# Analysis of Water Pollution Dynamics and Management Strategies in the Western Coastal Waters of Shenzhen

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**Abstract.** This study examines the coastal waters of western Shenzhen, employing a comprehensive approach that integrates remote sensing inversion, long-term official monitoring data, and field sampling results. It systematically assesses the spatio-temporal evolution characteristics and remediation effectiveness of water quality in representative areas such as Shenzhen Bay and Dacang Bay. Results indicate that between 2017 and 2023, inorganic nitrogen concentrations decreased by 54.4% and active phosphate concentrations by 10.3%. Significant water quality improvement trends were observed in certain areas (e.g., Dachan Bay), while the semi-enclosed Shenzhen Bay continues to face substantial pollution pressures. The study demonstrates that multi-source data fusion effectively compensates for the limitations of single monitoring methods, providing robust evidence for accurately identifying pollution sources and ecological risks. Concurrently, integrating multi-tiered comprehensive management measures—including wetland restoration, ecological shoreline construction, land-based pollution prevention and control, and port and shipping management—helps alleviate the pressure of human activities on marine ecosystems, achieving long-term, steady water quality improvement. This research provides valuable data support and governance insights for advancing marine ecological security and sustainable development within the Guangdong-Hong Kong-Macao Greater Bay Area.

**Keywords:** Remote sensing monitoring; Coastal water pollution; Ecological management.

## 1. Introduction

The western coastal waters of Shenzhen (Includes four major sub-water areas: Shenzhen Bay, Dachan Bay, Airport Sea Area and Dagang Port Waters) serve as the core region of the Guangdong-Hong Kong-Macao Greater Bay Area. It bears the dual mission of supporting technological advancement and safeguarding ecological conservation. In recent years, the region has suffered severe water pollution due to factors such as land-based discharges and combined sewer overflows. Among the nine national marine water quality monitoring sites in the western coastal waters of Shenzhen, only one site meets Class IV standards, while the remaining eight sites all fall below Class IV standards [1]. Given the region's significant ecological risks from pollution coupled with its high strategic importance, there is an urgent need to conduct a systematic assessment of pollution trends and remediation effectiveness by integrating remote sensing monitoring technology with field data.

Most extant domestic marine water quality studies have focused on large estuaries, such as the Yangtze River Estuary and the Pearl River Estuary. Research on the nearshore waters west of Shenzhen remains relatively scarce, and detailed analyses of pollution in this region using remote sensing tools are even rarer. Remote sensing retrieval technology has been applied to marine water quality monitoring with a solid foundation. It converts spectral reflectance signals captured by satellites into pollutant concentration values through empirical or semi-analytical models. The water quality parameters that are currently measurable via remote sensing include chlorophyll-a concentration, suspended solids concentration, and yellow substance concentration [2].

Through the integration of remote sensing retrieval, official monitoring data, and in-situ sampling, this study evaluates the spatiotemporal evolution of water pollution in representative regions of the western coastal waters of Shenzhen, analyzes the quantitative changes in water quality parameters before and after implementation of governance measures and explores the feasibility and applicability of integrating remote sensing monitoring with field surveys in the context of marine ecological management.

# 2. Research Area and Data Sources

## 2.1. Definition of Research Area

The western waters of Shenzhen refer to the nearshore waters within the administrative jurisdiction of Shenzhen at the eastern mouth of the Pearl River, covering a total area of approximately 500 square kilometers. Their geographical coordinates are 22.47°–22.75°N, 113.81°–114.05°E (Fig. 1).

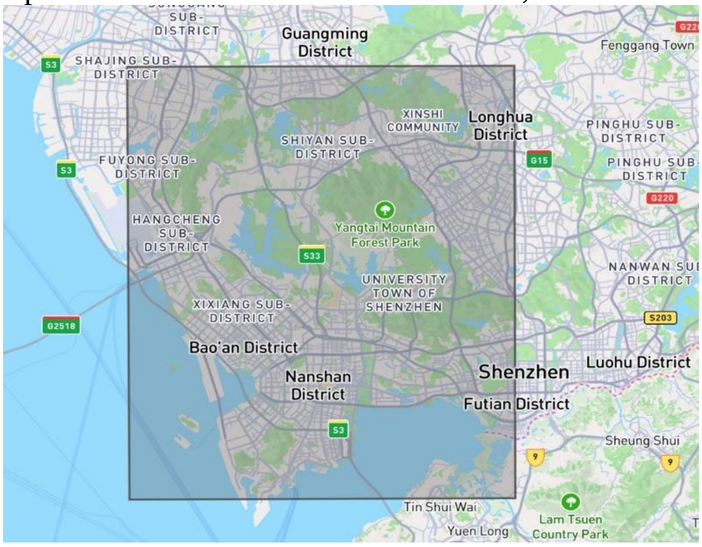


**Fig. 1** Schematic Map of the Study Area (green-framed region in the figure) (photo credit: Original)

The analytical units in this study encompass two representative water bodies: Shenzhen Bay and Dachan Bay. Shenzhen Bay is located near urban outfalls, while Dachan Bay is closer to open waters. These two areas respectively represent "high pollution risk" and "relatively clean" zones.

## 2.2. Data Type and Sources

This study employs a comprehensive analysis integrating remote sensing data, official documentation, and field monitoring records. Regarding remote sensing data, surface reflectance data provided by the European Space Agency (ESA) Sentinel-2 satellite (dataset: COPERNICUS/S2_SR_HARMONIZED) was acquired via the Google Earth Engine (GEE) platform. This data covers the Shenzhen Bay area (114.000°E–114.025°E, 22.490°N–22.515°N, blue area in Figure 2) and Dacawan Bay (113.820°E–113.910°E, 22.500°N–22.580°N, green area in Figure 2) from 2017 to 2023. Official data were sourced from the Marine Environmental Quality Bulletin (2017–2023) published by the Guangdong Provincial Department of Ecology and Environment, providing authoritative water quality background information for the study. To validate and supplement remote sensing and official data, field monitoring was conducted at three sampling points within the study area in July 2025. Key water quality indicators including ammonia nitrogen, dissolved oxygen, and pH were collected and analysed (Fig. 2).

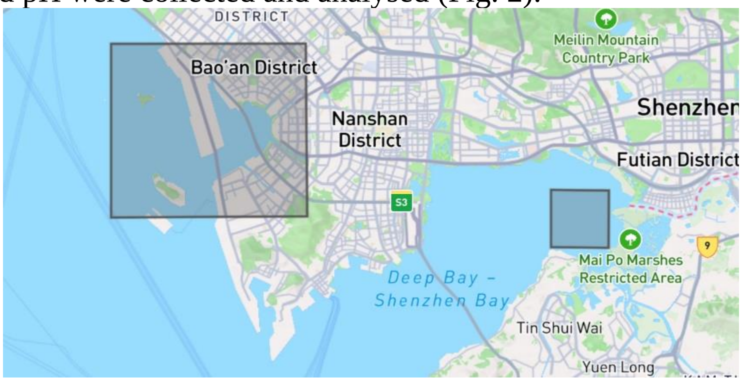


**Fig. 2** Remote Sensing Data Coverage (photo credit: Original)

# 3. Methods

## 3.1. Remote Sensing Retrieval of Water Quality

In the aspect of image preprocessing, to ensure the reliability of the results and minimize cloud interference with data, only images with cloud cover percentages below 20% are retained.

In acquiring valid data, this study selected blue light (B2), green light (B3), and near-infrared (B8) bands from raw data for water body identification and chlorophyll-a concentration estimation. The NDWI (Normalized Difference Water Index) was employed to filter non-water areas (NDWI = (B3-B8) / (B3 + B8)). Based on this, chlorophyll-a concentration was calculated using the empirical model (green light / blue light) ^ (-2.5) × 21.0, with the effective value range constrained (ratio $\in$ (0,10)) to avoid interference from outliers [3]. This study calculated the rate of change in chlorophyll a concentration during the study period by comparing the differences in chlorophyll a concentration between 2023 and 2017, using the 2017 concentration as the baseline to determine the relative increase or decrease.

## 3.2. In-situ Sampling and Parameter Explanation

This study conducted on-site water quality research at representative stations within the study area on July 27, 2025. Three sampling points were established, one located within Shenzhen Bay Park (part of the Shenzhen Bay area) (Sampling Point 1: 113.948811°E, 22.500799°N, sampling time: 12:00 PM), and two within the Dachan Bay area (Sampling Point 2: 113.828169°E, 22.595978°N, sampling time: 2:30 PM) (Sampling Point 3: 113.832785°E, 22.586140°N, Sampling Time: 15:00 PM).

In-situ sampling employed portable water quality test kits to measure the following three parameters at each sampling point:

1) Ammonia Nitrogen Concentration ($NH_4^+$-N):

Ammonia nitrogen encompasses both ionic (ammonium $NH_4^+$) and non-ionic (ammonia $NH_3$) forms, coming from waste materials, fertilizers, and natural processes. It poses a significant threat to aquatic life and contributes to plant eutrophication [4].

2) Dissolved Oxygen (DO):

Dissolved oxygen is the oxygen in water bodies that supports respiration in aquatic organisms, directly determining whether a water body possesses ecological sustainability. When levels are too low, most aquatic life cannot survive [5]; when levels are too high, aerobic microorganisms become overly active, leading to an imbalance in the food chain and excessive consumption of nutrients [6].

3) Acidity/Alkalinity (pH):

pH value controls the toxicity of ammonia nitrogen. As pH value increases, the proportion of non-ionic ammonia rises significantly, posing considerable toxicity to aquatic organisms. Conversely, when pH value is excessively low, fish growth can be suppressed [7].

## 3.3. Processing of Official Documentary Data

This study collates official water quality parameter data from the reference monitoring station in the western waters of Shenzhen (GD0304: 22.4910°N, 113.9620°E) for the period 2017 to 2023 [3], encompassing indicators such as inorganic nitrogen concentration (mg/L), active phosphate concentration (mg/L), and water quality classification. Inorganic nitrogen concentration reflects nitrogen pollution intensity from land-based inputs, while active phosphate concentration characterises phosphorus nutrient loading levels in the water body. Water quality classification is based on the monthly worst indicator values specified in the Seawater Quality Standards (GB3097-1997). The research findings are summarised in Table 3, with interannual variation rates calculated for inorganic nitrogen and active phosphate. Remote sensing-derived trends were further analysed against in situ monitoring data to elucidate water quality evolution characteristics under multi-source data conditions.

# 4. Results

## 4.1. Results of Remote Sensing Retrieval

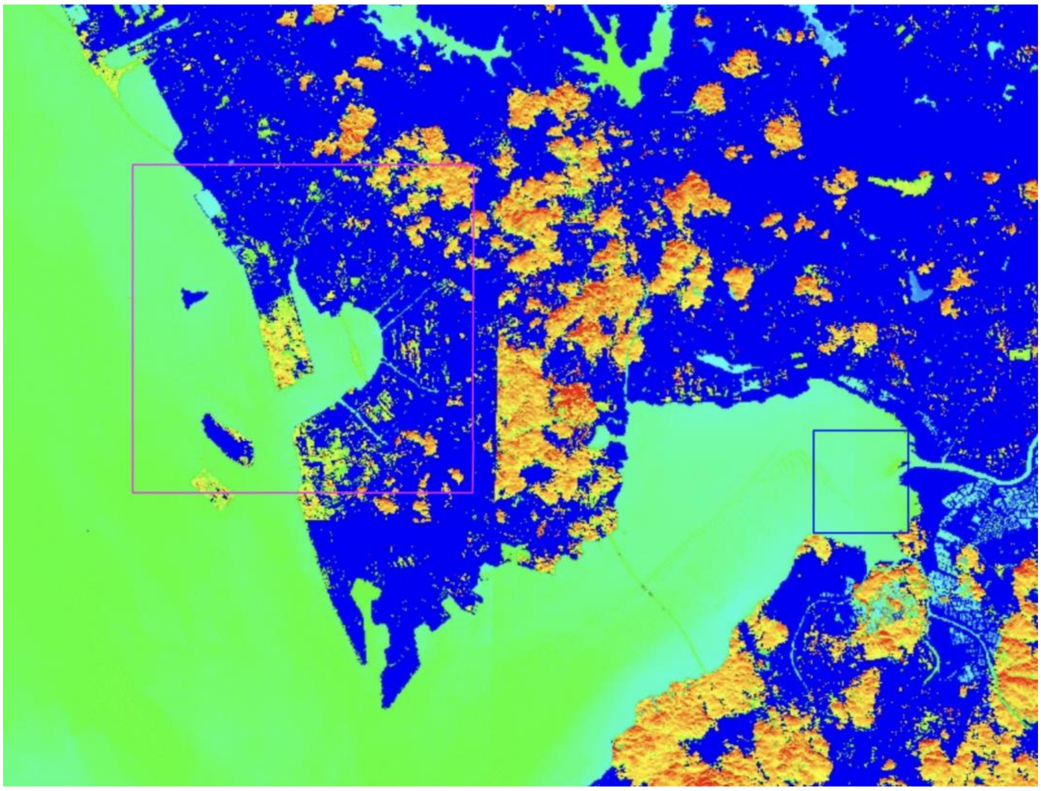

**Fig. 3** Remote Sensing Image of Chlorophyll-a Concentration in Western Shenzhen Waters (2023) (photo credit: Original)

**Table 1.** Chlorophyll-a Concentration Comparison Between Shenzhen Bay and Dachan Bay (2017–2023)

| period | Chlorophyll-a concentration in Shenzhen Bay (mg/m³) | Chlorophyll-a concentration in Dachan Bay (mg/m³) | period |
|---|---|---|---|
| 2017-2018 | 7.20 | 4.76 | 2017-2018 |
| 2019-2020 | 12.43 | 18.74 | 2019-2020 |
| 2021-2022 | 11.79 | 17.80 | 2021-2022 |
| 2023-2023 | 10.99 | 8.18 | 2023-2023 |

Note: Data derived from Sentinel-2 satellite remote sensing retrieval. Data from 2023 covers the entire year.

Chlorophyll-a concentrations in Shenzhen Bay and Dachan Bay showed significant increases from 2017 to 2023, with changing rates of 52.6% and 71.8%, respectively. Chlorophyll-a levels peaked between 2019 and 2022, followed by a substantial decline in 2023.Chlorophyll-a concentration serves as a key indicator reflecting water eutrophication. Studies indicate that elevated chlorophyll-a levels in water bodies primarily result from increased inputs of nitrogen and phosphorus nutrients, suggesting this trend may be linked to fossil fuel combustion and urban land-based pollution discharges (Fig. 3) (Table 1) [8].

## 4.2. Results of In-situ Sampling

Field survey data indicates that Shenzhen Bay Park has high DO levels, low pH levels, and a relatively high ammonia nitrogen concentration. This may be attributed to the enclosed nature of the water body and the area's central location within Shenzhen, which has a high volume of visitors and consequently multiple pollution sources. In contrast, both sampling sites at Dachan Bay show DO and pH levels within standard ranges, with ammonia nitrogen concentrations at relatively low levels. This suggests that pollution in this area is comparatively light, and initial results of pollution control efforts are becoming apparent (Table 2).

**Table 2.** Water Quality Results from In-situ Sampling on July 27, 2025

| Parameters | units | Shenzhen Bay Park (Sampling Site 1) | Dachan Bay (Sampling Site 2) |
|---|---|---|---|
| Sampling Time | | 12:00 | 14:30 |
| Geographical Coordinates | °E, °N | 113.948811°E, 22.500799°N | 113.828169°E, 22.595978°N |
| Dissolved Oxygen (DO) | mg/L | 10.0 | 6.5 |
| Ammonia Nitrogen Concentration ($NH_4^+$-N) | mg/L | 5.0 | 0-5 |
| pH value | | 6.8 | 7.0 |

### 4.3. Results of Official Water Quality Monitoring

**Table 3.** Water Quality Pollution Data for Western Shenzhen Waters (2017–2023)

| Year | Inorganic Nitrogen (mg/L) | Active Phosphorus (mg/L) | Water Quality Category |
|---|---|---|---|
| 2017 | 1.881 | 0.086 | below Class IV |
| 2018 | 0.843 | 0.082 | below Class IV |
| 2019 | 0.604 | 0.098 | below Class IV |
| 2020 | 0.981 | 0.113 | below Class IV |
| 2021 | 1.104 | 0.094 | below Class IV |
| 2022 | 0.788 | 0.085 | below Class IV |
| 2023 | 0.858 | 0.078 | below Class IV |

The study area decreased by 54.4%, while the concentration of active phosphorus in hydrochloric acid decreased by 10.3%. This demonstrates the effectiveness of the relevant management measures. However, the overall water quality category remains below Class IV, which requires continued action to improve (Table 3).

## 5. Discussion

The Shenzhen Bay area itself is a semi-enclosed water body. Land-based pollution discharge and intensive urban development have further increased the pressure on it, ultimately leading to significant pollution burdens. In contrast, the Dachan Bay area benefits from better water exchange conditions, stronger ecological restoration potential. So, the water pollution there is relatively low. Remote sensing trends generally align with field measurements and official data, demonstrating the effectiveness of remote sensing technology in monitoring nearshore water quality. Concurrently, in-situ sampling provides supplementary ecological indicators, which can address the limitations of remote sensing.

Currently, the pollution situation in the western coastal waters of Shenzhen has shown initial improvement in certain localized areas (such as Dachan Bay). This progress is closely linked to measures implemented by the Shenzhen government in recent years, including strengthened supervision of pollution sources, promotion of Source Reduction – Process Control – End-of-Pipe treatment and implementation of separate storm and sewage systems [9]. However, the overall pollution situation remains severe, particularly in relatively enclosed water bodies like Shenzhen Bay. Complex land-based discharges and pollutant retention remain the core challenges faced by this region. Data from this study consistently indicate that water bodies here remain severely polluted. To address this challenge, future governance should further implement the Guangdong Province Five-Year Action Plan for the Clear Water Defense Campaign (2021-2025) and the Shenzhen Municipal Ecological Environment Protection 14th Five-Year Plan. Additionally, remote sensing monitoring should be integrated with field sampling and incorporated into routine monitoring assessments.

Beyond Shenzhen's local governance measures, there were numerous successful international cases of coastal water management which can offer valuable insights and provide inspiration for Shenzhen's future governance. The Chesapeake Bay is the largest estuary in the United States. Long-term impacts from urban and industrial wastewater discharges have resulted in massive inputs of nitrogen and phosphorus, causing severe eutrophication. The U.S. federal government, in collaboration with six states within its watershed and the District of Columbia, established the Chesapeake Bay Initiative. Core measures of this plan include: 1. Targeted pollution source control 2. Ecological restoration of contaminated areas 3. Establishing a scientific monitoring network and management model 4. Public participation [10]. After over 40 years of sustained remediation, by 2024, total nitrogen inputs decreased by 15.3%, total phosphorus inputs decreased by 21.8%, and sediment inputs decreased by 7.6% [11].

Tokyo Bay is in central Japan, situated within a densely populated area with high development and utilization rates. Since the mid-20th century, rapid industrial growth in the region has led to increased discharges of industrial and domestic wastewater. Severe eutrophication causes Tokyo Bay to experience an average of 50 red tides annually [12]. In August 1993, the Japanese government established marine environmental quality standards and discharge limits for nitrogen and phosphorus, implementing emission restrictions on public waters flowing into semi-enclosed bodies at risk of eutrophication**错误!未找到引用源。** [13]. Between 1980 and 2010, Tokyo Bay's daily average chemical oxygen demand decreased from 477 tons to 183 tons. Concentrations of ammonium, nitrate, nitrite, and phosphate also declined [14].

## 6. Conclusion

This study demonstrates that the coordinated implementation of a multi-source data-driven integrated analysis approach alongside multi-tiered governance policies can achieve comprehensive improvement in water quality within the nearshore waters of western Shenzhen. Through the comprehensive utilisation of multi-dimensional data—including remote sensing inversion, long-term sequential monitoring, and field sampling—it is possible to comprehensively understand the spatiotemporal characteristics of nitrogen and phosphorus nutrient loads in water bodies, alongside key water quality indicators. This provides robust data support for scientifically assessing pollution sources and their evolving trends. Concurrently, integrated management measures encompassing wetland restoration, ecological shoreline rehabilitation, land-based pollution control, and port and shipping management can effectively mitigate human-induced pressures on the marine ecosystem, driving sustained long-term water quality enhancement in the region. The study emphasises that future efforts should continue to strengthen multi-source data integration and the development of high-precision monitoring networks, while refining policy coordination mechanisms. This will achieve the organic integration of scientific management, precise governance, and ecological conservation, thereby providing decision-making references and practical experience for marine ecological security and sustainable development in the Guangdong-Hong Kong-Macao Greater Bay Area.

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