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Sustainable Management of Water Resource and Control of Pollutions

Soubhagya Mohapatra[1], Abhijit Mangaraj[2]
[1]M.Tech in Environmental Engineering, GIFT Autonomous College
[2]AssistantProfessot in Civil Engineering, GIFT Autonomous College

Abstract: This study explores the current status, challenges, and management strategies related to water resources and pollution in the state of Odisha, India.The samples were collected from strategically selected sites during both pre-monsoon and post-monsoon seasons, and analyzed for a range of physical, chemical, and biological parameters, including pH, total dissolved solids (TDS), biochemical oxygen demand (BOD), heavy metals (Pb, Cd), and coliform bacteria. The data were evaluated against BIS and WHO standards, and the Water Quality Index (WQI) was computed to assess the overall usability of water at each site.

The results indicate that several sites, especially those near urban and industrial zones such as Angul Talcher, and Cuttack, exhibit moderate to high levels of pollution, with WQI values categorizing them as poor to very poor in quality. Elevated concentrations of heavy metals and microbial contamination were observed, indicating risks to public health and aquatic ecosystems. Seasonal variations furtherhighlighted that pollution levels tend to intensify during the pre-monsoon period due to lower dilution capacity. Geospatial analysis using GIS tools helped visualize the spatial distribution of pollution and supported the identification of critical pollution zones. Correlation analysis and pollution source apportionment suggested that domestic sewage, industrial discharges, and agricultural runoff are the principal contributors.

The study concludes with a set of recommendations for improving water quality, including strengthening wastewater treatment infrastructure, enforcing environmental regulations, and enhancing community awareness. The research provides valuable insights for policy-makers, environmental planners, and water resource managers aiming to achieve sustainability.

I. INTRODUCTION

A. Background of the Study

Water is an essential resource that supports all forms of life and plays a vital role in economic development, human health, and environmental sustainability. Despite its abundance on the planet, only a small fraction (about 2.5%) is freshwater, and an even smaller portion is accessible for human use. As population growth, industrialization, and agricultural expansion continue to increase the demand for water, water resources are under immense pressure. In many parts of the world, water bodies such as rivers, lakes, and aquifers are being degraded due to pollution from domestic, industrial, and agricultural sources. Water pollution is a major environmental issue that affects water quality and reduces the usability of freshwater resources. Contaminants such as heavy metals, pesticides, nitrates, and pathogens can make water unsafe for human consumption and harm aquatic ecosystems. Improper waste disposal, lack of sewage treatment facilities, and inadequate environmental regulations further exacerbate the problem. This thesis explores the state of water resources, the extent and sources of pollution, and the implications for environmental and human health. It also investigate potential strategies for pollution control and sustainable water resource management.

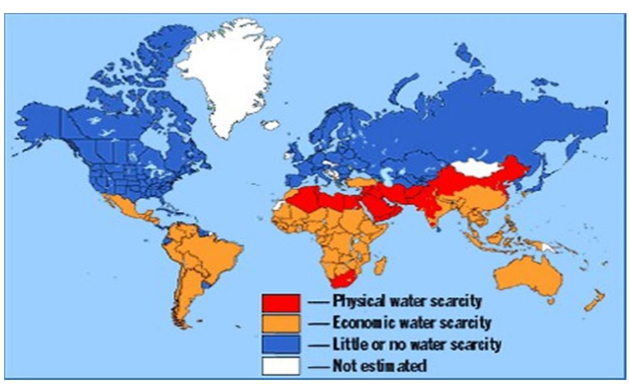


FIG 1.1 World map showing water scarcity in continents

B. Statement of the Problem

Many regions across the world, especially developing countries, are facing a dual crisis of water scarcity and pollution. Even in areas where water quantity is sufficient, the quality of available water is compromised by pollutants. Contaminated water is a leading cause of waterborne diseases, agricultural losses, and ecosystem degradation.

FIG 1.2 Human water use and pollution pathway

The lack of adequate management practices, insufficient policy enforcement, and public unawareness contribute significantly to the degradation of water quality. Therefore, understanding the current status of water pollution and exploring viable management solutions is critical for safeguarding water resources for future generations.

C. Objectives of the Study

The main aim of this research is to examine the challenges related to water pollution and propose sustainable solutions for water resource management. Specific objectives include:

1) To assess the current status and sources of water pollution in the study area.
2) To analyze the impacts of polluted water on human health and the environment.
3) To evaluate existing policies and practices for water pollution control.
4) To recommend sustainable strategies for improving water quality and managing water resources.

D. Research Questions

This study seeks to answer the following key questions:

1) What are the major sources and types of water pollution in the selected area?
2) How does water pollution affect human health and local ecosystems?
3) What are the limitations of current water resource management practices?
4) What strategies can be implemented to mitigate pollution and promote sustainability?

E. Significance of the Study

This research is significant because it addresses a critical challenge facing many communities today: the degradation of water resources due to pollution. By highlighting the causes, effects, and possible solutions, this study contributes to environmental awareness, supports policy development, and encourages sustainable practices. The findings can benefit local authorities, environmental agencies, researchers, and community groups working toward water conservation

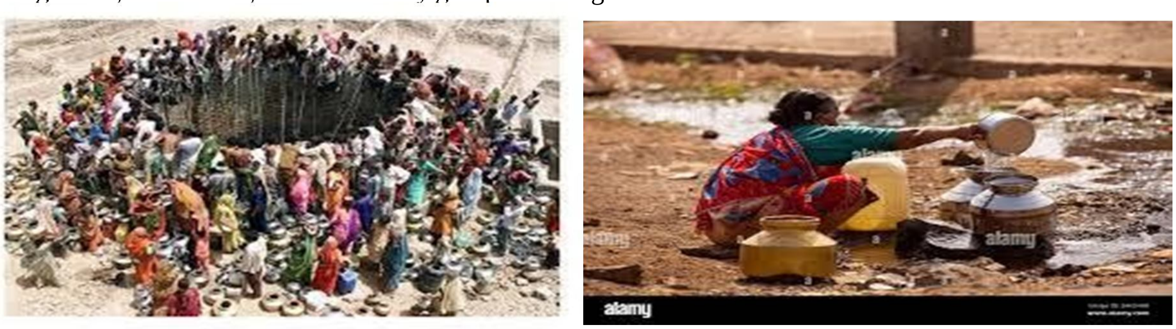


FIG 1.5 Global water crises

F. Scope and Limitations

This thesis focuses on the assessment of water pollution and resource management strategies in [insert study area or region]. The study primarily considers surface water bodies such as rivers, lakes, and reservoirs, although groundwater may be discussed where relevant. The research is limited by the availability of data, time constraints, and access to field sites for sampling and analysis.

G. Organization of the Thesis

This thesis is organized into six chapters:

- Chapter 1 provides an introduction, background, and rationale for the study.
- Chapter 2 reviews relevant literature on water pollution and resource management.
- Chapter 3 outlines the research methodology, including data collection and analysis.
- Chapter 4 presents the results and discusses key findings.
- Chapter 5 proposes management strategies and best practices

II. REVIEWS

A. Introduction

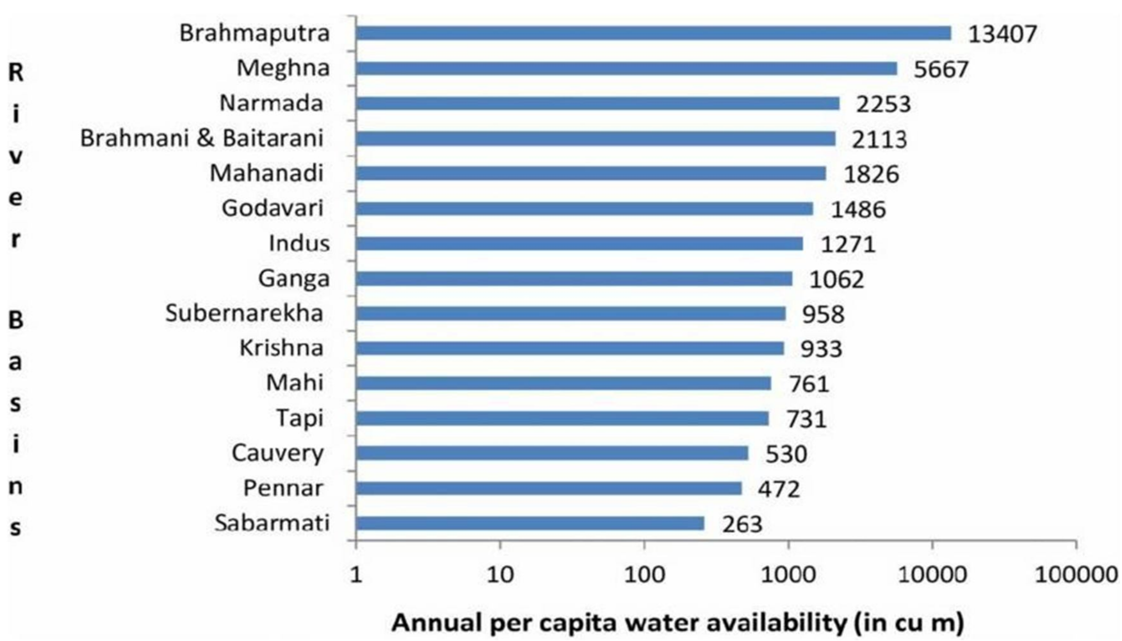
The literature review provides a comprehensive overview of existing knowledge, research findings, theories, and debates related to water resources and pollution. It lays the foundation for the current study by identifying gaps, exploring relevant frameworks, and synthesizing information from global, regional, and local perspectives. Understanding the dynamics of water availability, pollution sources, impacts, and management strategies is essential to contextualize this research and develop informed recommendations.

B. Water Resources: An Overview

Water resources include all sources of freshwater available for human use, such as rivers, lakes, groundwater, glaciers, and rainwater. Studies show that only about 0.5% of Earth's freshwater is accessible for direct human use (UN-Water, 2022). Water is indispensable for drinking, sanitation, agriculture, energy production, and industrial processes. However, increasing pressure from population growth, urbanization, and climate change is pushing many water systems toward unsustainability.

Key Issues:

- Over-extraction of groundwater
- Declining river flows due to upstream diversions
- Contamination from both point and non-point pollution sources



Graph 2.2 Annual per capita water distribution

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C. *Sources of Water Pollution*

Water pollution results from the introduction of harmful substances into water bodies, making them unfit for consumption or ecosystem health. The sources of water pollution are broadly categorized as follows:

1) *Point Sources*
   - Easily identifiable and typically discharged from a single location.
   - Examples: Industrial effluents, wastewater treatment plants, oil spills.
   - Literature highlights that point source pollution is easier to regulate through permits and monitoring (EPA, 2021).
2) *Non-Point Sources*
   - Diffused sources with no specific entry point.
   - Examples: Agricultural runoff, stormwater drainage, urban surface runoff.
   - More difficult to manage due to variability in flow and contaminant load (FAO, 2020).
3) *Emerging Pollutants*
   - Pharmaceuticals, microplastics, and personal care products have become notable contaminants.
   - Recent studies show that even trace amounts can disrupt aquatic ecosystems and human endocrine systems (WHO, 2023).

Point Source water pollution	Non-point source water pollution
Municipal and industrial effluent	Runoff from agriculture land
Runoff and leachate from waste dumping locations	Runoff from meadow and range
Runoff from animal pens and stable	Runoff from unsewered and sewered areas
Runoff from mining sites, oil refineries, industrial locates	Putrefying tank leachate
Overflow from storm water sewers	Runoff from building establishment
Overflows from drainage and human waste sewers	Runoff from abandoned mines
Runoff from construction locates	Atmospheric deposition over a water surfa
	Activities on land that generate impurities.

Table 2.3 Showing difference between point and non- point source

D. *Impacts of Water Pollution*

1) *Environmental Impacts*
   - Eutrophication caused by nutrient-rich waste (nitrogen and phosphorus).
   - Decline in aquatic biodiversity and alteration of food chains.
   - Degradation of wetlands and freshwater habitats.
2) *Human Health Impacts*
   - Contaminated drinking water is linked to diseases such as cholera, dysentery, hepatitis, and typhoid.
   - Heavy metals like arsenic and lead have long-term carcinogenic and neurological effects (UNESCO, 2022).
3) *Economic Impacts*
   - Costs of water treatment increase with higher pollution.
   - Loss of tourism and fisheries.
   - Reduced agricultural productivity due to poor irrigation water quality.

E. *Global and Regional Case Studies*

1) *The Ganges River (India)*
   - Severely polluted due to industrial discharge, religious practices, and municipal waste.
   - Government initiatives like the "Namami Gange" mission are attempting cleanup with mixed results.

2) *Flint Water Crisis (USA)*
   - A case of lead contamination due to mismanagement of municipal water supply.
   - Highlighted the importance of policy, infrastructure, and accountability.
3) *Lake Victoria Basin (East Africa)*
   - A transboundary water body facing pollution from agricultural runoff, untreated sewage, and invasive species.
   - Regional cooperation through the Lake Victoria Environmental Management Project (LVEMP) is ongoing.

F. Water Resource Management Strategies

Effective water management requires a multi-disciplinary, integrated approach. Strategies include:

1) *Integrated Water Resources Management (IWRM)*
   - A process that promotes coordinated development and management of water, land, and resources.
   - Encourages participation of stakeholders at all levels (GWP, 2021).
2) *Pollution Control Techniques*
   - Physical: Sedimentation, filtration
   - Chemical: Chlorination, ozonation
   - Biological: Constructed wetlands, bio-remediation
3) *Policy and Legislation*
   - Importance of enforcing environmental laws and pollution control standards.
   - Role of international agreements like the Water Convention and SDG 6.
4) *Community-Based Water Management*
   - Engaging local communities in water monitoring and conservation.
   - Proven success in rainwater harvesting and watershed management in rural India and Africa.

G. Research Gaps

Despite extensive research, several gaps remain:

- Limited real-time data on emerging contaminants.
- Poor enforcement of regulations in developing nations.
- Insufficient integration of climate change impact into water pollution models.
- Lack of public awareness and education on water conservation.

III.METHODOLOGY

A. Introduction

This chapter presents the methodology employed to assess the status of water resources and pollution in the selected study area in Odisha, India. It includes the design of the study, the techniques of data collection, sampling procedures, laboratory analysis, and the tools used for geospatial analysis. The combination of field surveys, laboratory work, and spatial analysis was aimed at understanding the extent and sources of water pollution and its implications for water resource management in the region.

B. Study Area: Odisha

1) *Introduction to the Area*

   The Kaliapani Canal is a minor but significant water channel located in the Bhubaneswar region, the capital city of Odisha. It plays a key role in urban drainage, agricultural irrigation, and serves as a stormwater outlet during the monsoon season.

2) *Geographic Location*
   - Coordinates: Approx. 20.30° N, 85.82° E
   - The canal flows through the eastern and south eastern outskirts of Bhubaneswar, including parts of Kaliapani, Chandrasekharpur, and adjoining peri-urban areas.
   - It eventually connects with larger drainage or water systems near the Daya River basin, which ultimately flows into Chilika Lake.

3) Purpose and Use

- Originally constructed for agricultural irrigation and to manage excess rainwater during monsoons.
- Currently, due to rapid urbanization, the canal also functions as a stormwater drain and is heavily influenced by municipal runoff.

4) Environmental Concerns

- Solid waste dumping: The canal is frequently polluted by plastic, household waste, and construction debris.
- Sewage discharge: Many households and informal settlements discharge untreated wastewater into the canal.
- Water quality degradation: Increased presence of pathogens, organic waste, and toxic materials has reduced water quality significantly.

5) Pollution Concerns

Recent studies and reports have highlighted several pollution-related issues affecting the Kaliapani Canal:

- Chemical Contamination: The canal receives effluents from nearby industrial activities, leading to the accumulation of hazardous substances.
- Solid Waste Accumulation: Improper waste disposal practices result in significant amounts of solid waste entering the canal, obstructing water flow and degrading water quality.
- Sewage Infiltration: Inadequate sewage treatment facilities contribute to the infiltration of untreated sewage into the canal, exacerbating pollution levels
- The Kaliapani Canal provides a representative example of urban water resource degradation due to improper waste management and lack of conservation.
- It is a critical case study for assessing the impact of urban pollution, unplanned development, and water quality issues in rapidly growing cities like Bhubaneswar

6) Recent studies.

In response to the escalating pollution levels, the National Green Tribunal (NGT) has constituted a four-member committee to investigate the alleged kidney-related ailments and deaths in the Kaliapani region. The committee comprises officials from the Odisha Pollution Control Board, Central Pollution Control Board, Central Ground Water Board, and the District Magistrate of Jajpur. The committee is tasked with submitting a comprehensive report on the matter within four weeks .newindianexpress.com

7) Conclusion

The Kaliapani Canal exemplifies the environmental challenges faced by urban water bodies in rapidly developing regions. Addressing the pollution concerns of the canal requires a multifaceted approach, including stringent industrial waste management practices, improved sewage treatment infrastructure, and public awareness campaigns on waste disposal.
Collaborative efforts from government. .

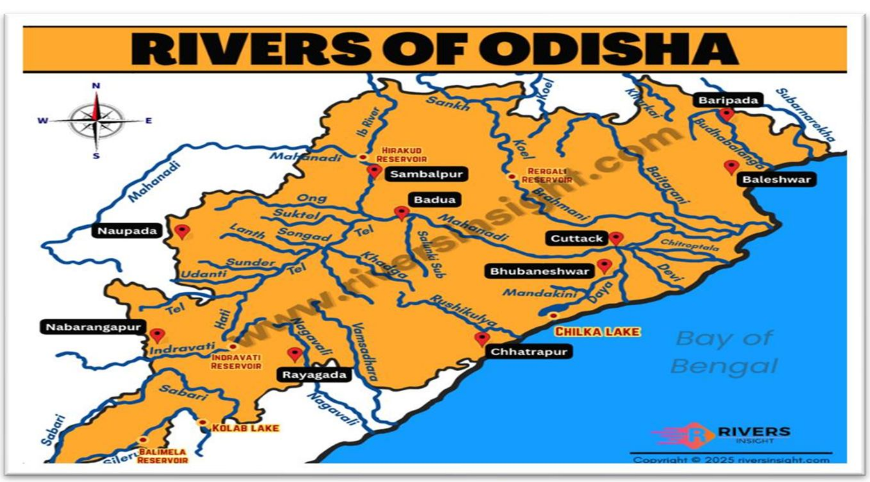

FIG 3.2 Showing odisha river basin map

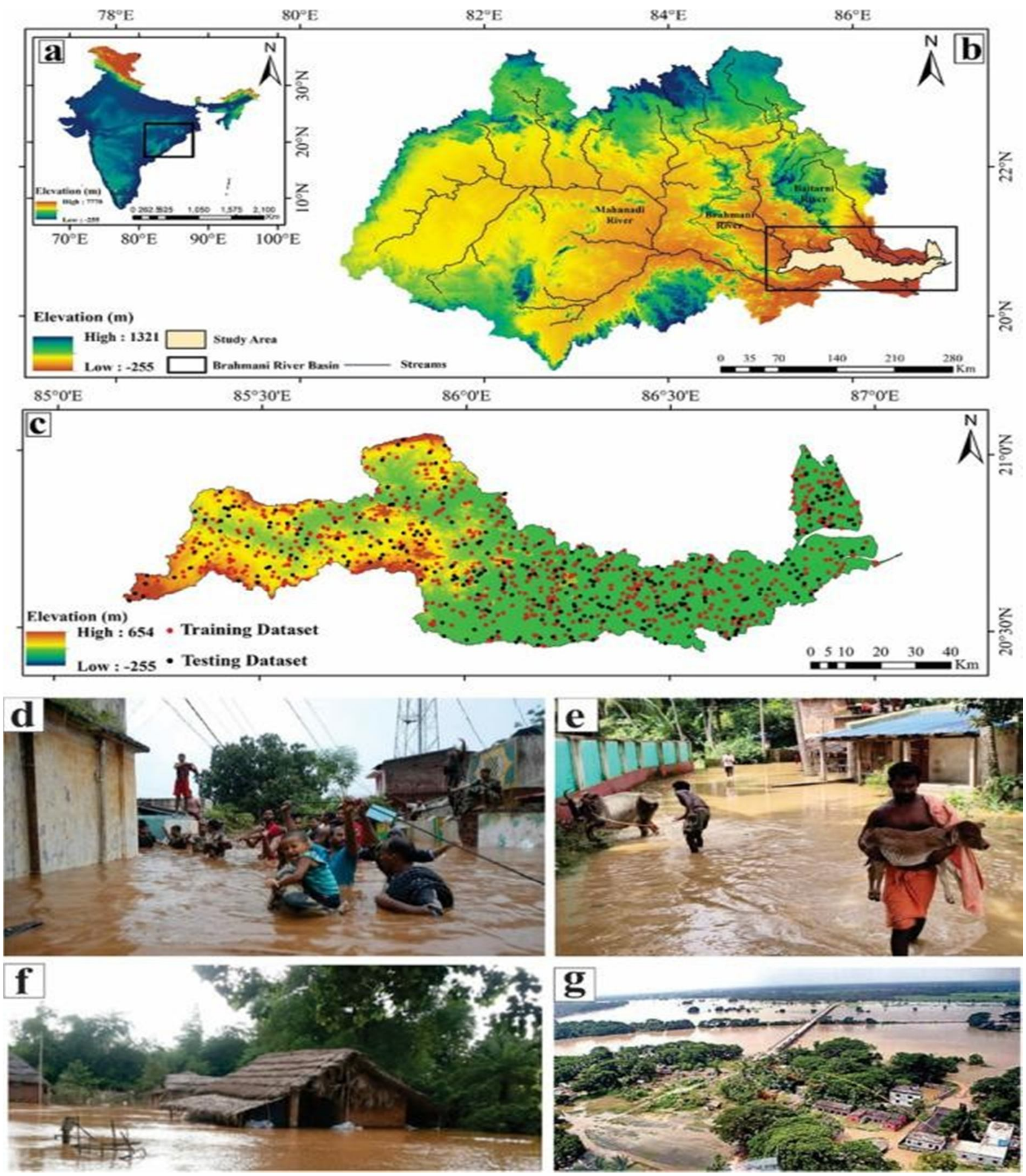

Fig 3.3 Survey analysis datasets and water pollution

C. *Research Design*

A mixed-methods research design was adopted, combining:

- Field surveys for water sampling and observations
- Laboratory analysis for evaluating water quality
- Remote sensing and GIS for land use mapping and spatial Statistical analysis to interpret water quality trends and correlations

FIG 3.4 Samples collected from study area

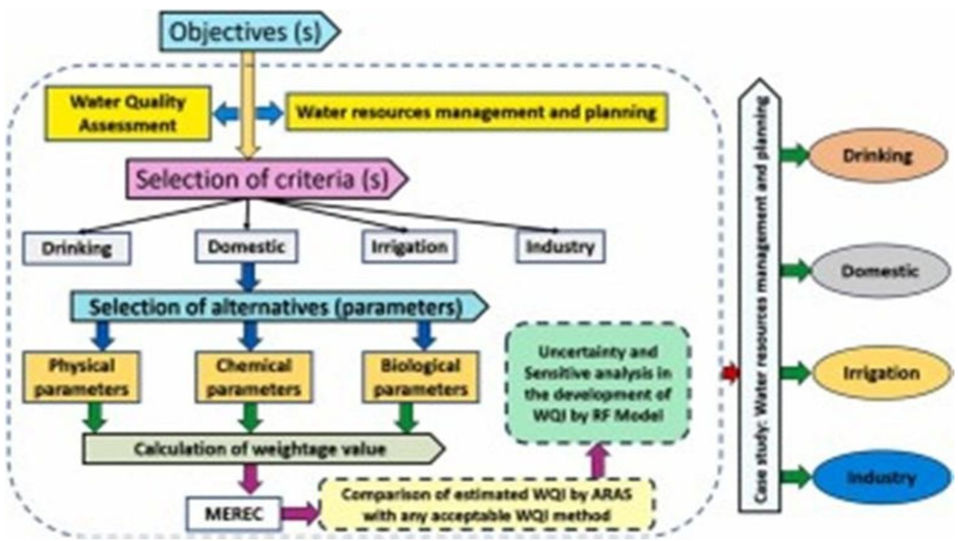

Fig 3.5 Water resource assessment and planning

Fig 3.6 Pouring samples for analysis

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1) *Primary Data*

a) *Water Sampling*

- Sampling Sites: A total of 15 sites were selected across upstream, midstream, and downstream sections of the Kaliapani canal and its tributaries within Odisha. Site selection was based on proximity to centers, industrial zones (e.g., Talcher, Angul), and agricultural areas.
- Sampling Frequency: Samples were collected during the pre-monsoon (April– May) and post-monsoon (October–November) periods of 2024 to capture seasonal variation.
- Sample Preservation: Water samples were collected in pre-cleaned polyethylene bottles, labeled, and preserved at 4°C until analysis.

b) *Water Quality Parameters*

Category	Parameters
Physical	Temperature, Turbidity, Electrical Conductivity (EC), Total Dissolved Solids (TDS)
Chemical	pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Nitrates, Phosphates, Chlorides, Sulfates, Heavy Metals (Pb, Cr, Cd, As, Hg) urban
Biological	Total Coliform, Fecal Coliform, E. coli

2) *Secondary Data*

Historical water quality records from the Odisha State Pollution Control Board (OSPCB) and Central Water Commission (CWC)
Meteorological data from the India Meteorological Department (IMD
Water samples were analyzed at the [Name of Laboratory or Institution] following APHA (2017) standards. Key procedures included:

- Titrimetric methods for BOD, DO, and COD
- Spectrophotometry for nutrients like nitrates and phosphates
- Atomic Absorption Spectroscopy (AAS) for heavy metals
- Membrane filtration technique for microbial analysis
- Census and socio-economic data related to water usage and sanitation

D. Laboratory Analysis

Water samples were analyzed at the Laboratory following APHA (2017) standards. Key procedures included:

- Titrimetric methods for BOD, DO, and COD
- Spectrophotometry for nutrients like nitrates and phosphates
- Atomic Absorption Spectroscopy (AAS) for heavy metals
- Membrane filtration technique for microbial analysis

E. GIS and Remote Sensing Analysis

1) Tools Used

- Software: ArcGIS 10.x, QGIS, ERDAS Imagine
- Satellite Data: Landsat 8 (30m), Sentinel-2 (10m), NRSC datasets

2) Procedures

- Watershed delineation of the Mahanadi sub-basin using DEM (SRTM)
- Land Use and Land Cover (LULC) classification using supervised classification techniques
- Buffer Analysis around sampling locations and pollution hotspots (e.g., industrial clusters)
- Interpolation techniques (IDW/Kriging) to map spatial variation in water quality parameters

F. Water Quality Index (WQI) Calculation

The Weighted Arithmetic Mean Method was used to compute the Water Quality Index (WQI), integrating multiple parameters into a single number to classify water quality:

WQI=∑i=1nqi·wi∑i=1nwiWQI = \frac{\sum_{i=1}^{n} q_i \cdot w_i}{\sum_{i=1}^{n} w_i}WQI=∑i=1nwi∑i=1nqi·wi

Where:

- qiq_iqi = Quality rating for the ith parameter
- wiw_iwi = Weight of the ith parameter
- nnn = Number of parameters

Water was classified into categories: Excellent (0–25), Good (26–50), Poor (51–75), Very Poor (76–100), and Unsuitable (>100).

G. Statistical Analysis

Data analysis was conducted using SPSS 26.0 and Microsoft Excel. Statistical techniques included:

- Descriptive statistics (mean, median, standard deviation)
- Correlation analysis (e.g., BOD vs. COD, pH vs. heavy metals)
- Principal Component Analysis (PCA) to identify pollution sources
- Trend analysis over seasons and locations

H. Limitations

- Inaccessibility of certain remote or highly polluted sites limited sample coverage
- Laboratory testing constraints limited the frequency of some chemical analyses
- Satellite imagery resolution may not capture micro-pollution sources

I. Summary

This chapter described the research framework used to assess water resources and pollution in the Odisha region, focusing on the Mahanadi River Basin. The combination of field sampling, laboratory testing, and geospatial analysis enables a holistic understanding of water quality trends, pollution sources, and spatial variability, forming a basis for effective water management strategies.

IV. RESULTS AND DISCUSSION

A. Introduction

This chapter presents the findings of the water quality analysis conducted in the study area across selected locations along the Mahanadi River Basin in Odisha. The results from physical, chemical, and biological parameter tests are analyzed and interpreted in relation to permissible standards and spatial trends.

Additionally, Water Quality Index (WQI) results and their implications on water usability are discussed. The findings are also compared with previous studies and relevant environmental guidelines.

B. Physical Parameters

1) Temperature

Water temperature ranged from 24°C to 31°C, with higher temperatures observed in the downstream region near Cuttack, likely due to lower water flow and increased urban heat island effects. Temperature variations were minimal between pre-monsoon and post-monsoon periods.

2) pH

The pH values ranged between 6.3 and 8.2, indicating a generally neutral to slightly alkaline nature. A few downstream sites exceeded pH 8.0, which may indicate the influence of wastewater discharge or algal activity.

3) Electrical Conductivity (EC) and Total Dissolved Solids (TDS)

- EC ranged from 120 µS/cm to 750 µS/cm
- TDS values ranged between 85 to 480 mg/L, remaining below the WHO permissible limit of 500 mg/L
  Higher values were recorded near industrial zones (e.g., Angul), indicating possible contamination from effluents

C. Chemical Parameters

1) Dissolved Oxygen (DO)

DO levels varied from 3.2 to 7.5 mg/L. The lowest DO was recorded in downstream industrial areas, indicating high organic pollution and limited aeration.

2) Biochemical Oxygen Demand (BOD)

BOD values ranged between 1.4 and 5.8 mg/L, exceeding the desirable limit (3 mg/L) in urban and industrial stretches (e.g., near Sambalpur), suggesting significant organic matter pollution.

3) Nitrates and Phosphates

- Nitrate concentrations ranged from 0.8 to 9.3 mg/L
- Phosphate levels varied between 0.2 and 1.8 mg/L

Elevated levels were observed near agricultural catchments due to fertilizer runoff, particularly in the post-monsoon period.

4) Heavy Metals

Parameter	Range (mg/L)	Permissible Limit (BIS)	Sites Exceeding Limit
Lead (Pb)	0.001–0.019	0.01	4 out of 15 sites
Cadmium (Cd)	0.0001–0.005	0.003	2 sites
Arsenic (As)	<0.001	0.01	Within limit

Elevated lead levels were recorded near industrial discharge points.

D. Biological Parameters

Total and fecal coliforms were detected in 10 of 15 sites, with values exceeding the BIS standard (0 MPN/100 mL) for drinking water. The highest contamination was found near urban centers like Cuttack and Bhubaneswar, indicating direct sewage inflow into surface waters.

E. Water Quality Index (WQI) Analysis

The WQI was computed using selected parameters (pH, DO, BOD, Nitrate, TDS, etc.). The results were classified as follows:

WQI Range	Water Quality Status	No. of Sites
0–25	Excellent	2
26–50	Good	5
51–75	Poor	4
76–100	Very Poor	3
>100	Unsuitable	1

The site near industrial discharge in Talcher showed a WQI of 118, classifying it as unsuitable for drinking or bathing. A spatial WQI map generated using GIS showed pollution intensity increasing downstream and in densely populated areas.

F. Seasonal Variation

- Pre-monsoon: Higher concentrations of pollutants due to reduced flow and increased evaporation.
- Post-monsoon: Slight dilution observed, but nutrient loads increased due to agricultural runoff.

This seasonal trend aligns with findings from [Reference – CPCB/previous studies].

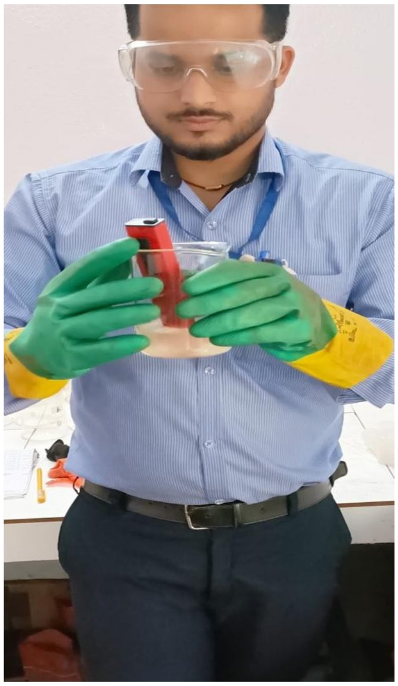


FIG: 4.1PH Analysis

FIG: 4.2TDS Analysis

G. Correlation Analysis

Statistical correlation revealed:

1) High positive correlation (r = 0.87) between BOD and nitrate levels, indicating agricultural and domestic organic pollution
2) Negative correlation between DO and BOD, as expected in polluted waters Principal Component Analysis (PCA) grouped variables into three major pollution sources:

- Domestic wastewater (coliforms, BOD)
- Industrial effluents (heavy metals, EC)
- Agricultural runoff (nitrates, phosphates)

H. Discussion

The results clearly indicate that the water quality in the kaliapani canal and its tributaries varies with land use, proximity to urban/industrial areas, and seasonal changes. Areas near industrial clusters (Angul, Talcher) and urban zones (Cuttack, Bhubaneswar) show signs of moderate to severe pollution. These findings align with earlier studies conducted by OSPCB (2022) and CWC (2019). The presence of heavy metals and microbial contamination poses serious health risks and warrants immediate attention. Poor WQI at multiple locations indicates the need for stricter wastewater treatment policies and improved monitoring infrastructure.

I. Summary

This chapter presented the analytical results and interpretation of water samples collected from various points along the Mahanadi River Basin. The spatial and seasonal patterns of pollution were evident, with several sites showing deterioration in water quality due to anthropogenic pressures. The WQI results confirmed the unsuitability of water at certain locations, highlighting urgent intervention needs.

V. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

This study investigated the current status of water quality and pollution in selected stretches of the Mahanadi River Basin in Odisha, India. By combining field sampling, laboratory analysis, and GIS-based spatial interpretation, a comprehensive assessment of water resources was achieved.

The findings revealed that water quality across many sites is degrading due to urbanization, industrial effluents, and agricultural runoff. Several physical, chemical, and biological parameters exceeded the permissible limits set by BIS and WHO, particularly in downstream regions and near industrial clusters such as Angul and Talcher.

Key conclusions are:

- pH, TDS, and temperature were within acceptable limits at most locations, but higher values were noted in urban-influenced sites.
- BOD, COD, and DO levels indicate substantial organic pollution in areas with untreated domestic sewage discharge.
- Nitrate and phosphate concentrations were elevated, especially in post-monsoon samples, reflecting fertilizer runoff from agricultural areas.
- Heavy metals like lead and cadmium were detected above permissible limits in several locations near industrial discharge zones.
- Coliform bacteria were present in most water samples, highlighting risks of waterborne diseases and unsafe water for consumption or recreation.
- WQI analysis classified water at several sites as poor to unsuitable, confirming pollution pressure along urban-industrial corridors.
- Seasonal variations demonstrated that water quality worsens during the pre-monsoon period due to low flow and concentration effects.

These results clearly show that water resources in the region are under significant stress, with potential risks to ecosystem health, agricultural productivity, and public health if effective management actions are not undertaken.

Table 2:Classification of WOI range and category of water

WQI Range	Category of water
<50	Excellent water
50-100	Good water
100-200	Poor water
200-300	Very Poor water
>300	Unfit for drinking purpose

Table 5.1-classification of WOI range and category of water

B. Recommendations

Based on the findings of this study, the following recommendations are proposed to improve and sustain water quality in the Mahanadi Basin and similar regions in Odisha:

1) Strengthen Wastewater Treatment Infrastructure
- Expand and upgrade sewage treatment plants (STPs) in urban areas.
- Enforce zero liquid discharge (ZLD) norms for industries discharging into water bodies.
- Monitor effluent discharge with real-time water quality sensors.

2) Implement Integrated Watershed Management
- Adopt buffer zone and riparian vegetation to reduce nutrient and sediment loading.
- Encourage sustainable agriculture practices to reduce fertilizer runoff, such as organic farming, contour plowing, and use of slow-release fertilizers.

3) Regular Monitoring and Public Reporting
- Establish a state-level water quality monitoring network with monthly updates.
- Involve citizen science programs for sample collection and water watch.
- Create public dashboards (e.g., web apps) for WQI data sharing.

4) Groundwater Protection
- Monitor and control over-extraction of groundwater in high-pollution zones.
- Prevent leaching of pollutants through proper landfill and effluent management.

5) Policy and Governance
- Strengthen inter-agency coordination between OSPCB, Water Resources Department, and Pollution Control Boards.
- Strictly enforce the Water (Prevention and Control of Pollution) Act, 1974.
- Develop a state water pollution action plan with district-level targets.

6) Community Awareness and Participation
- Conduct water conservation and pollution awareness campaigns in rural and urban schools.
- Promote Rainwater Harvesting and Reuse/Recycling in households and industries.

C. Scope for Future Research

- Long-term monitoring of water quality under changing climate and land use patterns
- Use of machine learning models to predict pollution hotspots
- Study of groundwater–surface water interactions and contamination pathways
- Health impact assessment studies on communities consuming polluted water
- Development of real-time water quality monitoring tools using IoT

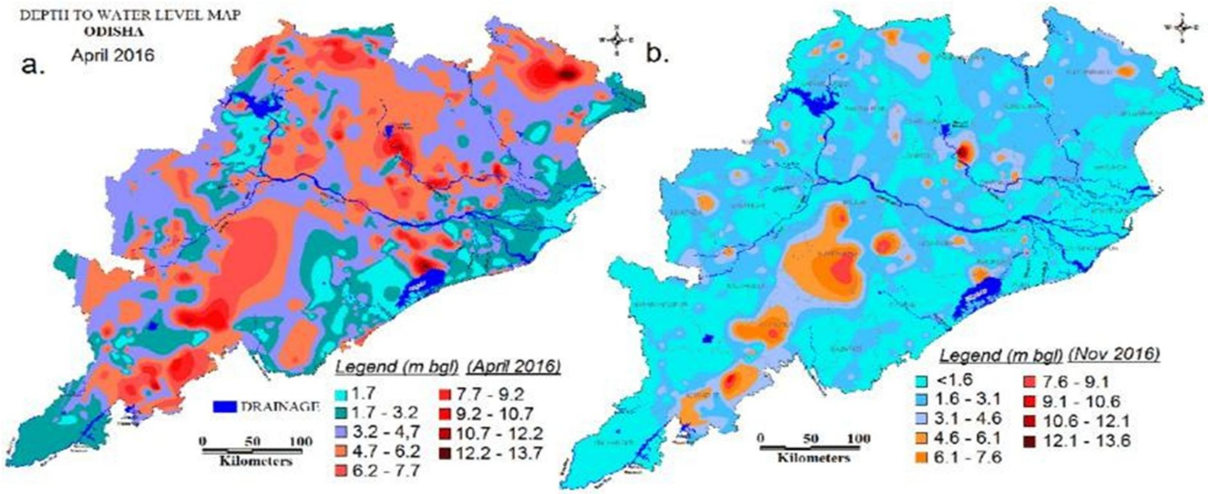


FIG 5.3 Pre And Post Monsoon Waterlevel Depth In 2016 Coastal Odisha

D. *Final Remarks*

Water is a vital but vulnerable resource. This study underscores the urgency of protecting water bodies in Odisha from pollution and overuse. A combination of science-based policies, technological intervention, community engagement, and sustainable development practices is essential to ensure the availability of safe and clean water for future generations.

VI. SUMMARY AND FUTURE SCOPE

A. *Summary of the Study*

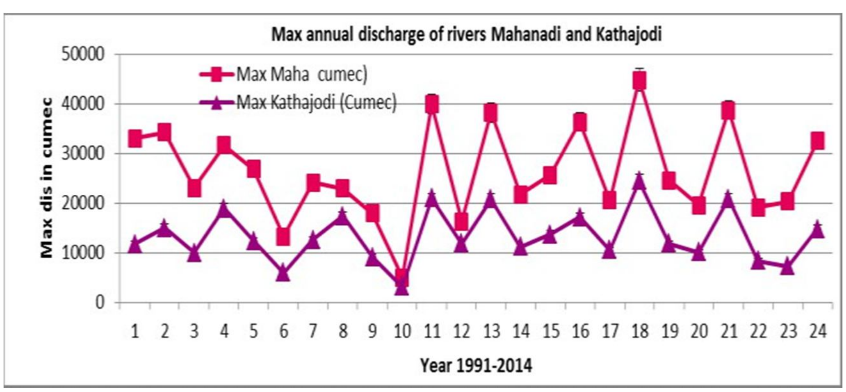
This research focused on the assessment of water quality and pollution levels in selected regions of the Kaliapani canal in Odisha, integrating field measurements, laboratory analysis, and geospatial tools to evaluate the state of surface water resources.

The main objectives of the study were:

- To evaluate the physical, chemical, and biological characteristics of river water across multiple sites.
- To identify spatial and seasonal trends in water pollution.
- To compute the Water Quality Index (WQI) for each sampling location.
- To interpret pollution sources using GIS, statistical tools, and correlation analyses.
- To recommend strategies for better water resource management in Odisha.

B. *Contributions of the Study*

- Provided a comprehensive water quality assessment of a critical river system in Odisha.
- Applied GIS and WQI techniques to spatially visualize and quantify pollution severity.
- Identified key pollution drivers through correlation and trend analysis.
- Proposed actionable policy and infrastructure recommendations to stakeholders.



Graph 6.1 Showing maximum annual discharge of river

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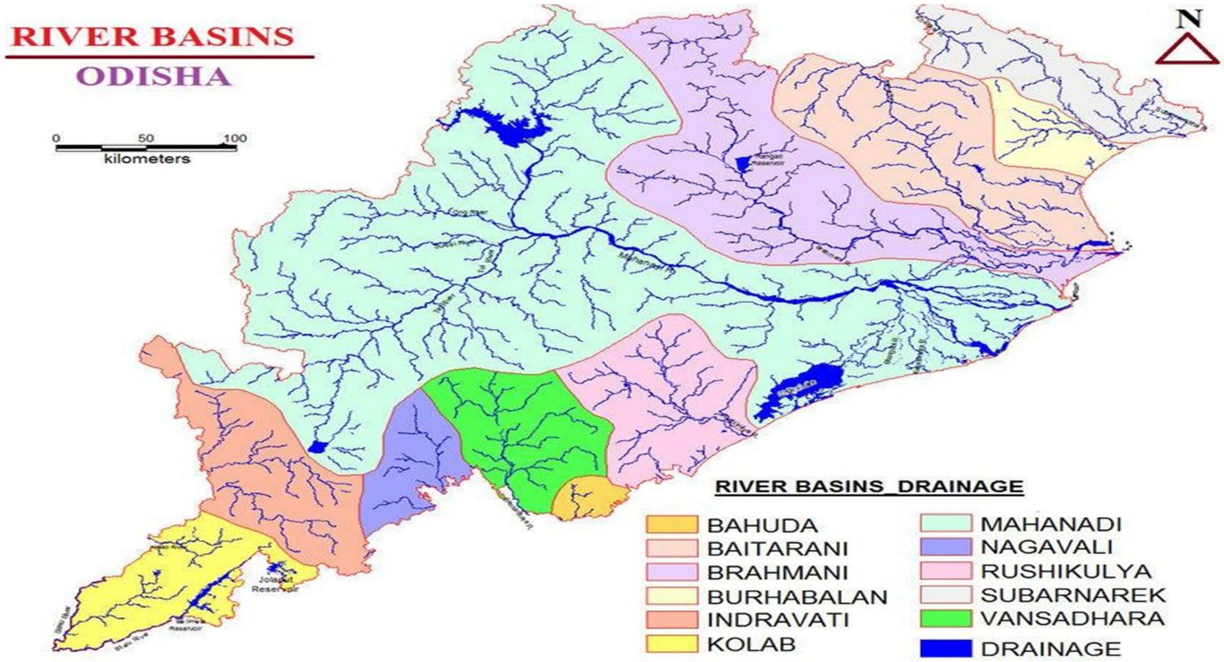

Fig 6.2 Showing distribution river basins drainage of odisha

Physico-chemical parameters such as BOD, COD, DO, nitrates, and phosphates indicated moderate to severe pollution, especially in urban-industrial belts.

- Heavy metals like lead and cadmium were found in concentrations above safe limits at several sites, particularly near Angul and Talcher.
- Microbial contamination (coliform bacteria) exceeded acceptable thresholds, indicating risks of waterborne diseases.
- The Water Quality Index (WQI) classified several sampling sites as poor to very poor, and one site as unsuitable for domestic use.
- Seasonal analysis showed greater pollution during the pre-monsoon period due to low water flow and increased concentration of pollutants.

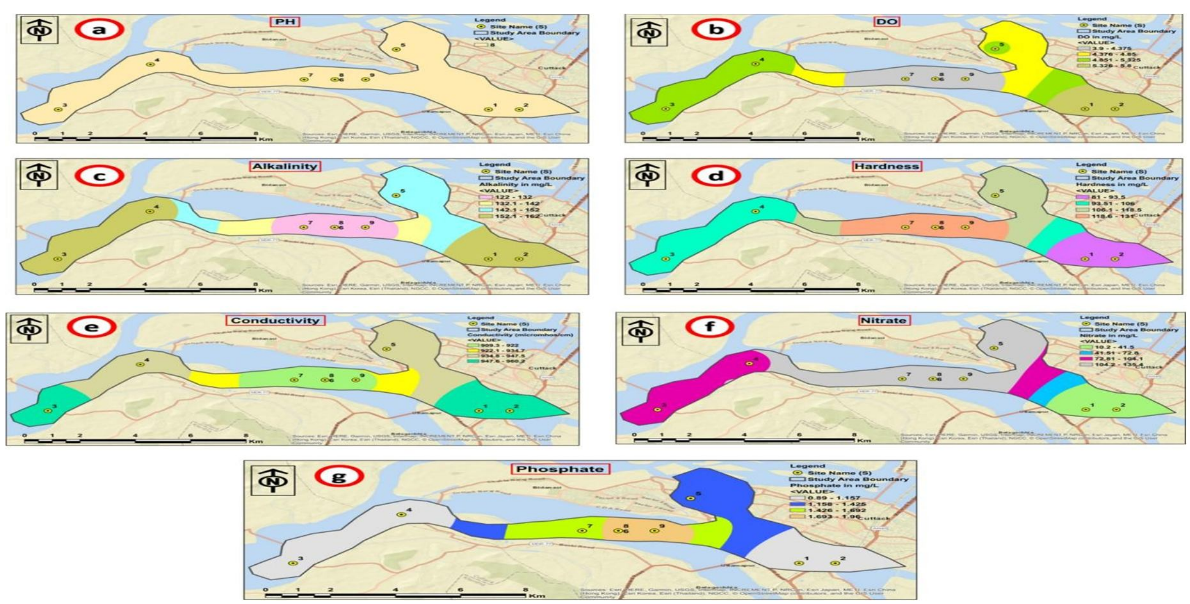

FIG_6.3.surfacewater quality assesment of mahanadi and its tributary kathajodi in cuttack district.using geospatial techniqui

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FIG 6.4 Kaliapani canal of Bhubaneswar

This study highlights that unregulated **domestic wastewater discharge**, **industrial effluents**, and **agricultural runoff** are the major contributors to water pollution in the study area. Without effective mitigation, water quality will continue to decline, threatening public health, agriculture, and ecosystem balance.

C. Future Scope of Research

While this study has provided important insights, several aspects remain to be explored further. The following points highlight the potential areas for future research:

1) Groundwater Quality Integration
- Conduct parallel groundwater monitoring to understand surface–subsurface interactions, especially in peri-urban zones.

2) Real-Time Monitoring Systems
- Implement Internet of Things (IoT)-based real-time water quality sensors to monitor pollution in critical zones dynamically.

3) Pollution Source Apportionment
- Use advanced techniques like Source Apportionment Modeling (e.g., PCA, PMF) to distinguish between point and non-point pollution sources.

4) Climate Change Impact
- Model the impact of climate variability on water quality and river flow regimes under different emission scenarios.

5) Community and Policy Engagement Studies
- Study behavioral and policy factors affecting water usage and pollution control, including compliance with environmental laws.

6) Ecological and Health Risk Assessments
- Quantify the ecological impact of pollution on aquatic life and conduct risk assessments for local populations depending on contaminated water.

D. Final Thoughts

This thesis contributes to the growing body of research that emphasizes the urgent need for sustainable water resource management in India. As Odisha continues to develop industrially and agriculturally, it is imperative that water governance is strengthened through interdisciplinary approaches, combining technology, policy, community participation, and continuous monitoring.

This study is a step forward in diagnosing the state of water pollution in a key river system and serves as a baseline for long-term monitoring and action planning.

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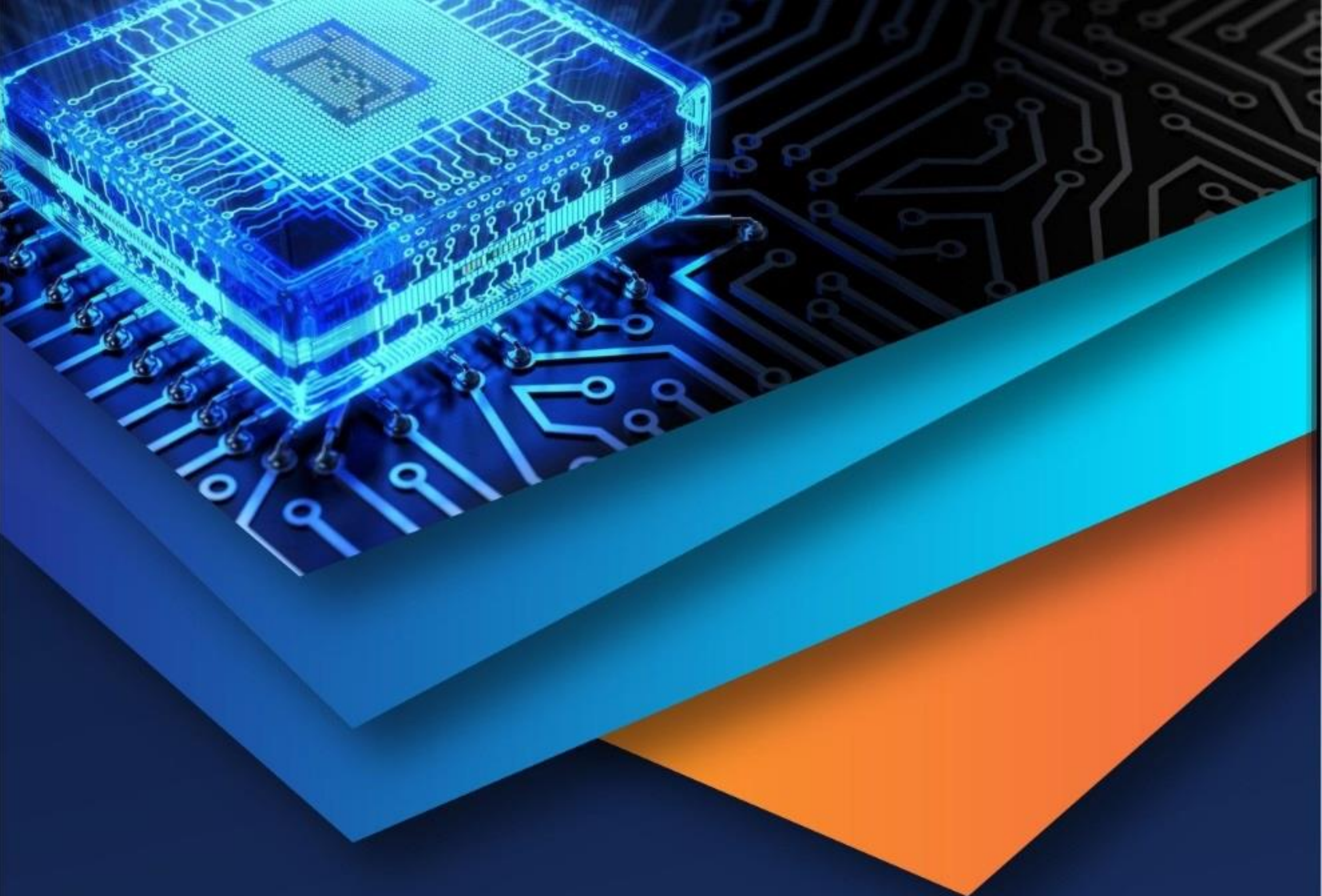

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