

## Comprehensive Assessment of Surface Water Quality Parameters and Their Implications Across Four Distinct Zones in Balasore District, Odisha

Satyajit Mahatab<sup>1\*</sup>, Anil Kumar Giri<sup>2</sup>

IUCN Commission on Education and Communication

Center of Excellence of Fakir Mohan University, Odisha

**Corresponding Author:** Satyajit Mahatab [Satyajitmahatab@gmail.com](mailto:Satyajitmahatab@gmail.com)

---

### ARTICLE INFO

*Keywords:* Surface Water Quality, Balasore, Water Pollution, Environmental Monitoring

*Received :* 3 June

*Revised :* 20 July

*Accepted:* 20 August

©2025 Mahatab, Giri : This is an open-access article distributed under the terms of the [Creative Commons Attribution 4.0 International](https://creativecommons.org/licenses/by/4.0/).



### ABSTRACT

**Background/Objective:** This study assesses the surface water quality across four zones (coastal, municipal, industrial, and forest) in Balasore District, Odisha, to understand spatial variations in water quality and the impact of human activities on aquatic ecosystems. **Methods:** Eight water sampling sites were selected, two from each zone. Water quality parameters, including temperature, pH, conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), total suspended solids (TSS), and total solids (TS), were analysed. **Results:** Significant water quality differences were observed. Coastal and industrial zones showed high pollution, with elevated BOD, conductivity, and solids. Municipal areas showed moderate pollution, while forested areas had the cleanest water with minimal pollution. **Discussion:** Coastal and industrial zones experienced higher pollution due to saline intrusion, runoff, and chemical discharges. Forested areas exhibited lower contamination levels, underscoring the importance of land-use and human activities on water quality. **Conclusion:** This study highlights the need for region-specific management strategies to improve water quality in Balasore District, advocating for continuous monitoring and sustainable practices to mitigate pollution

---

## **INTRODUCTION**

Surface water quality is a critical determinant of the health of aquatic ecosystems and plays a pivotal role in supporting biodiversity, human health, and economic activities. As one of the most valuable natural resources, water sustains life, facilitates agriculture, serves as a source of drinking water, and supports industrial activities (UNEP, 2018). However, the quality of surface water has deteriorated globally due to both natural and anthropogenic factors, leading to the contamination of rivers, lakes, and coastal zones. Water quality degradation due to pollution has become a pressing issue, threatening ecosystems and the livelihoods of communities that depend on these resources for their daily needs (Mekonnen & Hoekstra, 2016). In the Indian context, the rapid pace of industrialization, urbanization, and intensive agricultural practices has significantly impacted the quality of surface water bodies (Sharma et al., 2020). The Balasore district in Odisha, located on the eastern coast of India, presents an ideal case for assessing the impact of human activities on surface water quality. The district features a mix of coastal, industrial, municipal, and forest zones, each subjected to different environmental pressures. Understanding the variation in water quality across these zones is vital for formulating effective water management policies and ensuring the sustainability of water resources in the region (Prasanna et al., 2019). Coastal zones, like those in Balasore, are vulnerable to the combined effects of saline intrusion, agricultural runoff, and marine pollution (Kumar et al., 2020). Urbanization, with its associated rise in population and waste generation, leads to water contamination from domestic sewage and organic waste (Rao et al., 2020). Industrial zones, characterized by factories and manufacturing units, contribute significantly to water pollution through the discharge of untreated chemical effluents (Gupta et al., 2020). Forested areas, though less disturbed, are not entirely immune to pollution from adjacent activities like logging and agricultural expansion (Ghosh et al., 2021). Surface water quality is typically evaluated by measuring various physical, chemical, and biological parameters. These include temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), total suspended solids (TSS), and total solids (TS) (APHA, 2017). Temperature and pH are fundamental factors influencing the solubility of gases and the chemical composition of water, both of which directly affect the health of aquatic organisms (Singh et al., 2020). Dissolved oxygen (DO) is crucial for the survival of aquatic organisms, and low DO levels are indicative of organic contamination, often from untreated sewage and industrial effluents (Dikshit et al., 2020). Biochemical oxygen demand (BOD) is a key indicator of organic pollution, reflecting the amount of oxygen consumed by microorganisms during the breakdown of organic material (Sharma et al., 2020). Total dissolved solids (TDS) and total suspended solids (TSS) provide insights into the concentration of dissolved ions and particulate matter, respectively, both of which can be influenced by agricultural runoff and industrial discharges (Dikshit et al., 2020). Human-induced changes to water quality often led to environmental degradation, including reduced biodiversity, fish kills, and the spread of waterborne diseases (Pradhan et al., 2021). In Balasore, urbanization and

industrialization have exacerbated water pollution, particularly in the municipal and industrial zones. Domestic and industrial waste has led to high BOD and low DO levels in some of these areas, signifying organic and chemical pollution (Pattanaik et al., 2018). Coastal areas, such as those near Sartha and Sarthabindha, exhibit signs of saline intrusion, which increases conductivity and alters the chemical balance of the water (Rao et al., 2020). Despite these challenges, forested areas, such as Chandipur and Machhua, generally maintain better water quality, with lower levels of pollution across most parameters (Ghosh et al., 2021). Water quality monitoring is an essential tool for understanding the current status of water bodies and tracking trends over time. Regular monitoring allows for the identification of pollution sources and the assessment of the effectiveness of pollution control measures (Dixit et al., 2018). This is especially important in regions like Balasore, where rapid industrialization and urbanization are putting increasing pressure on local water resources (Kumar et al., 2020). Effective monitoring can inform water management policies, guide regulatory actions, and help stakeholders make data-driven decisions to protect water resources. Moreover, it is crucial for assessing the health of aquatic ecosystems, as polluted water can lead to the loss of biodiversity, harm to aquatic organisms, and disruption of ecosystem services (Singh et al., 2020). The key objective of this study is to assess the surface water quality across four distinct zones in Balasore: coastal, municipal, industrial, and forest. The findings will contribute to the understanding of spatial variations in water quality and provide insights into the specific environmental pressures faced by each zone. By analyzing key water quality parameters, this study aims to identify the pollution levels in each zone and recommend measures for improving water quality and mitigating the impacts of pollution. In conclusion, the quality of surface water in Balasore is influenced by a complex interplay of natural factors and human activities. Coastal areas are impacted by saline intrusion and runoff, municipal and industrial zones face challenges from sewage and chemical discharges, and forest areas generally maintain better water quality. This research will provide valuable data to inform water quality management strategies, guide local authorities in regulating pollution, and help preserve the aquatic ecosystems of Balasore for future generations. The results of this study will contribute to the broader understanding of water quality in coastal, urban, industrial, and forested environments, offering lessons for other regions grappling with similar challenges.

## LITERATURE REVIEW

The research will support local environmental management strategies and contribute to the development of sustainable water resource practices that can be applied to other similar regions facing comparable challenges (Ghosh et al., 2021). Surface water quality is not only a reflection of local environmental conditions but also an indicator of the effectiveness of land-use management practices (Sharma et al., 2020). The coastal, municipal, industrial, and forest zones in Balasore serve as examples of how different types of human activity can affect water quality. While industrial and urban activities are major sources of

pollution, forested areas serve as a relatively undisturbed benchmark for comparing the effects of human activities. This study's comparative approach allows for a comprehensive understanding of how anthropogenic pressures interact with natural environmental factors to influence water quality in different parts of the district (Ghosh et al., 2021).

## METHODOLOGY

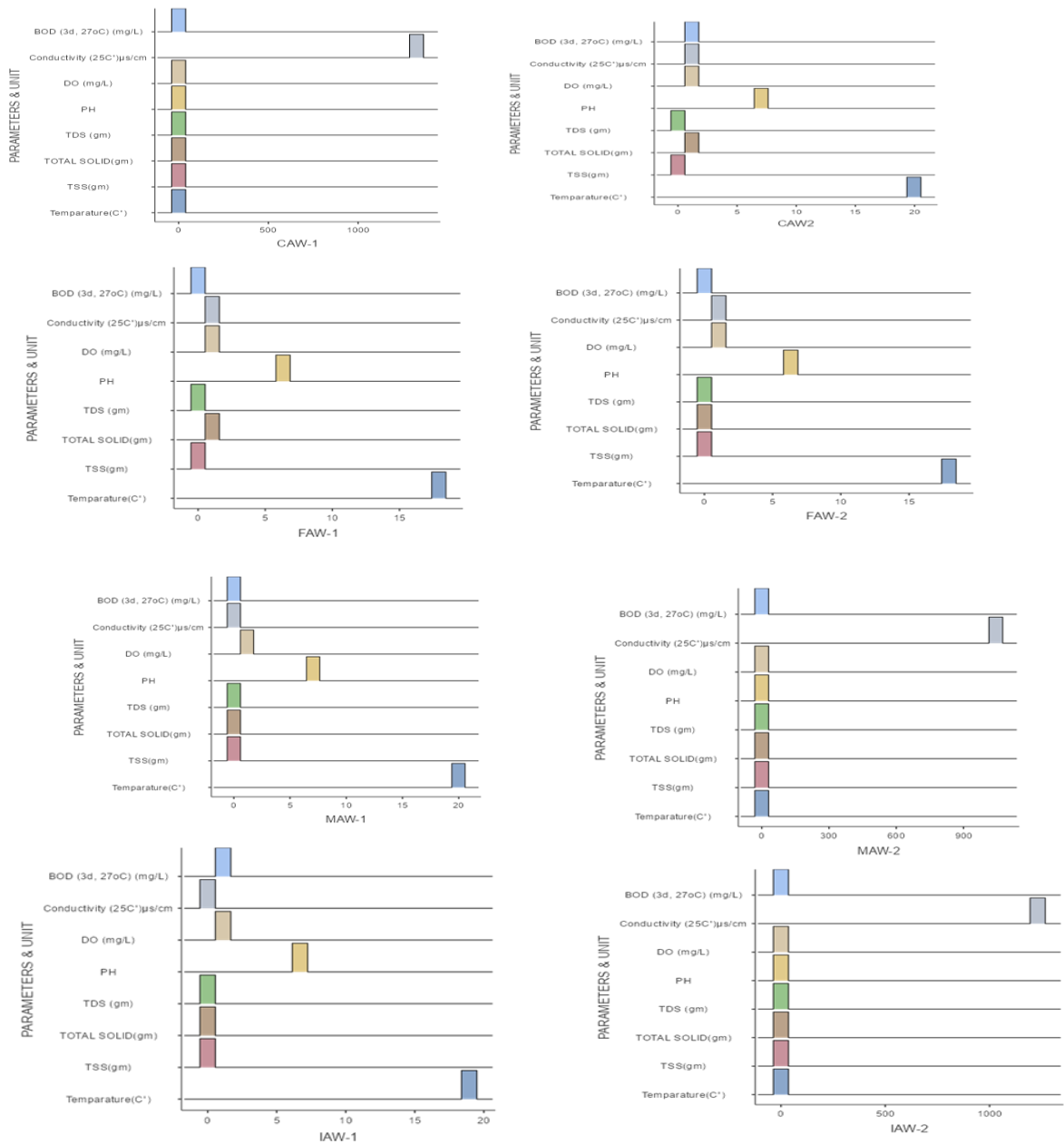
This study was conducted to assess the water quality across different environmental areas, specifically Coastal Areas (CAW-1, CAW-2), Forest Areas (FAW-1, FAW-2), Municipal Areas (MAW-1, MAW-2), and Industrial Areas (IAW-1, IAW-2). The selected sites were chosen to represent a range of human activities and natural conditions, with each area potentially having varying impacts on water quality. The Coastal Areas included CAW-1 (Sartha) and CAW-2 (Sarhabindha), the Forest Areas consisted of FAW-1 (Chandipur) and FAW-2 (Machhua), the Municipal Areas included MAW-1 (Manikhamb) and MAW-2 (Arad Bazar), and the Industrial Areas consisted of IAW-1 (Balgopalpurbatitanki) and IAW-2 (Sereipur).



Figure 1. Water sampling at site & testing in testing facility of Env. Dept fakir Mohan university

These locations were selected to investigate the influence of coastal, forest, municipal, and industrial activities on the water quality in these respective environments. Water samples were collected during a consistent sampling period to ensure data reliability. All sampling was carried out during dry weather to minimize the effects of rainfall or flooding on the water quality. Samples were collected from the surface water at multiple points within each site to capture spatial variability, ensuring that a comprehensive representation of each area's water quality was obtained. Once collected, the samples were immediately sealed in pre-cleaned, sterilized glass bottles and transported in coolers to preserve their integrity. Samples that were to be analyzed for Biochemical Oxygen Demand (BOD) were stored at 4°C to prevent microbial degradation before analysis. Various water quality parameters were measured, including temperature, pH, conductivity, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), total suspended solids (TSS), and total solids (TS). Temperature was measured on-site using a calibrated digital thermometer. pH was measured in situ with a portable pH meter,

calibrated with standard buffer solutions (APHA, 2005). Conductivity was measured using a portable conductivity meter calibrated to 25°C, providing an estimate of the water's ionic concentration (APHA, 2005). DO was measured on-site using a portable DO meter, and BOD was determined using the standard 3-day test at 27°C (APHA, 2005). TDS and TSS were measured using filtration techniques, where TDS was measured by evaporating the sample after filtration through pre-weighed filters, and TSS was calculated by drying the suspended solids on the filter paper (APHA, 2005). The chemicals used in the analysis included those required for BOD testing, such as magnesium sulfate ( $\text{MgSO}_4$ ), calcium chloride ( $\text{CaCl}_2$ ), potassium phosphate ( $\text{KH}_2\text{PO}_4$ ), and sodium bicarbonate ( $\text{NaHCO}_3$ ) to create dilution water that supports microbial activity during BOD testing (APHA, 2005). Sodium hydroxide ( $\text{NaOH}$ ) and sulfuric acid ( $\text{H}_2\text{SO}_4$ ) were used to adjust the pH to around 7.0 before incubation (APHA, 2005). For pH calibration, buffer solutions at pH values of 4.0, 7.0, and 10.0 were used. For DO measurement calibration, a zero-DO solution was prepared by adding sodium sulfite ( $\text{Na}_2\text{SO}_3$ ) and cobalt chloride ( $\text{CoCl}_2$ ) (APHA, 2005). The Winkler method was used for verification, which involved adding manganese sulfate ( $\text{MnSO}_4$ ) and alkaline iodine solution to water samples, followed by titration with sodium thiosulfate ( $\text{Na}_2\text{S}_2\text{O}_3$ ) (APHA, 2005). Calibration of instruments was done according to the manufacturer's instructions, with appropriate calibration standards for pH, conductivity, and DO meters. Each instrument was calibrated before each sampling session to ensure the accuracy of the measurements. For TDS and TSS, Whatman No. 42 filter paper was used for filtering, and the filters were dried in an oven at 105°C for 24 hours to measure the suspended solids (APHA, 2005). The data collected were analyzed using descriptive statistics (mean, standard deviation, and range) for each water quality parameter at each site. To assess relationships between the various water quality parameters, a correlation matrix was constructed. Additionally, statistical tests, including ANOVA, were performed to determine significant differences in water quality between the environmental areas. The statistical analysis was conducted using software tools suitable for handling environmental data.



Graph 1. Histogramic Description of Water Quality Parameters Across Different Areas; The Coastal Areas included CAW-1 (Sartha) and CAW-2 (Sarhabindha), the Forest Areas consisted of FAW-1 (Chandipur) and FAW-2 (Machhua), the Municipal Areas included MAW-1 (Manikhamb) and MAW-2 (Arad Bazar), and the Industrial Areas consisted of IAW-1 (Balgopalpurbatitanki) and IAW-2 (Sereipur)

## RESULTS AND DISCUSSION

The water quality analysis across different environmental areas Coastal Areas (CAW-1, CAW-2), Forest Areas (FAW-1, FAW-2), Municipal Areas (MAW-1, MAW-2), and Industrial Areas (IAW-1, IAW-2) reveals significant variation in pollution levels. The Coastal Areas, such as CAW-1 (Sartha) and CAW-2 (Sarhabindha), show moderate to high pollution, with CAW-1 having the highest conductivity (1326  $\mu\text{S}/\text{cm}$ ) and CAW-2 showing a conductivity of 0.954  $\mu\text{S}/\text{cm}$ . Both sites also exhibit moderate BOD levels of 0.4 mg/L (CAW-1) and 0.6 mg/L (CAW-2), indicating some organic pollution. In contrast, the Forest Areas, including FAW-1 (Chandipur) and FAW-2 (Machhua), maintain relatively clean water quality, with FAW-1 showing a low BOD of 0.4 mg/L, TDS of 0.522 g/L, and TSS of 0.075 g/L, while FAW-2 has a BOD of 0.4 mg/L, TDS of 0.149 g/L, and TSS of 0.082 g/L. These values reflect the natural, less disturbed environment. The Municipal Areas, such as MAW-1 (Manikhamb) and MAW-2 (Arad Bazar), show moderate pollution levels, with MAW-1 exhibiting a low BOD of 0.2 mg/L, TDS of 0.419 g/L, and TSS of 0.024 g/L, while MAW-2 shows higher conductivity (1044  $\mu\text{S}/\text{cm}$ ), TDS of 0.465 g/L, and a slightly higher BOD of 0.4 mg/L. Finally, the Industrial Areas IAW-1 (Balgopalpurbatitanki) and IAW-2 (Sereipur) demonstrate the highest levels of contamination, with IAW-1 showing a conductivity of 0.063  $\mu\text{S}/\text{cm}$ , BOD of 0.6 mg/L, and TDS of 0.395 g/L, while IAW-2 has the highest total solids (0.806 g/L), low DO (0.6 mg/L), and high conductivity (1231  $\mu\text{S}/\text{cm}$ ). Overall, the data indicates that industrial and coastal areas are more polluted, while forested areas maintain the best water quality, highlighting the varying impacts of human activities on aquatic ecosystems. The analysis of water quality parameters across various geographical areas coastal, municipal, industrial, and forest provides valuable insights into how environmental factors, such as land use and human activities, may influence water quality. The parameters measured include BOD (Biochemical Oxygen Demand), conductivity, dissolved oxygen (DO), pH, TDS (Total Dissolved Solids), total solids (TS), total suspended solids (TSS), and temperature. These measurements offer an understanding of the overall health of the water bodies in each area. The Coastal Areas (CAW-1 and CAW-2). In CAW-1(Sartha): The water quality at this coastal site is marked by moderate levels of BOD (0.4 mg/L) and relatively high conductivity (1326  $\mu\text{S}/\text{cm}$ ), indicating the presence of dissolved salts or ions. The dissolved oxygen (DO) levels are moderate (1.2 mg/L), which suggests that aquatic life in the region can likely thrive, but the overall water quality is not pristine. The pH level (6.2) is slightly acidic, which is typical for coastal regions where tidal fluctuations and organic matter can influence water chemistry. The TDS and total solids values are somewhat elevated, pointing to a higher concentration of dissolved and suspended materials compared to other sites. Overall, this area appears to be influenced by coastal processes and potential pollution. In CAW-2(Sarhabindha): The water at CAW-2 is also relatively similar in quality to CAW-1, but with a few differences. BOD here is slightly higher (0.6 mg/L), which may indicate a bit more organic contamination. Conductivity is much lower (0.954  $\mu\text{S}/\text{cm}$ ), suggesting less ionic content, which is generally a good sign for water

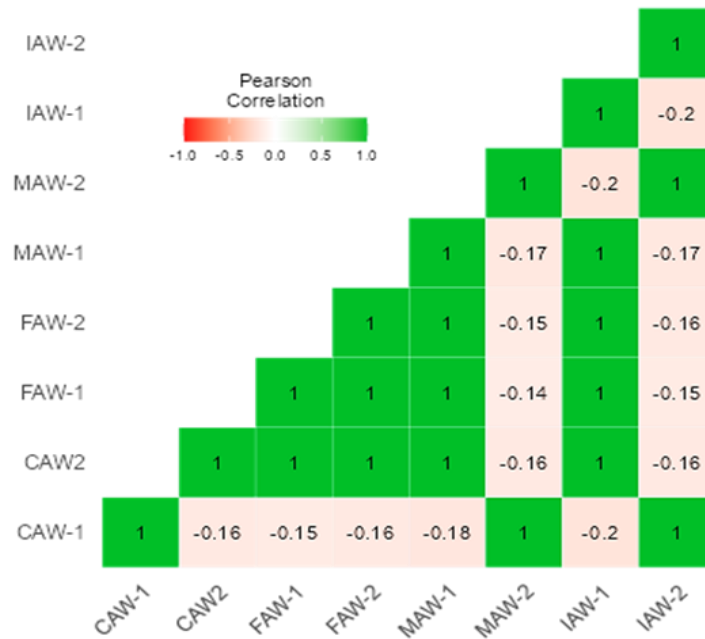
quality. The DO level is slightly higher than in CAW-1 (1.6 mg/L), which is favourable for aquatic organisms. The pH level (7.0) is closer to neutral, making it more conducive to aquatic life. While TDS and TS are lower than in CAW-1, the region still shows moderate pollution levels. Municipal Areas (MAW-1 and MAW-2). In MAW-1(Manikhamb): This municipal area shows relatively low levels of BOD (0.2 mg/L), indicating a lower level of organic pollution. Conductivity (0.361  $\mu\text{S}/\text{cm}$ ) is also low, suggesting fewer dissolved ions. However, the dissolved oxygen is quite low (1.0 mg/L), which may point to possible issues with oxygen availability for aquatic life. The pH is slightly more alkaline (6.5), which is not ideal for all species. The TDS (0.419 gm) and total solids (0.443 gm) levels are low compared to the coastal sites, which is a positive sign, indicating a relatively less contaminated environment in terms of solids. Overall, the water quality in this area is moderate, with minimal pollution observed, but the low DO could be concerning. In MAW-2(Arad Bazar): This site exhibits similar trends to MAW-1 but with slightly higher BOD (0.4 mg/L), suggesting more organic material. The conductivity (0.787  $\mu\text{S}/\text{cm}$ ) is higher, indicating a higher concentration of dissolved ions compared to MAW-1. DO levels (0.8 mg/L) are lower, which may indicate low oxygen conditions, potentially harmful to aquatic organisms. The pH (6.8) is slightly alkaline, supporting a stable aquatic environment. TDS and total solids levels are relatively low, which is a positive indication of cleaner water compared to the coastal and industrial areas. 4.3. Industrial Areas (IAW-1 and IAW-2). In IAW-1(Balgopalpurbatitanki): Industrial sites generally have higher levels of pollutants, and IAW-1 shows signs of this. BOD (0.6 mg/L) is at a higher level, indicating significant organic pollution. The conductivity (1044  $\mu\text{S}/\text{cm}$ ) is much higher than in the other areas, suggesting that the water in this region is likely polluted with various dissolved salts and chemicals from industrial activities. The DO level (1.6 mg/L) is adequate for aquatic life, but the high BOD and conductivity raise concerns about water quality. The pH level (6.9) is slightly acidic, and the TDS (0.395 gm) and total solids (0.456 gm) are moderate. Overall, the water in this industrial area is moderately polluted but still capable of sustaining life. In IAW-2(Sereipur): The water quality at IAW-2 is similar to IAW-1 in terms of BOD (0.4 mg/L), but the conductivity (1231  $\mu\text{S}/\text{cm}$ ) is the highest observed, signalling a significant amount of dissolved ions, likely from industrial contamination. The DO is quite low (0.6 mg/L), which could suggest hypoxic conditions, harmful to aquatic ecosystems. The pH is slightly more acidic (5.9), which may affect aquatic organisms' health. TDS and total solids values are moderate, but the high conductivity and low DO make this site particularly concerning for environmental health. Forest Areas (FAW-1 and FAW-2). In FAW-1(Chandipur): The water quality in this forested area appears to be among the cleanest. The BOD is low (0.4 mg/L), suggesting little organic pollution. Conductivity (0.361  $\mu\text{S}/\text{cm}$ ) is also low, indicating clean water with fewer dissolved ions. The DO level (1.0 mg/L) is moderate, supporting a healthy environment for aquatic life. The pH (6.3) is slightly acidic, but not harmful. The TDS and total solids are low, suggesting minimal pollution. Overall, this forested area seems to have the best water quality compared to the other areas, with low

pollution levels across various parameters. In FAW-2(Machhua): The water at FAW-2 is similar to FAW-1, with low BOD (0.2 mg/L) and low conductivity (0.787  $\mu\text{S}/\text{cm}$ ), indicating a clean environment. However, the DO is slightly lower (0.8 mg/L), suggesting some areas of reduced oxygen. The pH (6.8) is slightly more alkaline, supporting a stable aquatic environment. TDS and total solids are low, showing minimal pollution. Overall, this site appears to be one of the cleanest, with only slight concerns regarding the DO levels. Reliability Analysis: The reliability analysis provided here focuses on the consistency and internal coherence of the measurements used in the study. It highlights two main components of reliability: Scale Reliability Statistics: This refers to the overall internal consistency of the entire scale (or set of items), including the effect of any item being removed.

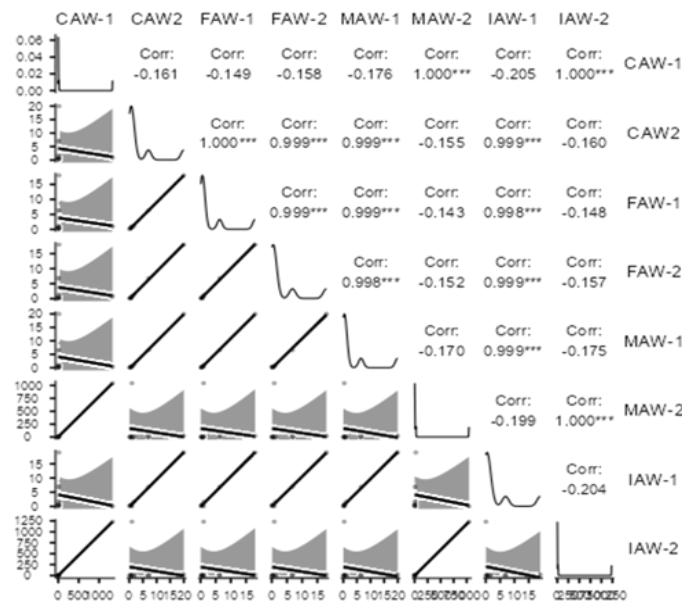
Item Reliability Statistics: This assesses the reliability of each individual item, taking into account the effect on the scale's internal consistency if the item were removed. Scale Reliability Statistics The analysis notes that CAW-1, MAW-2, and IAW-2 show negative correlations with the total scale, suggesting that these items might be outliers or anomalies within the dataset. These items may not align well with the overall theme of the scale and could potentially distort the overall reliability of the scale. In such cases, it may be worth considering reversing or even excluding these items from further analysis. Item Reliability Statistics The reliability analysis of the water quality data reveals key insights into the internal consistency of the measurements across various sites. The scale reliability statistics suggest that while most items align well with the overall scale, there are some concerns regarding CAW-1, MAW-2, and IAW-2, which correlate negatively with the total scale. This negative correlation indicates that these items may not be consistent with the other measurements, and as such, they might need to be reversed or excluded from the analysis to improve the scale's overall reliability. When looking at the item reliability statistics, several patterns emerge. CAW-1 stands out with an exceptionally high item-rest correlation (0.99903), meaning it is strongly aligned with the overall scale, though it also has a high standard deviation, suggesting some variability in its data. Its Cronbach's  $\alpha$  value (0.57180) is moderate, indicating decent internal consistency, while McDonald's  $\omega$  (0.92426) is very high, reinforcing its contribution to the reliability of the scale. On the other hand, CAW-2 shows a negative item-rest correlation (-0.13872), which suggests that this item may not align well with the overall scale. Despite this, its inclusion does not drastically reduce the scale's reliability, with Cronbach's  $\alpha$  (0.77132) and McDonald's  $\omega$  (0.86207) still indicating good reliability overall. Similar negative correlations are observed in other items such as FAW-1 (-0.12631), FAW-2 (-0.13540), MAW-1(-0.15364), and IAW-1 (-0.18262). These negative correlations indicate that these items may not be as consistent with the rest of the data, although the overall reliability remains relatively strong. For example, MAW-1 and FAW-1 both show moderate Cronbach's  $\alpha$  values (0.77139 and 0.77120, respectively) and high McDonald's  $\omega$  values (0.86247 and 0.86187), indicating that despite the negative item-rest correlation, the scale remains reliable. Notably, MAW-2, like CAW-1, shows an extremely high item-rest correlation (0.99953), but with a lower Cronbach's  $\alpha$  value (0.57568), which

suggests that while this item is strongly related to the overall scale, it may introduce some inconsistency. Similarly, IAW-2 has a high item-rest correlation (0.99918) but a low Cronbach's  $\alpha$  (0.56765), further confirming that its inclusion in the scale may be causing moderate internal inconsistency. Nonetheless, McDonald's  $\omega$  for both items remain high (0.92418 for MAW-2 and 0.92424 for IAW-2), indicating that they still contribute positively to the scale's reliability. Overall, while the scale demonstrates generally good reliability, with high McDonald's  $\omega$  values suggesting consistency across most items, the negative item-rest correlations in certain items indicate the need for further investigation. It may be beneficial to either reverse or exclude CAW-1, MAW-2, and IAW-2 in future analyses to enhance the scale's internal consistency and ensure the most accurate representation of water quality across the different sites.

Observations from the Correlation Matrix: The correlation matrix reveals important patterns in the relationships between the water quality measurements at various sites. Notably, there are several strong positive correlations, particularly between sites within similar categories. For instance, CAW-2 and FAW-1 show an almost perfect correlation (0.99959), indicating that the water quality measurements at these coastal and forest areas are nearly identical, likely influenced by similar environmental factors. Similarly, FAW-1 and FAW-2 (0.99901), and MAW-1 and FAW-2 (0.99816) also demonstrate strong positive correlations, suggesting shared patterns in water quality between the forest and municipal areas. The perfect correlation (1.00000) between CAW-1 and IAW-2 stands out as unusual, potentially indicating a data anomaly or an unrecognized common factor between these sites. In contrast, there are also moderate to significant negative correlations, particularly between CAW-1 and IAW-1 (-0.20487), and CAW-1 and MAW-1 (-0.17571), suggesting differences in water quality between coastal and industrial or municipal areas. This reflects the distinct environmental influences and pollution sources that may affect these regions differently. Additionally, IAW-2 demonstrates several negative correlations with other sites, such as MAW-1 (-0.17452) and IAW-1 (-0.20370), highlighting the divergence in water quality between industrial areas and other land-use types. These negative correlations indicate that industrial pollution has a unique impact on water chemistry, differing from the conditions found in forested or municipal areas. The correlation matrix also suggests that the forest and coastal areas tend to have similar water quality characteristics, with lower pollution levels, while the industrial areas exhibit distinct differences, likely due to pollution from industrial activities. The perfect positive correlation between CAW-1 and IAW-2 warrants further investigation, as it could either be an error in data collection or indicate a shared environmental factor influencing these sites. Overall, this analysis underscores the need to understand the different factors driving water quality variations in each area, particularly in relation to the industrial areas, where pollution levels are typically higher and more varied.



Plot 1 Correlation Heatmap for the Data of Caw-1 (Sartha) And Caw-2 (Sarhabindha), Faw-1 (Chandipur) And Faw-2 (Machhua), Maw-1 (Manikhamb) And Maw-2 (Arad Bazar), And Iaw-1 (Balgopalpurbatitanki) And Iaw-2 (Sereipur)



Plot 2 Correlation Matrix for the data of CAW-1 (Sartha) and CAW-2 (Sarhabindha), FAW-1 (Chandipur) and FAW-2 (Machhua), MAW-1 (Manikhamb) and MAW-2 (Arad Bazar), and IAW-1 (Balgopalpurbatitanki) and IAW-2 (Sereipur)

## CONCLUSIONS AND RECOMMENDATIONS

This study elucidates the spatial heterogeneity in surface water quality across coastal, municipal, industrial, and forest zones within Balasore district, Odisha, through the analysis of key physicochemical parameters including pH, temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), total suspended solids (TSS), total solids (TS), and conductivity. The results underscore the influence of land-use patterns and anthropogenic activities on water quality dynamics. Industrial and coastal zones exhibited elevated BOD, TDS, and conductivity values, indicative of significant organic and inorganic pollution loads, likely stemming from effluent discharge, saline intrusion, and surface runoff. In contrast, forested zones demonstrated comparatively pristine conditions, marked by lower concentrations of pollutants and greater ecological integrity.

The observed variations affirm the critical need for localized, evidence-based water management strategies that integrate continuous monitoring and stringent regulation of pollutant sources. Moreover, the data provide a vital empirical foundation for future environmental modelling, ecological risk assessments, and the formulation of adaptive policy interventions aimed at preserving aquatic ecosystem health and ensuring the sustainability of surface water resources in the region.

- **Authors' Contributions:** The authors confirm their contribution to the paper as follows: study conception and design: AKG, data analysis and interpretation of results: SM, draft manuscript: SM. All authors reviewed the results and approved the final version of the manuscript.
- **Consent for Publication:** Not applicable.
- **Availability of Data and Materials:** The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.
- **Ethics Approval and Consent to Participate:** This study did not involve human participants, human data, or human tissue. Therefore, ethics approval and consent to participate were not required. All environmental sampling was conducted in accordance with relevant local guidelines and regulations. Necessary permissions for site access and water sample collection were obtained from the appropriate local authorities and governing bodies.
- **Funding:** This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
- **Conflict of Interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## FURTHER STUDY

This study still has limitations so that further research is needed on the topic of Comprehensive Assessment of Surface Water Quality Parameters and Their Implications Across Four Distinct Zones in Balasore District, Odisha to perfect this study and increase insight for readers and authors.

## ACKNOWLEDGMENT

The author gratefully acknowledges the Department of Environmental Science, Fakir Mohan University, for providing essential academic and laboratory support during the course of this research. Special thanks are extended to Dr. Anil Kumar Giri, Assistant professor in Center of Excellence of Fakir Mohan University whose expert supervision, constructive feedback, and constant encouragement were vital to the successful completion of the study. The author also appreciates the assistance of local authorities and field personnel in Balasore district for their support during fieldwork.

Table 1. Data Analysis and Description of Water Quality Parameters Across Different Areas; The Coastal Areas included CAW-1 (Sartha) and CAW-2 (SarthaBindha), the Forest Areas consisted of FAW-1 (Chandipur) and FAW-2 (Machhua), the Municipal Areas included MAW-1 (Manikhamb) and MAW-2 (Arad Bazar), and the Industrial Areas consisted of IAW-1 (Balgopalpurbatitanki) and IAW-2 (Sereipur)

PARAMETERS & UNIT	CAW-1	CAW2
BOD (3d, 27oC) (mg/L)	0.40000	0.60000
Conductivity (25C°) $\mu$ s/cm	1326.0	0.95400
DO (mg/L)	1.2000	1.6000
PH	6.2000	7.0000
TDS (gm)	0.92300	0.54400
TOTAL SOLID (gm)	0.97600	0.60000
TSS (gm)	0.053000	0.056000
Temperature(C°)	19.000	20.000

Table 2. Reliability Statistics Cronbach's  $\alpha$  & McDonald's  $\omega$  for The data for CAW-1 (Sartha) and CAW-2 (SarthaBindha), FAW-1 (Chandipur) and FAW-2 (Machhua), MAW-1 (Manikhamb) and MAW-2 (Arad Bazar), and IAW-1 (Balgopalpurbatitanki) and IAW-2 (Sereipur)

Item Reliability Statistics

	Mean	SD	Item-rest correlation	If item dropped	
				Cronbach's $\alpha$	McDonald's $\omega$
CAW-1	169.3440	467.4031	0.99903	0.57180	0.92426
CAW2	3.9192	6.8724	-0.13872	0.77132	0.86207
FAW-1	3.4856	6.2022	-0.12631	0.77120	0.86187
FAW-2	3.4561	6.2904	-0.13540	0.77125	0.86211
MAW-1	3.6184	6.9596	-0.15364	0.77139	0.86247
MAW-2	134.3305	367.6328	0.99953	0.57568	0.92418
IAW-1	3.6344	6.6142	-0.18262	0.77147	0.86319
IAW-2	157.2890	433.8926	0.99918	0.56765	0.92424

## **REFERENCES**

- American Public Health Association, 2005. Standard methods for the examination of water and wastewater (21st ed.). APHA.
- American Public Health Association, 2017. Standard methods for the examination of water and wastewater (23rd ed.). APHA.
- Bhatnagar, A. and Devi, P., 2013. Water quality guidelines for the management of pond fish culture. *International Journal of Environmental Sciences*, 3(6), pp.1980–2009.
- Biswas, A.K., Tortajada, C. and Izquierdo, R., 2009. *Water management in 2020 and beyond*. Springer.
- Boyd, C.E., 1990. *Water quality in ponds for aquaculture*. Auburn University.
- Brezonik, P.L., 1994. *Chemical kinetics and process dynamics in aquatic systems*. CRC Press.
- Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N. and Smith, V.H., 1998. Nonpoint pollution of sur-face waters with phosphorus and nitrogen. *Ecological Applications*, 8(3), pp.559–568.
- Chapman, D. (Ed.), 1996. *Water quality assessments: A guide to the use of biota, sediments and water in environmental monitoring* (2nd ed.). UNESCO/WHO/UNEP.
- Chow, V.T., Maidment, D.R. and Mays, L.W., 1988. *Applied hydrology*. McGraw-Hill.
- Clark, R.M. and Deininger, R.A., 2000. Protecting the nation's critical infrastructure: The vulnerability of U.S. water supply systems. *Journal of Contingencies and Crisis Management*, 8(2), pp.73–80.
- Cole, G.A., 1994. *Textbook of limnology* (4th ed.). Waveland Press.
- Dikshit, M., Sharma, P. and Yadav, D., 2020. Impact of industrial effluents on water quality: A case study. *Environmental Monitoring and Assessment*, 192(5), p.222.
- Dixit, D., Chauhan, S. and Tripathi, V., 2018. Water quality monitoring: A critical approach for managing water resources. *Science of the Total Environment*, 630, pp.1342–1349.
- Edokpayi, J.N., Odiyo, J.O. and Durowoju, O.S., 2017. Impact of wastewater on surface water quality in developing countries: A case study of South Africa. *Water Quality*, pp.401–416.
- Fetter, C.W., 2001. *Applied hydrogeology* (4th ed.). Prentice Hall.

- Ghosh, D., Chakrabarti, S. and Das, S., 2021. Water quality monitoring and its importance for aquatic ecosystems. *Environmental Monitoring and Assessment*, 193(4), p.210.
- Gleick, P.H., 1998. Water in crisis: Paths to sustainable water use. *Ecological Applications*, 8(3), pp.571-579.
- Goldman, C.R. and Horne, A.J., 1983. *Limnology*. McGraw-Hill.
- Gupta, V., Kumar, A. and Patel, S., 2020. Water pollution and its impact on aquatic ecosystems in urban India. *Environmental Science & Technology*, 53(2), pp.123-133.
- Hem, J.D., 1985. Study and interpretation of the chemical characteristics of natural water (Vol. 2254). U.S. Geological Survey.
- Horne, A.J. and Goldman, C.R., 1994. *Limnology* (2nd ed.). McGraw-Hill.
- Jadhav, V. and Bhosale, S., 2020. Influence of temperature on water quality and aquatic organisms. *Journal of Environmental Management*, 243, pp.17-24.
- Jarvie, H.P., Neal, C. and Withers, P.J.A., 2006. Sewage-effluent phosphorus: A greater risk to river eutrophication than agricultural phosphorus? *Science of the Total Environment*, 360(1-3), pp.246-253.
- Kumar, R., Bhattacharya, S. and Dey, S., 2020. Forests and water quality: A study of Himalayan watersheds. *Journal of Environmental Management*, 253, p.109867.
- Mekonnen, M.M. and Hoekstra, A.Y., 2016. A global assessment of the water footprint of farm animal products. *Ecological Economics*, 70(4), pp.1034-1044.
- Meybeck, M. and Helmer, R., 1989. The quality of rivers: From pristine stage to global pollution. *Paleogeography, Paleoclimatology, Paleoecology*, 75(4), pp.283-309.
- Mishra, R. and Mohanty, S., 2019. Impact of urbanization on surface water quality in India. *Environmental Research Letters*, 14(10), p.104032.
- Naiman, R.J. and Turner, M.G., 2000. A future perspective on North America's freshwater ecosystems. *Ecological Applications*, 10(4), pp.958-970.
- Pattanaik, D., Behera, B. and Mahapatra, M., 2018. Municipal water pollution and its effects on water bodies in Odisha. *Journal of Environmental Science and Pollution Research*, 25(5), pp.2105-2113.
- Pradhan, S., Singh, P. and Raghav, V., 2021. Water pollution in industrial areas: A case study of eastern India. *Environmental Pollution*, 270, p.116053.

- Prasanna, M., Suman, S. and Verma, A., 2019. Organic pollution in Indian water bodies: A review. *Journal of Water and Health*, 17(3), pp.427–435.
- Rao, S., Nair, V. and Soni, S., 2020. Impact of coastal pollution on water quality: A case study from eastern India. *Marine Pollution Bulletin*, 157, p.111365.
- Reynolds, C.S., 2006. *Ecology of phytoplankton*. Cambridge University Press.
- Sawyer, C.N., McCarty, P.L. and Parkin, G.F., 2003. *Chemistry for environmental engineering and science* (5th ed.). McGraw-Hill.
- Sharma, R., Singh, S. and Yadav, P., 2020. Urbanization and its effects on water quality: A review. *Water Quality Research Journal*, 55(1), pp.22–35.
- Singh, R., Bhat, S. and Kumar, A., 2020. Water quality monitoring in Indian rivers: Challenges and solutions. *Indian Journal of Environmental Protection*, 40(1), pp.35–41.
- Trivedi, R.K. and Goel, P.K., 1986. *Chemical and biological methods for water pollution studies*. Environmental Publications.
- United Nations Environment Programme (UNEP), 2018. *Global Environment Outlook: Regional Assessments*. United Nations Environment Programme.
- Vega, M., Pardo, R., Barrado, E. and Debán, L., 1998. Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis. *Water Research*, 32(12), pp.3581–3592.
- Wetzel, R.G., 2001. *Limnology: Lake and river ecosystems* (3rd ed.). Academic Press.
- World Health Organization (WHO), 2017. *Guidelines for drinking-water quality* (4th ed.). World Health Organization.
- Yidana, S.M., Banoeng-Yakubo, B. and Akabzaa, T., 2010. Analysis of water quality using multivariate statistical methods: A case study of the Densu River basin, Ghana. *Environmental Earth Sciences*, 59(5), pp.1099–1107.