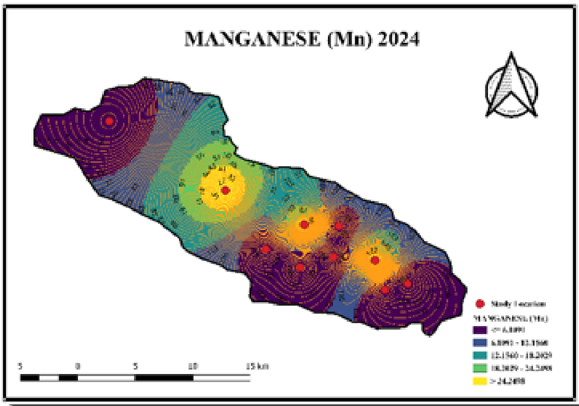


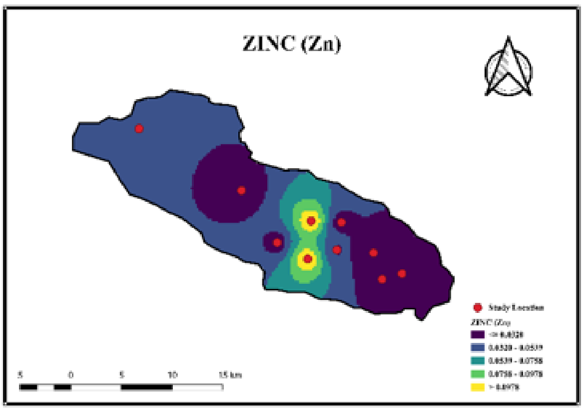

TOTAL DISSOLVED SOLIDS (TDS) 2024

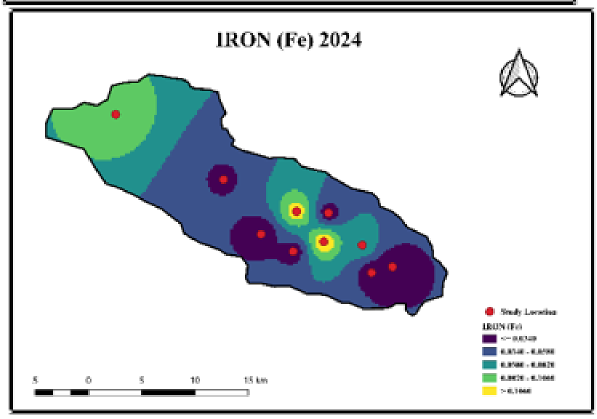

TOTAL ALKALINITY (CaCO3)

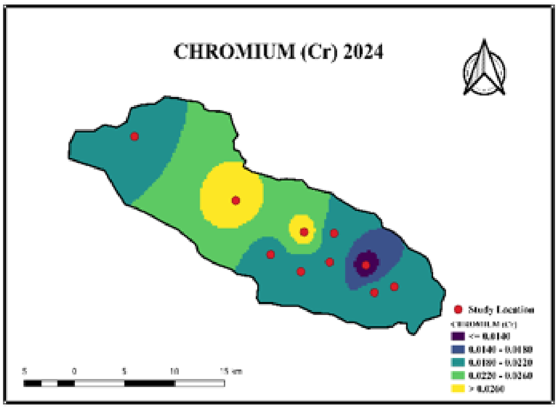

POTASSIUM (K+) 2024

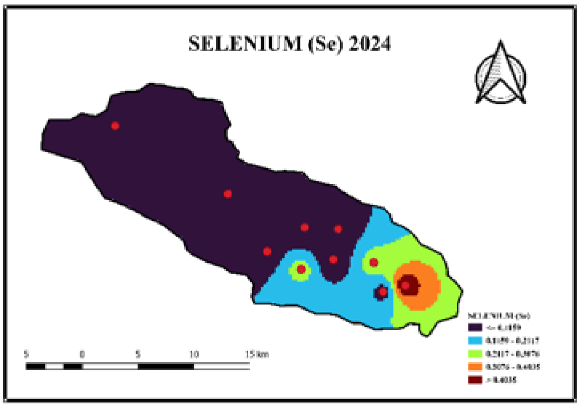

CALCIUM (Ca2+) 2024

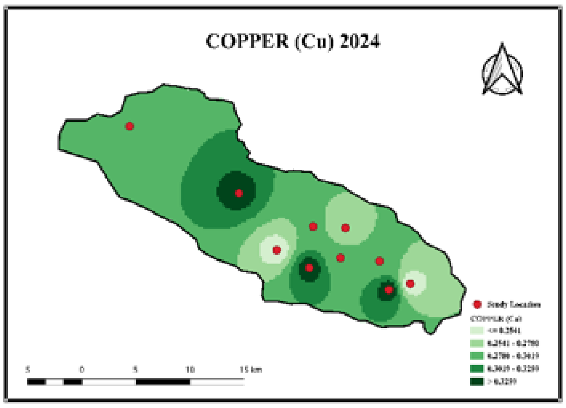

MANGANESE (Mn) 2024


ZINC (Zn)


IRON (Fe) 2024


CHROMIUM (Cr) 2024





Trace Metals:

1) **Potassium (K^+)**: Potassium levels ranged from 1 to 6.7 mg/L, with the highest concentration recorded at Antaragaon. Elevated potassium levels can influence the ion balance and fertility of the surrounding soils, affecting agricultural practices near the river.
2) **Calcium (Ca^{2+})**: Calcium concentrations varied from 37.9 to 65.85 mg/L. The highest concentrations were observed at Chinchpipri, which may reflect regional differences in mineral content, influencing water hardness and potential scaling in pipes and infrastructure.
3) **Magnesium (Mg^{2+})**: Magnesium concentrations ranged from 16.5 to 28.92 mg/L, with the highest concentration seen at Izatgaon. This variation suggests a significant influence of regional geology on the magnesium content of the river water.
4) **Manganese (Mn)**: Manganese concentrations exhibited wide variation, with values ranging from 0.04 to 30.31 µg/L. Notably, high concentrations were recorded at Balegaon and Bhayegaon, which may indicate localized pollution or natural mineral deposits. Manganese is a key trace element that can be toxic at high concentrations, affecting both human health and aquatic organisms.
5) **Zinc (Zn)**: Zinc levels ranged from 0.01 to 0.12 µg/L, with the highest concentrations recorded at Antargaon. While zinc is essential for plant and animal life, excessive levels can lead to toxicity, particularly in aquatic environments.
6) **Iron (Fe)**: Iron concentrations varied between 0.01 to 0.13 µg/L. The highest value was observed at Izatgaon, potentially indicative of natural geological formations or industrial influences, as iron contamination can lead to rusting of infrastructure and discoloration of water.
7) **Chromium (Cr)**: Chromium levels were relatively low, ranging from 0.01 to 0.03 µg/L. Despite being a toxic metal, chromium in trace amounts does not pose a significant threat unless concentrations exceed regulatory limits.
8) **Selenium (Se)**: Selenium levels varied from 0.02 to 0.5 µg/L. The highest concentration, observed at Hatni, is noteworthy as selenium is a micronutrient that can become toxic in high concentrations, affecting both plants and animals.
9) **Copper (Cu)**: Copper levels ranged from 0.23 to 0.35 µg/L. The uniform distribution of copper suggests that the river might be influenced by urban runoff or natural mineral deposits. While copper is essential in trace amounts, higher concentrations could harm aquatic species.

5. Discussion

This study assessed the accumulation of trace metals in the Godavari River near Balegaon Dam, focusing on the impact of agricultural runoff. Water samples were collected from ten locations and analyzed for pH, electrical conductivity, total dissolved solids, and concentrations of various trace metals. The results showed slightly alkaline pH levels, moderate EC and TDS values, and significant spatial variations in trace metal concentrations. Elevated manganese and selenium levels were observed in certain areas, potentially indicating localized contamination. While some metals remained within safe limits, others could pose risks to the ecosystem. The findings highlight the need for ongoing monitoring and management of trace metal contamination in the Godavari River. Further research, including source identification and multi-year studies, is essential for developing effective water quality management strategies.

6. Conclusion

The study of trace metal concentrations in the Godavari River across various sampling locations reveals important insights into the water quality and the potential environmental impacts of these metals. The pH levels indicate slightly alkaline water, which may affect the solubility of trace elements, influencing both their mobility and toxicity. Electrical conductivity (EC) and total dissolved solids (TDS) levels suggest that the river is moderately conductive, with varying ion concentrations that could have implications for aquatic life and water use. The trace metals show significant spatial variation, with elements like manganese, potassium, calcium, and magnesium exhibiting concentrations that suggest both natural and potentially anthropogenic influences. While some metals, like iron and chromium, remain within relatively safe levels, others such as manganese and selenium present higher concentrations at specific locations, indicating possible local contamination or mineral deposits. These elevated levels could pose risks to aquatic ecosystems and potentially to human health if water from these sites is used for consumption or irrigation without adequate treatment. The findings underscore the importance of continued monitoring and management of the Godavari River's water quality, particularly focusing on the trace metals that exhibit higher concentrations in certain regions. Addressing the sources of these elevated metal concentrations and implementing effective water quality control measures will be crucial for maintaining the ecological balance of the river and safeguarding public health. Regular assessment and targeted interventions can help mitigate potential risks posed by these trace metals, ensuring sustainable use of water resources in the region.

7. Limitations and Future scope

The study has several limitations that should be considered when interpreting the results. First, the spatial coverage is limited to a few selected sampling locations along the Godavari River. While these locations provide valuable data, they may not fully represent the overall trace metal distribution across the entire river system, as concentrations can vary significantly in different regions. A broader sampling network would offer a more comprehensive understanding of the trace metal dynamics throughout the river.

Second, the study is constrained by its temporal scope, as it only examines trace metal concentrations for a single year (2024). Water quality in rivers is subject to seasonal fluctuations due to factors such as rainfall, agricultural runoff, and industrial activities. To capture these variations and establish long-term trends, a multi-year study would be necessary.

Additionally, the analysis focused on a specific set of trace metals, which leaves out other potentially harmful elements such as arsenic, lead, or cadmium. These metals are also significant pollutants and could provide important insights into water quality. Future studies should expand the range of trace metals analyzed to offer a more holistic view of the river's contamination.

Finally, the study does not explore the specific sources of the elevated trace metal concentrations observed at certain locations, particularly for manganese and selenium. Identifying the sources of contamination, whether natural or anthropogenic, is critical for addressing the root causes of pollution. A more detailed investigation into the local sources, such as industrial activities or agricultural runoff, would be beneficial for more targeted water quality management strategies.

Future Scope

1) **Expanded Sampling Network**: Future studies could increase the number of sampling sites along the river, including tributaries, to obtain a more comprehensive understanding of the spatial distribution of trace metals.
2) **Longitudinal Monitoring**: Ongoing monitoring across multiple years would help assess seasonal and long-term fluctuations in trace metal concentrations, offering more detailed insights into the river's water quality trends.
3) **Source Identification**: Future research should focus on identifying the sources of contamination for elevated trace metal levels, especially for metals like manganese and selenium, using environmental tracers and detailed surveys.
4) **Comprehensive Water Quality Assessment**: Additional pollutants such as heavy metals, pesticides, and organic contaminants should be included in future studies for a more holistic understanding of the river's water quality.
5) **Impact on Aquatic Ecosystems**: Future studies should investigate the effects of elevated trace metals on aquatic life, including fish, plants, and microorganisms, to assess the environmental impact.
6) **Water Quality Management Plans**: Based on study findings, future research can contribute to the development of better water quality management strategies, including pollution control measures and sustainable practices in the region.
7) **Integration of Remote Sensing and GIS**: Incorporating remote sensing technology and GIS would allow for real-time mapping and monitoring of trace metal concentrations, enhancing future research's spatial and temporal resolution.

By addressing these limitations and expanding future research efforts in these areas, a more comprehensive understanding of trace metal contamination in the Godavari River can be achieved, leading to improved water quality management practices.

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