

Current Situation of China's Marine Environment and Its Intelligent Monitoring Development Outlook

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Abstract: In recent years, the quality of China's marine environment has improved, and the area of the sea area that meets the Seawater Quality Standard Grade I has increased significantly, but there is still a large area of seriously polluted water in the eastern coastal area, and disasters such as red tide and green tide still occur from time to time. In view of China's marine pollution problems, the study discusses the necessity and superiority of using artificial intelligence, machine learning, big data analysis and Internet of Things technology combined with intelligent sensor networks, automated monitoring equipment and remote data transmission systems and other advanced technological means to monitor and protect the environment of the ocean, and analyses and discusses the progress of research in related fields. At the meantime, we discusses the technical bottlenecks and solutions faced by the current intelligent monitoring of the marine environment. Finally, we discusses the technical bottlenecks and solutions to the current intelligent marine environmental monitoring.

Keywords: Marine Environment Monitoring; Big Data; Intelligence; 3S Technology; Artificial Intelligence; Internet of Things (IoT).

1. Introduction

China, as a major maritime country, has vast areas of sea and rich marine resources. According to the Ministry of Ecology and Environment's "2023 China's Marine Ecological and Environmental Condition Bulletin" (hereinafter referred to as the "Marine Bulletin"), China's territorial sea water quality in general improved steadily in 2023, the overall quality of marine water environment showed a stable and improving trend, with 97.9% of the marine water under jurisdiction of China meeting the Seawater Quality Standard Grade I. 85.0% of the coastal area had excellent or good water quality (meeting Grade I and Grade II standards), up by 3.1 % compared with last year. The area with water quality inferior to the Seawater Quality Standard Grade IV is mainly distributed in the coastal waters of Liaodong Bay, Yangtze River Estuary, Hangzhou Bay and Pearl River Estuary, and inorganic nitrogen and reactive phosphorus are the main indicators of exceeding the standard. Among the typical marine ecosystems studied, 7 are in a healthy state, 17 are in an unhealthy state, and none is in an abnormal state. The water quality of rivers entering the sea nationwide is generally in good condition. The water quality of sea bathing beaches and the environmental quality of marine fishery waters is generally good. However, the water quality of China's coastal waters still needs to be improved, eutrophication is more serious in some coastal waters, and marine environmental disasters such as red tides and green tides still occur from time to time.

2. Status of Marine Environmental Pollution in China

(1) Water Quality of Sea Areas under Jurisdiction of China
According to the Marine Bulletin, 1,359 national control points in jurisdictional waters were monitored for seawater

quality during the summer of 2023. The overall water quality of jurisdictional waters improved steadily, with 97.9% of the territorial sea meeting Seawater Quality Standard Grade I in the summer, an increase of 0.5 % from last year. The area with water quality inferior to the Seawater Quality Standard Grade IV was 21,410 km², 3,470 km² less than that of last year, and the exceeding indicators were mainly inorganic nitrogen and reactive phosphate. The sea area with inorganic nitrogen content failing to meet the Seawater Quality Standard Grade I was 52,170 km².

Among China's four major sea areas, The sea area of Bohai sea with water quality failing to meet the Seawater Quality Standard Grade I was 12,210 km², decreasing by 12,440 km² compared with that in the previous year. The sea area with water quality failing to meet Grade IV mainly located at Liaodong Bay, Bohai Bay and Yellow River Estuary.

The sea area of Yellow Sea with water quality failing to meet the Seawater Quality Standard Grade I was 5,700 km², decreasing by 8010 km², compared with that in the previous year. The sea area with water quality inferior to Grade IV mainly located at the northern Yellow Sea.

The sea area of East China Sea with water quality failing to meet the Seawater Quality Standard Grade I was 39,070 km², which increased by 10,130 km², compared with that in the previous year. The sea area with water quality inferior to Grade IV mainly located at Yangtze River Estuary and Hangzhou Bay.

The sea area of South China Sea with water quality failing to meet the Seawater Quality Standard Grade I was 6,900 km², decreasing by 2,640 km² compared with that in the previous year. The sea area with water quality inferior to Grade IV mainly located at Pearl River Estuary.

The areas of the four major sea areas with Grade I - inferior Grade IV waters are shown in Table 1, and the distribution of the water quality situation of the sea areas under China's jurisdiction is shown in Figure 1.

Table 1. Area of non-Grade I Water in the Four Major Sea Areas in 2023

Sea Area	Area of Grade II Waters	Area of Grade III Waters	Area of Grade IV Waters	Area of inferior Grade IV Waters
Bohai sea	6660	2360	860	2330
Yellow Sea	4850	470	120	260
East China Sea	16190	3260	2980	16640
South China Sea	2930	890	900	2180



Figure 1. Water Quality Status of Sea Areas under Jurisdiction of China in 2023

(2) Main Pollution Sources into the Sea

In 2023, 230 water sections of rivers flowing into the sea were monitored under the national monitoring program. Among the monitored sections, the proportion of sections meeting surface water quality standard Grade I, Grade II and Grade III accounted for 80.9% of the total, which increased by 0.9 % compared with the previous year. Proportion of water sections at different quality levels of sea-entering rivers in different sea areas are shown in Table 2 and pollution

indicators of water sections of sea-entering rivers are shown in Table 3.

In 2023, 455 of industrial sewage outlets, domestic sewage outlets, and comprehensive sewage outlets with daily discharge volume exceeding or equal to 100 tons were monitored. The total sewage discharge amount of 455 monitored outlets was approximately 7,755.09 million tons. Among the various types of sewage outlets into the sea, comprehensive outlets contributed the largest amount of sewage, followed by industrial outlets, and domestic sewage outlets the smallest. Among all the monitored pollutants, the comprehensive outlets discharged the largest amount of pollutants. Total amount of sewage and major pollutants from sewage outlets received by different sea areas are shown in Table 4.

As can be seen from the above, the East China Sea sea area compared to last year's inferior Grade IV water area increased by 35 per cent, of which the inferior Grade IV water area in the non-grade I water area accounted for 42.59 per cent, and in the Bohai Sea, the Yellow Sea, the East China Sea waters, which accounted for 19.08%, 4.56%, 31.59% respectively. The more serious water quality conditions are concentrated in the Liaodong Bay, the Yangtze River estuary, Hangzhou Bay and the Pearl River estuary, of which the East China Sea waters of the Yangtze River estuary, Hangzhou Bay area of the worst water quality; four major sea ports, the Bohai Sea sea ports of the worst water quality conditions, Grade IV water area accounts for a large proportion of COD, potassium permanganate index exceeded the standard serious; four major sea ports of the East China Sea to receive the largest amount of sewage from the source of direct discharge of pollution, the main pollutants are COD, TN.

The above data show that China's East China Sea area is affected by the direct discharge of sea pollution sources, while the Bohai Sea area is seriously affected by the sewage into the sea. The reason for this is that the East China Sea has developed shipping, while the Bohai Sea area has more industrial enterprises in the sea, and the government needs to carry out the corresponding pollution control according to the characteristics of each sea area, and the corresponding environmental monitoring technology should be further advanced with the progress of the quality of China's marine environment.

Table 2. Proportion of Water Sections at Different Quality Levels of Sea-entering Rivers in Different Sea Areas in 2023

Sea Area	Water Quality*	Grade I (%)	Grade II	Grade III	Grade IV	Grade V	Inferior Grade V
Bohai sea	Slight Pollution	0.0	17.2	46.6	36.2	0.0	0.0
Yellow Sea	Good	0.0	8.8	75.4	15.8	0.0	0.0
East China Sea	Good	0.0	31.8	56.8	9.1	2.3	0.0
South China Sea	Good	0.0	45.1	42.3	11.3	1.4	0.0

*Rivers flowing into the sea are classified into five grades

through comprehensive water quality evaluation:

Excellent: 90% and above of waters meet Grade I – II quality level;

Good: 75% (including 75%)-90% of waters meet Grade I-II;

Slight Pollution: less than 75% of waters meet Grade I-III, and less than 20% of waters are inferior to Grade V:

Moderate Pollution: less than 75% of waters meet Grade I-III, and 20% (including 20%)-40% of waters are inferior to Grade V:

Heavy Pollution: less than 60% of waters meet Grade I-III, and 40% and above of waters are inferior to Grade V.

Table 3. Pollution indicators of water sections of sea-entering rivers in China in 2023

Sea Area	Exceedance Ratio >20%	20%≥Exceedance Ratio≥10%	Exceedance Ratio <10%
atio	COD、permanganate index		BOD ₅ 、Fluoride
Yellow Sea		COD	BOD ₅ 、permanganate index、TP
East China Sea		COD	BOD ₅ 、permanganate index
South China Sea			BOD ₅ 、permanganate index、COD、DO
All		COD	BOD ₅ 、permanganate index、TP、Fluoride、DO

Table 4. Total Amount of Sewage and Major Pollutants from Sewage Outlets received by Different Sea Areas in 2023

Sea Area	Number of Outlets	Amount of Sewage (10 ⁴ ton)	Petroleum (ton)	COD (ton)	NH ₃ -N (ton)	TP (ton)	TN (ton)
Bohai sea	58	64573	45	6268	116	50	2036
Yellow Sea	80	97843	132	20965	621	134	7790
East China Sea	171	452105	340	82797	2195	519	31522
South China Sea	146	160988	45	33373	1355	267	12017

3. The Need for Intelligence in Monitoring the Marine Environment

Intelligent marine environment monitoring technology covers a variety of advanced technical means and equipment, including two major aspects of collection and processing. In data collection there are sensor technology, unmanned underwater vehicles (AUVs) and underwater robots (ROVs) technology, buoy systems, satellite remote sensing technology, etc; in data processing there are Internet of Things (IoT) technology, big data and cloud computing technology, artificial intelligence and machine learning technology. Meanwhile, monitoring platforms and application software based on intelligent technology can integrate multi-source data and provide visualisation and decision support^[1].

The necessity of intelligent technology for marine environment monitoring is reflected in the following aspects: Intelligent technology has significantly improved monitoring accuracy and efficiency. Traditional marine environment monitoring methods often rely on manual sampling and laboratory analysis, which is not only time-consuming and labour-intensive, but also has certain human errors. Intelligent technology can achieve real-time monitoring of the marine environment through automated equipment and intelligent sensors, significantly improving the precision and efficiency of data collection. For example, the use of unmanned underwater vehicles and buoy systems can continuously monitor marine water quality parameters, such as temperature, salinity, dissolved oxygen, etc., to provide continuous and accurate environmental data; intelligent technology can achieve large-scale, multi-dimensional data collection. The marine environment is complex and variable, and there are numerous parameters to be monitored. Intelligent technology can make use of the Internet of Things, big data analysis and cloud computing to carry out large-scale, multi-dimensional data collection and processing of the marine environment.

This all-round data monitoring can not only detect environmental anomalies in a timely manner, but also provide detailed environmental change trends, providing strong support for scientific research and environmental management; intelligent technology can significantly improve data analysis and prediction capabilities. Artificial intelligence and machine learning algorithms in intelligent technology can handle massive amounts of monitoring data and perform complex pattern recognition and predictive analysis. Through deep learning of historical data, intelligent systems can predict future trends in the marine environment, such as the spread of marine pollution and the response of marine ecosystems, to provide a scientific basis for decision makers. This prediction ability is of great significance for taking timely countermeasures to prevent and mitigate marine environmental problems; intelligent technology can enhance environmental emergency response capability. In the face of sudden marine environmental events, such as oil spill accidents and red tide outbreaks, the intelligent monitoring system can respond quickly and provide accurate environmental information through real-time data transmission and analysis, helping the relevant departments to quickly formulate and implement emergency response plans to reduce environmental damage and economic losses. For example, the use of satellite remote sensing technology can quickly locate pollution sources and monitor the spread of pollutants, providing important support for emergency response.

In summary, intelligent technology in the marine environment monitoring has an important necessity and advantage, he can break in the substantial expansion of marine monitoring data in the traditional data analysis, storage, management methods of the dilemma, more able to co-ordinate the coordination of various departments to deal with the problem of marine pollution conveniently and quickly.

4. Application of Intelligent Technology in Marine Environmental Monitoring

Smart sensor technology is the foundation of marine environmental monitoring, which includes a variety of physical, chemical and biological sensors for detecting a wide range of parameters in the marine environment, such as temperature, salinity, dissolved oxygen, pH, nitrogen and phosphorus content. Advanced sensor technologies can achieve high sensitivity, high accuracy and stable monitoring over long periods of time. Traditional marine monitoring technology is mainly applicable to offshore environmental monitoring, with a limited monitoring range, low dimensional monitoring technology, low monitoring accuracy, and the traditional method of monitoring pollution sources for a long period of time, resulting in the fact that once the pollution source is found, it may have drifted to other regions. Some experts and scholars have proposed a marine big data intelligent detection system^[2] that can achieve high-precision full-coverage marine monitoring, which introduces intelligent remote sensing technology and water quality sensors, and optimises big data analysis methods. Through remote sensing technology to achieve multi-level real-time monitoring of the marine environment, remote sensing technology can effectively obtain the ocean chlorophyll, yellow matter and suspended sediment and other information^[3, 4], and then through the establishment of the marine satellite image database to intelligently screen useful information^[5]; water quality sensors can be targeted at multiple monitoring points for monitoring, to achieve a comprehensive collection, which is of great significance for the monitoring of marine water quality^[6].

Through remote sensing technology to monitor the ocean from space on a large scale and high resolution, ocean satellite remote sensing has the unique advantages of all-weather, all-weather, large-range, and long time-series observation, and is widely used in the fields of marine ecology and resource monitoring and investigation, marine disaster monitoring, maintenance of maritime rights and interests, and marine environment forecasting and security^[7, 8]. In 2002, China successfully launched the first ocean satellite - Ocean-1A (HY-1A) satellite. As of September 2021, China has launched three series of ocean water colour (Ocean-1 (HY-1) series), ocean power environment (Ocean-2 (HY-2) series) and ocean surveillance and monitoring (Ocean-3 (HY-3) series), with a total of 10 ocean satellites (including Gaofen-3 (GF-3) satellites), which has initially formed the observation pattern of operational observation of the ocean satellite group network. In recent years, the relevant departments have used HY-1C and HY-1D satellites to monitor a number of red tide events in the Bohai Sea, Yellow Sea, East China Sea and South China Sea in China, obtaining important information such as their location and the scope of their influence^[9].

IoT technology plays an important role in marine environment monitoring by interconnecting sensors, buoys, AUVs, ROVs and other devices to form a large monitoring network. IoT technology can realise data sharing and remote control between devices, and enhance the coordination and intelligence of the monitoring system. IoT technology applied to marine environment monitoring collects marine environment data through wireless sensor network. The monitoring terminal is responsible for the aggregation, collation and forwarding of sensor data, while the information

management system controls the data acquisition subsystems and monitoring terminals and is responsible for storing, analysing and distributing environmental monitoring data^[10, 11]. A LoRaWAN-based IoT device has been proposed to be able to collect long-distance marine environmental data in an energy-efficient manner^[12]. Some experts and scholars have proposed a environment monitoring system for China's marine environment, which combines sensor technology, 4G communication technology and Zigbee communication technology to design a marine environment monitoring system based on the Internet of Things (IoT).^[13]

Data are collected through remote sensing, sensors, and IoT technologies, and then these massive data can be stored, processed, and analysed using big data and cloud computing technologies. Big data analysis can identify the patterns and trends of environmental changes, and cloud computing provides powerful computing capabilities to support complex model simulation and real-time data processing^[14, 15]. Ocean big data has the characteristics of massive, diverse, real-time, and complexity^[16, 17], and currently countries around the world are establishing ocean big data systems, such as the 'Neptune' programme expected to be implemented by the United States and Canada, the European Marine Observation and Data Network (EMODnet) of the European Union, the 'ARANA' programme by Japan, "Africa Offshore Resources Data and Network Information Platform" of several African coastal countries, and "iOcean" platform of China^[18-20].

Artificial intelligence and machine learning techniques are used for data analysis and pattern recognition in marine environmental monitoring. By training models, AI can extract useful information from complex monitoring data, predict environmental changes, and identify unusual events. For example, AI algorithms can be used to detect and track marine pollution sources and predict red tide outbreaks^[21, 22]. Some scholars collected marine monitoring data before and after the occurrence of red tide in Xiamen waters from 2009 to 2017, and proposed a gated recurrent unit (GRU) prediction model based on the main characteristic factors to predict the occurrence of red tide, which provides an effective method for the early warning of red tide in Xiamen waters^[23].

5. Conclusion and Outlook

With the continuous progress of technology and the continuous expansion of application scenarios, the scale of intelligent ocean monitoring will continue to expand, but at the same time intelligent ocean monitoring will also encounter corresponding challenges and obstacles.

Firstly, the high cost of research and development and maintenance of marine monitoring equipment restricts large-scale deployment, and intelligent marine monitoring also requires multidisciplinary cross-cutting technologies, such as artificial intelligence, the Internet of Things, big data, etc., which puts forward higher requirements for the ability and collaboration of relevant technicians; Secondly, marine monitoring data involves national security and commercial confidentiality, so how to protect the privacy of the data and at the same time promote the sharing of data is an important issue, and the global nature of ocean environmental problems requires the cooperation of all countries. However, differences in data standards, laws and regulations, and technical levels among countries increase the complexity of cooperation.

To cope with the above problems faced by intelligent

marine monitoring, the government should increase investment in marine environmental monitoring, introduce relevant policies and regulations, promote the application and development of intelligent technology, and formulate corresponding policies for targeted management of the pollution characteristics of different marine areas; at the same time, the improvement of the public's awareness of the environment and the increase in the degree of participation will also help to promote the development of the monitoring and protection of the marine environment.

Intelligent monitoring of the marine environment faces many challenges, but is also accompanied by great opportunities. Through technological innovation, international cooperation and policy support, it is possible to overcome these challenges, promote the intelligent development of marine environmental monitoring and enhance the capacity of marine environmental protection and resource management.

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