Implementing the Strategic Action Programme for the Yellow Sea Large Marine Ecosystem: Restoring Ecosystem Goods and Services and Consolidation of a Long-term Regional Environmental Governance Framework (UNDP/GEF YSLME Phase II Project)

Proposal for the Guideline on Regional Pollution Monitoring of Target Pollutants and Framework Plan for Establishing the Monitoring Network in the Yellow Sea

FINAL VERSION

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UNDP/GEF Yellow Sea Large Marine Ecosystem (YSLME) Phase II Project.

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1. Guidelines of marine environmental monitoring

1.1 Guidelines of China

1.1.1 Marine ecological and environmental monitoring technical system of China

Chinese marine environmental monitoring began in the 1970s. After more than 40 years of development, the primary objectives of the marine environmental monitoring of China has gradually developed and changed from pollution to comprehensive monitoring of ecological environment quality, pollution and damage pressure. The Ministry of Environmental Protection (MEP), the State Oceanic Administration (SOA) and the Ministry of Agriculture (MOA) respectively organized routine monitoring of water quality, sediment, and biology in coastal areas. Monitoring of pollution sources of rivers and drain outlets into the sea were also involved by MEP and SOA. According to the authorization, MEP, SOA and MOA issued respectively relevant communiqués and reports every year. For example, MEP issued *China Environmental Quality Status Bulletin* (including the offshore environmental quality status), and SOA issued *China Marine Environment Status Bulletin*.

In 2015, the China government issued the *Action Plan for Prevention and Control of Water Pollution*, which put forward the targets and action plans for water environmental protection in China. The corresponding monitoring and assessment based on the action plan were involved in national and local monitoring plans and programs. For example, the Ministry of Ecology and Environment (MEE) is conducting the assessment of coastal water quality, which requires that the good rate of coastal water quality should reach 70% by 2020.

The marine ecological and environmental monitoring is an important and integral part of national ecology and environment management. The marine ecological and environmental monitoring technical system is the basis for systematically carrying out the monitoring and recognizing the marine ecological environment and pressure (Figure 1). The system is constructed based on a series of standards, such as quality standards, pollutant emission standards, monitoring and assessment method standards, reference materials and instrument standards, and motivated by the improvement of new technology and new methods. It focuses on marine ecological and environmental quality by monitoring and assessing the environment status, pollution pressure and their change trends, and services for the decision-making of national policy of environmental protection, pollution prevention and control.

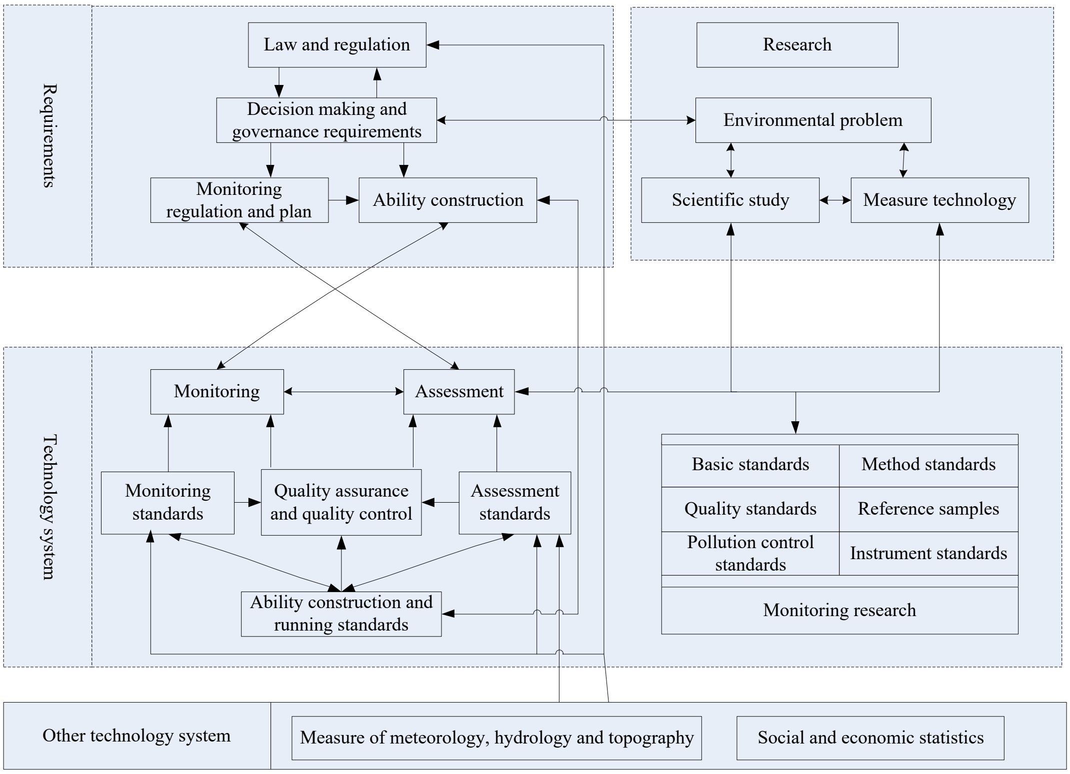
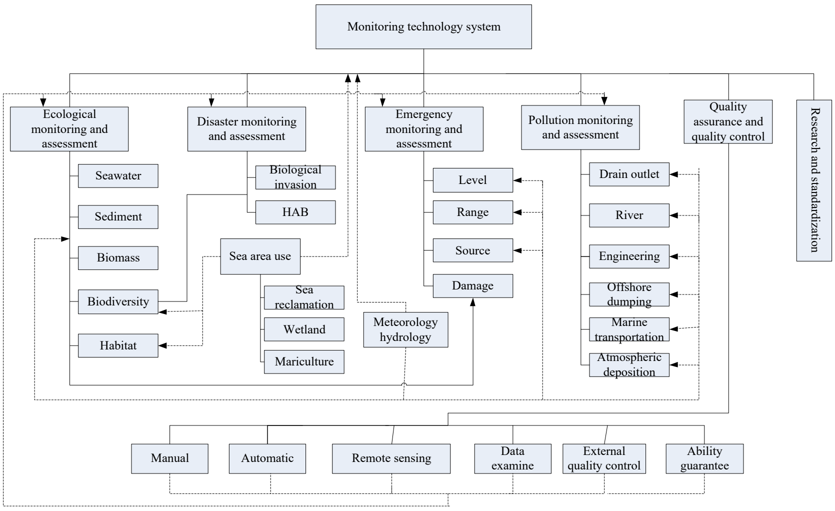


Figure 1. Relationship between marine ecological and environmental monitoring system with environment management and scientific research (source: Discussion on Ecological Environmental Monitoring System in Marine, *Environmental Monitoring in China*)

Following the transition of national environmental management from pollution control to environmental quality management, the marine environmental monitoring and assessment of China has gradually changed the objective from pollution control to comprehensive monitoring and assessment of ecology and environment. As for marine environmental monitoring, pollution and some environmental element monitoring methods have been standardized, as well as some research results are gradually being converted into standards.

As an integral part of the national eco-environmental monitoring technology system, the marine ecological and environmental monitoring technical system is composed of various standards, regulation, technical guidelines and mutual relations involved in monitoring and assessment (Figure 2).



The system includes ecological, pollution, emergency and disaster monitoring and assessment, as well as monitoring and assessment of surface water, pollution sources and the atmosphere. Each monitoring event involves manual, automatic, aerial survey, remote sensing, data audit, internal quality control and external quality control, etc.

The pollution monitoring and assessment mainly includes the following parts: rivers and drain outlet reach the sea, oceanographic and coastal engineering, offshore dumping, marine transportation and atmospheric deposition, as well as the quality of seawater, sediment and biomass. Quality assurance and quality control of monitoring run through the different aspects of the technical system. At the same time, the system also needs the support of various technical fields, such as hydrology, meteorology, topography, land use, social development and economic statistics.

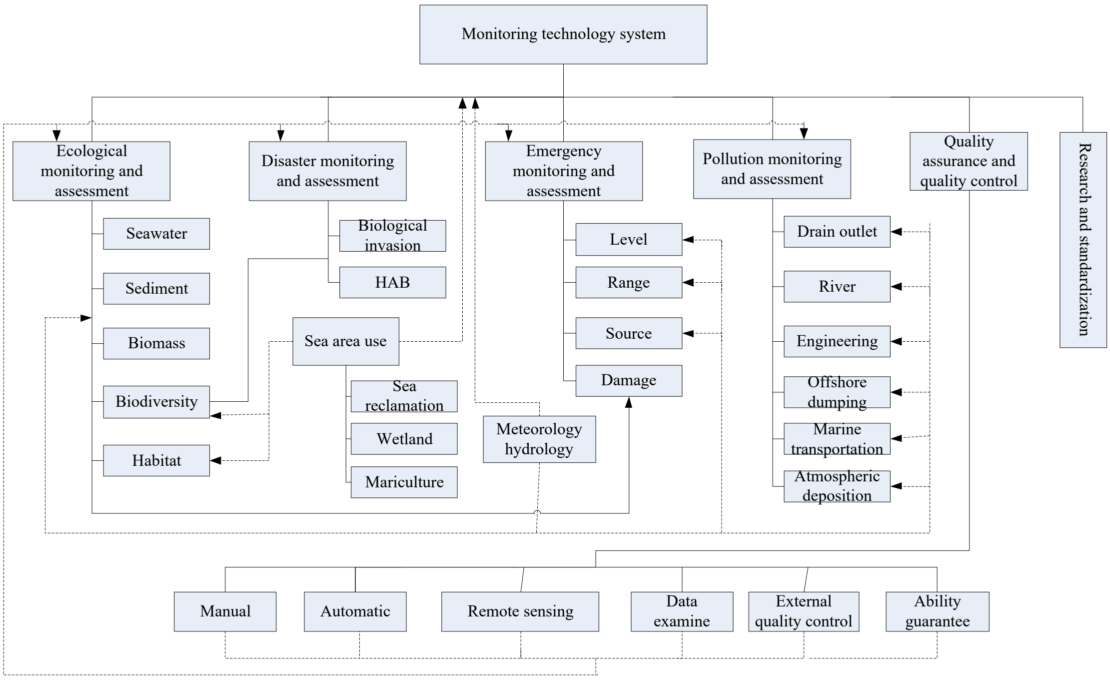


Figure 2. Marine ecological and environmental monitoring technical system of China (source: Discussion on Ecological Environmental Monitoring System in Marine, *Environmental Monitoring in China*)

1.1.2 Marine ecological and environmental protection standards system of China

Marine eco-environmental protection standard system is one of the important contents of the national marine standardization system. The system reflects the emphasis and needs of China's marine eco-environmental protection work; it also is the top-level design of marine eco-environmental protection standardization, as well as an important guidance and technical support for carrying out the eco-civilization construction of China. By analyzing the quantity and types of marine eco-environmental protection standards and the existing problems in the standardization process, based on the basic standards, the national marine eco-environmental protection standard system was developed and formed gradually, which contains four sections: (1) marine ecological and environmental monitoring and assessment; (2) Pollution prevention and supervision; (3) Ecological protection and rehabilitation; and (4) Marine pollution accident and eco-disaster (Figure 3).

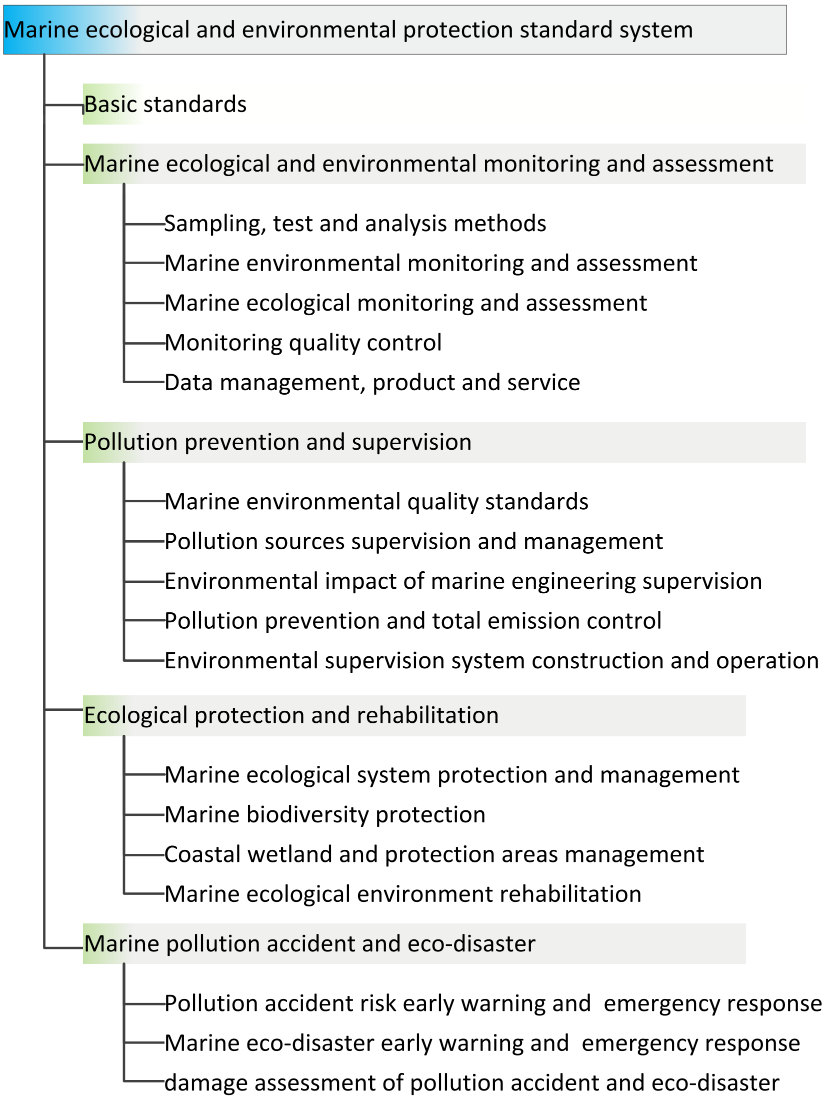


Figure 3. Marine ecological and environmental protection standards system of China

Marine eco-environmental protection standards in China mainly consist of five categories: (1) environmental quality standards; (2) monitoring methods standards; (3) assessment methods standards; and (4) environmental management standards and basic standards. There are significant differences in the number of various standards, showing the characteristics of the highest number of standards for monitoring methods, the second highest number for assessment methods, and less environmental management standards and basic standards.

1.1.3 Standards of marine pollution monitoring and assessment

The technical standards of marine pollution monitoring and assessment are mainly distributed in two parts: marine eco-environmental monitoring and assessment; and pollution prevention and supervision. The relevant standards mainly involve the following categories: (1) marine environmental quality standards; (2) sampling, test and analysis methods; (3) marine environmental monitoring and assessment; (4) monitoring quality control; (5) pollution sources supervision and management; (6) environmental impact of marine engineering supervision; (7) pollution prevention and total emission control; and (8) damage assessment of pollution accident and eco-disaster.

(1) Marine environmental quality standards

Marine environmental quality standards involve the quality of seawater, sediment, biomass, biology and habitat.

The existing standards mainly include:

- ❑ Seawater quality standard (GB 3097-1997)
- ❑ Marine sediment quality standard (GB 18668-2002)
- ❑ Marine biological quality (GB 18421-2001)
- ❑ Regulation for offshore environmental monitoring (HJ 442-2008) (biodiversity assessment)
- ❑ Guidance for the assessment of coastal marine ecosystem health (HY/T 087-2005)

(2) Sampling, test and analysis methods

Sampling, test and analysis method standards are the most commonly used standards in marine environmental monitoring (Figure 4). The marine environmental protection monitoring standard system, which is different from China's environmental protection monitoring standards that are mainly single (or similar) element analysis methods, includes both single (or similar) element analysis methods and comprehensive monitoring method standards. For example, as a comprehensive standard, *Specification for marine monitoring* (GB 17378-2007) covers more than 100 analysis methods. It is widely used as the basic technical document for national marine environmental monitoring. In addition to the comprehensive standards, such as *Specification for marine monitoring* (GB 17378-2007) and *Code of practice for marine monitoring technology* (HY/T 147-2013), nearly 100 standards of single (or similar) element analysis methods are also issued. Fourteen of which are for basic environmental parameters, inorganic and heavy metal pollutants, twenty for organic pollutants. In addition, it also includes 25 standards for the analysis of typical environmental parameters/pollutants in specific functional areas. Now, the number of issued and being revised single (or similar) element analysis methods is increasing quickly, and these standards are used in a wider and wider range.

To date, the existing comprehensive environmental monitoring methods mainly involve:

❑ Specification for marine monitoring (GB 17378-2007)

❑ Specifications for oceanographic survey (GB/T 12763-2007)

❑ Code of practice for marine monitoring technology (HY/T 147-2013)

❑ Regulation for offshore environmental monitoring (HJ 442-2008)

❑ Specifications on spot location of monitoring sites related to coastal area environment (HJ 730-2014)

❑ Specification for automated water quality monitoring in coastal area (HJ 731-2014)

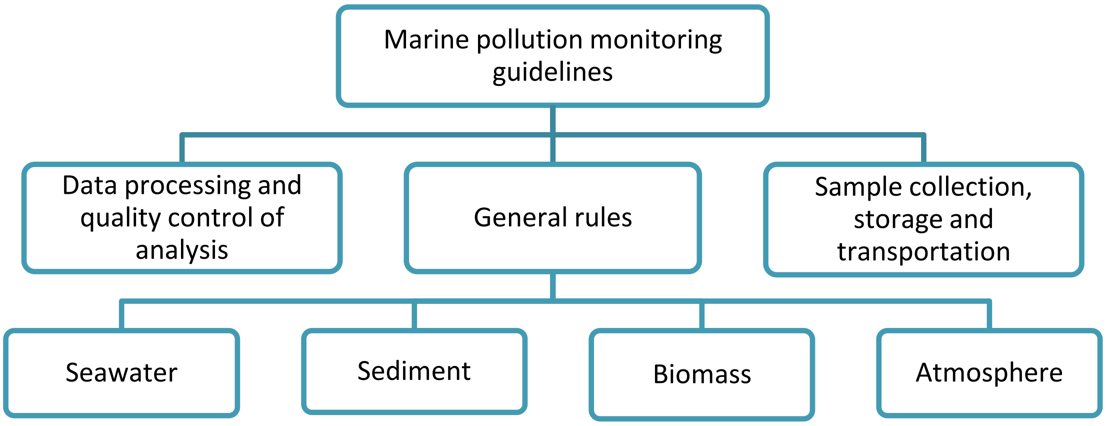


Figure 4 Marine pollution monitoring guidelines of China

(3) Marine environmental monitoring and assessment

Marine environmental assessment is an important part of marine environmental protection work and a basic support for marine environment management. Most assessment standards are based on the existing environmental quality standards, which are relatively perfect. However, the number of active marine environmental assessment standards of China is low, especially for the comprehensive assessment technical standards that directly support marine environmental management, which will be the emphasis of standard development work in the future.

The monitoring and assessment system of water, sediment, organisms and typical ecosystems quality for specific demonstration areas has been established (or has been established within a certain range), and the related monitoring and assessment results and achievements has also been included in the issued relevant bulletins. *Guideline of nearshore ecological and environmental quality assessment technology* has been set to study and develop, and to be released soon.

The primary marine environmental assessment standards include:

❑ Guidelines for assessing status and trends of marine environmental quality (approved, not issued yet)

❑ Technical specification for monitoring and evaluation of pollutant loads from river to the sea (approved, not issued yet)

❑ Technical specifications for environment monitoring and assessment on mariculture zones (approved, not issued yet)

❑ Environmental monitoring and assessment guidance for land-based discharge outlets and adjacent sea area (approved, not issued yet)

❑ Assessment methods for current status and trend of nearshore sediment quality (approved, not issued yet)

(4) Monitoring quality control

Quality is the lifeline of monitoring work. The quality assurance and quality control system is an integral part of the monitoring system, which runs through each part of the monitoring system and is embodied in each method and specifications. The established internal and external quality control technology is relatively mature, but the type and quantity of the relevant reference materials are insufficient. To date, China has not established a complete standard system of marine environmental monitoring quality control. Few individual standards of monitoring quality control are issued. Most technical guidelines of quality control exist as an integral part of some standards. As a commonly used standard in marine environmental monitoring, *Specification for marine monitoring* (GB 17378-2007) was divided into five (5) parts, and part 2 of which is devoted to the monitoring quality control – data processing and quality control of analysis. There are also specific contents about monitoring quality control in part 1 (general rules) and part 3 (sample collection, storage and transportation) of the standard. *Regulation for offshore environmental monitoring* (HJ 442-2008) also makes clear and detailed provisions on monitoring quality control. These two standards are now the most important technical documents for quality control in marine environmental monitoring of China.

(5) Pollution sources supervision and management

The pollution sources supervision and management standards cover five (5) major parts: (1) rivers and drain outlet into the sea; (2) atmospheric deposition; (3) marine garbage; (4) and pollution sources at sea. On the whole, pollution sources supervision and management standard system are establishing, and many aspects of standards are seriously deficient or blank, such as the standards of marine atmospheric deposition, pollution sources at sea and online monitoring.

The main pollution sources supervision and management standards are as follows:

❑ Technical specification for terrestrial pollution source and near sea area monitoring (HY/T 076-2005)

❑ Technical specification for monitoring of total amount of pollutants discharged from river to sea (HY/T 077-2005)

❑ Technical specification for monitoring and evaluation of pollutant loads from river to the sea (approved, not issued yet)

❑ Guidelines for estimation of pollutant flux in the harbor (approved, not issued yet)

❑ Guidelines for monitoring and assessment of marine debris (approved, not issued yet)

(6) Environmental impact of marine engineering supervision

Based on the current classification system of marine functional areas of China, as well as the existing marine functional areas monitoring, assessment, supervision and management work, the standard system of environmental impact of marine engineering supervision of China has been improved incrementally. The various parts of the standards cover marine dumping, oil and gas development and marine engineering construction projects areas. Compared with other standard systems, there are more and relatively sound standards to support the marine functional areas environment monitoring and assessment of China.

The primary standards of environmental impact of marine engineering supervision are:

❑ Assessment procedure for marine dumping of dredged material (GB 30980-2014)

❑ Technical guidelines for environmental impact assessment of marine engineering (GB/T 19485-2014)

❑ Directives of strategic environmental assessment for the reclamation planning in bays (GB/T 29726-2013)

❑ Technical guidelines for environmental impact assessment of seawater multi-purpose utilization engineering (GB/T 22413-2008)

❑ Water impact assessment methods for discharge sea area of seawater multi-purpose utilization engineering (HY/T 129-2010)

❑ Effluent limitations for pollutants from offshore petroleum exploration and production (GB 4914-2008)

❑ Biological toxicity for pollutants from marine petroleum exploration and exploitation (GB/T 18420-2009)

❑ Specifications and test methods of dispersants in common use in offshore oil exploration and exploration (HY 044-1997)

❑ Limitation on infilling components of sea reclamation and enclosure project (GB 30736-2014)

❑ Assessment procedure for marine dumping of inert inorganic geological material (GB 30979-2014)

(7) Pollution prevention and total emission control

Total emission control of pollutants is one of the most important policies for marine environmental management and pollution prevention/control in China. There has been some foundation and experience on this aspect, but the standardization of control technology and assessment methods is lagging behind management needs. Currently, the standard system of pollution prevention and total emission control is being established, and lots of relevant standards are needed to develop it in the near future.

(8) Damage assessment of pollution accident and eco-disaster

A great deal of work on monitoring and damage assessment of marine pollution accident has been carried out. The current monitoring and assessment methods are suitable for routine monitoring; however, emergency monitoring has special requirements, and most existing methods cannot meet the emergency monitoring needs. Standard system establishment of the emergency monitoring of marine pollution accidents and their damage assessment methods is one of the key tasks of marine pollution monitoring and assessment.

1.1.4 Needs for standardization of marine environmental protection of China

(1) Applicability and effectiveness of the standards need to be improved

According to the issued date, more than 25% of the current marine environmental protection standards have been more than 10 years, and about 2/3 of them have been more than 5 years. Some of them are incapable of affording the demands of national marine ecological civilization construction and marine comprehensive management, and the applicability and effectiveness of these standards need to be further assessed and improved. Taking an example of three primary quality standards, *Seawater quality standard* (GB 3097-1997), *Marine sediment quality standard* (GB 18668-2002) and *Marine biological quality* (GB 18421-2001), they have been issued for more than 15 years. Both the pollution indicators and the limit values cannot meet the requirements of the current marine environmental protection. One urgent requirement based on research is to carry out the study on the marine environmental criteria, and revise the three primary quality standards. Moreover, the major technical standards of marine environmental monitoring, *Specification for marine monitoring* (GB 17378-2007), was issued 10 years ago, and some of the monitoring methods cannot meet the requirements at the present stage. With the development of new technology, the revision of the standard is imperative.

(2) Process of standard-making and revising needs to be accelerated

The aim of standardization is to promote optimum overall economic results. With the continuous development of China's marine industry, the importance of marine standardization has become more and more prominent. At present, there are heavy tasks on making and revising marine standards. A standardized and unified monitoring and assessment system need to be established. National ocean ecological environment monitoring tasks of 2017 was divided into 28 monitoring tasks, while only 50% of the assessment methods are the national standards or industrial standards, and other assessment methods have not been standardized yet. On the other hand, more and more scientific research achievements are putting forward new demands for the standard system and revision.

(3) Structure of monitoring method standards need to be standardized and unified

Monitoring methods of marine environmental protection include the single/similar element analysis standards and the comprehensive monitoring method standards. This structure is prone to reducing the use frequency of the standard. Taking the comprehensive standard, *Specification for marine monitoring* (GB 17378-2007), as an example, it covers more than 100 methods, and is widely used as the basic technical document for national marine environment monitoring. However, the single/similar element analysis standards are restricted due to various factors and used in a small range. Therefore, it is urgent to normalize the standard’s style and structure.

(4) New technology standard system needs to be established

New ideas and new technology are important for marine standardization, and they are also important means to promote the development of marine environmental management in China. Under the guidance of the ecological civilization theory, the comprehensive governance and control measures for marine ecology and environment are constantly proposed and gradually implemented, such as marine ecological red line, monitoring and early warning of marine resources and environmental carrying capacity, marine environment real-time online monitoring system. However, the relevant standardization work that provides technical support is just beginning, and the support capability of the standard system is weak. For example, the standards for monitoring of sources of pollution into the sea (rivers in the sea, drain outlets in the land, activities at sea and the atmospheric deposition at sea) are being revised; standards for emerging environmental issues such as marine microplastics and ocean acidification are still at an exploratory stage; comprehensive technologies such as real-time on-line monitoring, total pollution load control, and monitoring and early warning of marine resources and environmental carrying capacity have been continuously developing, and corresponding standard methods and systems need to be established.

(5) Multidisciplinary standards with other industry standards to be coordinated

Interdisciplinary integration is a creative method to solve problems for modern science and technology, which reflects the dialectics of wide connection and development. Marine environmental protection covers many disciplines, such as marine chemistry, marine ecology, ecological toxicology and marine disaster science. Scientific research and technological methods have obvious intersections and correlations among different disciplines. Marine ecological red line, monitoring and early warning of marine resources and environmental carrying capacity, and total pollution load control accord with the features of interdisciplinary integration, which is an inevitable embodiment of the integration of the development of oceanography, ecology and geography. Multidisciplinary integration also puts forward higher requirements for standardization. To carry out the standardization smoothly, cooperation and coordination need to be strengthened among various technical committees on marine environmental protection, marine biological resources development and protection, coastal wetlands and marine investigation techniques and methods. In addition, since there is overlap among the standards of marine environmental protection, terrestrial environmental protection and fishery, the connection between various standards should be taken into account in carrying out their standardization.

1.1.5 Guidelines on target pollutants monitoring

1.1.5.1 Nutrients

Since the beginning of the 20th century, nutrient in seawater has been an important research content of chemical oceanography. Strictly speaking, many major components and trace metals in seawater are also nutrients; however, only phosphate, nitrate, nitrite, ammonium salt and silicate are traditionally identified as nutrients in chemical oceanography. Nutrients are essential for the growth and reproduction of phytoplankton in the ocean and form the basis of primary marine productivity and food chains. Nutrient is the most important monitoring index in marine environmental research and monitoring of China. Up to now, a variety of analytical methods based on different principles have been developed to detect and analyze different forms of nutrients in marine environments. These methods have their own advantages and disadvantages. Along with the development of science and technology, they have also been constantly improved and matured, and gradually developed from the original manual detection to instrument detection and automatic detection, as well as the detection accuracy and precision improved continuously.

Table 1 and

Table 2 list the adopted monitoring guidelines in China's marine environmental monitoring for various forms of nutrients in seawater and sediment, respectively. It should be noted that there are several analytical methods for a specific nutrient. Considering these technical guidelines are national or industry standards that are officially approved, agencies can select an appropriate method as an adopted monitoring guideline according to specific situations and conditions.

Table 1. List of monitoring guidelines of China for nutrients in seawater.

Pollutants	Method	Standard No.
Nitrate	Cadmium column reduction method	GB 17378.4-2007
	Zinc-cadmium reduction method	GB 17378.4-2007
	Cadmium copper column reduction method	GB/T 12763.4-2007
	Zinc-cadmium reduction method	GB/T 12763.4-2007
	Continuous flow analytical method	HY/T 147.1-2013
	Portable spectrography	HY/T 147.1-2013
	Gas phase molecular absorption spectroscopy	HJ/T 198-2005
Nitrite	N-(1-naphthyl)ethylene diamine spectrophotometry	GB 17378.4-2007
	Continuous flow analytical method	HY/T 147.1-2013
	Portable spectrography	HY/T 147.1-2013
	Diazo - azo method	GB/T 12763.4-2007
	Gas phase molecular absorption spectroscopy	HJ/T 197-2005
Ammonia	Indophenol blue photometric method	GB 17378.4-2007
	Hypobromite oxidation method	GB 17378.4-2007
	Sodium hypobromite oxidation method	GB/T 12763.4-2007

Pollutants	Method	Standard No.
	Indophenol blue method	GB/T 12763.4-2007
	Continuous flow analytical method	HY/T 147.1-2013
	Portable spectrography	HY/T 147.1-2013
	Gas phase molecular absorption spectroscopy	HJ/T 195-2005
Phosphate	Phosphomolybdenum blue spectrophotometric method	GB 17378.4-2007
	Phosphomolybdenum blue extraction spectrophotometric method	GB 17378.4-2007
	Continuous flow analytical method	HY/T 147.1-2013
	Portable spectrography	HY/T 147.1-2013
	Ascorbic acid reduction phosphorus molybdenum blue method	GB/T 12763.4-2007
Silicate	Silicon molybdenum blue method	GB17378.4-2007
	Silicon molybdenum yellow method	GB17378.4-2007
	Silicon molybdenum blue method	GB/T 12763.4-2007
	Silicon molybdenum yellow method	GB/T 12763.4-2007
	Continuous flow analytical method	HY/T 147.1-2013
Total Phosphorus	Potassium persulfate oxidation method	GB 17378.4-2007
	Potassium persulfate oxidation method	GB/T 12763.4-2007
	Continuous flow analytical method	HY/T 147.1-2013
Total Nitrogen	Potassium persulfate oxidation method	GB 17378.4-2007
	Potassium persulfate oxidation method	GB/T 12763.4-2007
	Continuous flow analytical method	HY/T 147.1-2013

Table 2. List of monitoring guidelines of China for nutrients in sediment.

Pollutants	Method	Standard No.
Total Phosphorus	Kjeldahl method	GB 17378.5-2007
	Potassium persulfate oxidation method	HJ 442-2008
Total Nitrogen	Spectrophotometric method	GB 17378.5-2007
	Potassium persulfate oxidation method	HJ 442-2008

1.1.5.2 Legacy/new POPs

Persistent organic pollutants (POPs) are organic compounds that are toxic and resistant to environmental degradation through chemical, biological, and photolytic processes. Because of their persistence, POPs bioaccumulate with potential adverse impacts on humans and the environment. Given the adverse impacts of POPs on human health and ecological environment, the *Stockholm Convention on Persistent Organic Pollutants* (hereinafter referred to as *Stockholm Convention*) was concluded by the international community in 2001 to eliminate or severely restrict their production and consumption. In general, POPs listed in the *Stockholm Convention* are called legacy POPs, and new POPs are those organic pollutants with properties similar with POPs but not listed in the *Stockholm Convention*. Many POPs are used, currently and in the past, as pesticides, solvents, pharmaceuticals and industrial chemicals. Although some POPs arise naturally, for example, volcanoes and various biosynthetic pathways, most are man-made via synthesis.

In the current seawater, marine sediment and marine biological quality standards of China, only a limited number of POPs are involved. These are DDT, hexachlorocyclohexane (HCHs) and benzo(a)pyrene (BaP) in seawater quality standard; DDT, HCHs and polychlorinated biphenyls (PCBs) in marine sediment quality standard; and DDT and HCHs in marine biological quality standard. As a result, the target POPs of national marine environmental monitoring are limited to the abovementioned pollutants. However, considering the potential inverse impacts and future monitoring demand, China is pushing to step up efforts to make and revise the monitoring standards for POPs in the marine environment. The existing monitoring standards for legacy/new POPs in various environmental media are presented in Annexed Tables 1-4.

1.1.5.3 Heavy metals

Sources of the heavy metals in the sea are both natural and anthropogenic. Natural sources include crustal rock weathering, undersea volcanic eruptions, and land soil erosion which inject large amounts of heavy metals into the sea through rivers or atmosphere, their levels can be considered as the background value of heavy metals in the sea. Marine heavy metal pollution refers to the pollution caused by human activities that introduce heavy metals into the marine environments. In general, heavy metal elements in the sea mainly include mercury, cadmium, lead, arsenic, zinc, nickel, chromium and copper. Heavy metal pollution is one of the most important concerns in marine environmental monitoring. At present, different analysis methods of heavy metals have been developed, and they are relatively mature too. However, the analysis of heavy metals is also one of difficulties in marine environmental monitoring because of its very low concentrations and vulnerability to contamination. The environmental requirements of the laboratory for heavy metal analysis are very high. To meet the demand of quality control for heavy metal analysis, the ultraclean laboratory is necessary.

The monitoring guidelines listed in national or industrial standards for heavy metals in marine environments are presented in Annexed Tables 1-4.

1.1.5.4 Emerging contaminants

New analytical capabilities have allowed scientists to identify chemicals in the environment in extremely small concentrations. Emerging contaminants (ECs) are those chemicals that recently have been shown to occur widely in environments, they are not new pollutants, they have been existing or in mass production and use for a long time, but there has been no corresponding legal supervision or regulation is imperfect. ECs are important in marine environmental monitoring because the risk they pose to human health and the environment is not yet fully understood. The list of ECs is open. In general, the components of detergents, fragrances, prescription and nonprescription drugs, disinfectants, and pesticides can be classified into ECs.

In China, ECs are out of the index lists of marine environmental quality standards, as a result, the monitoring of these ECs has not been involved in the national marine environmental monitoring yet. However, considering the inverse effects that cannot be ignored of ECs in marine environments, the monitoring guidelines for several typical pollutants of ECs have been developed and standardized. Annexed Tables 1-4 list the current monitoring guidelines for typical ECs that have been standardized.

1.2 Guidelines of the Republic of Korea

1.2.1 Laws on marine environment management of RO Korea

Laws on the early marine environment of RO Korea are a part of the land environmental legal system. In 1996, the establishment of the Ministry of Oceans and Fisheries (MOF), as a milestone of marine environmental management in RO Korea, greatly promoted the construction and improvement of the marine environmental legal system. Furthermore, as the most significant result, the Marine Pollution Prevention Act (promulgated in 1977) was repealed in 2007, and replaced by a new law, the Marine Environment Management Act, which was promulgated and enacted in January 2008. The Act became the fundament of the current marine environment management of RO Korea.

The main contents of the Act are, first of all, to formulate a comprehensive marine environment management plan every five years, including the current situation and future projects of marine environment, and submit it to the Marine Environment Management Committee; second, to give the central and local governments duties of preventing marine environment pollution/damage and restoration of damaged marine ecology and environment; third, based on the principle of “Who damages who compensates”, order responsible subjects to restore the polluted environment and bear the corresponding costs.

In the Marine Environment Management Act, the relative requirements of marine environmental monitoring are stipulated. Article 9 of the Act stipulates the marine environmental monitoring network, Article 10 stipulates the Korean standard method of examination for marine environment, Article 11 stipulates the marine environmental information networks, Article 12 stipulates the accuracy control for marine environmental measuring and analyzing institutes, and Article 13 stipulates the certification of measuring and analyzing capabilities.

Moreover, detailed requirements in the Act are put forward for marine environmental monitoring network (Article 9):

1. In order to implement comprehensive inspection of marine environment pursuant to Article 18 (1) of the Act on Conservation and Utilization of the Marine Environment, MOF shall organize marine environmental monitoring networks, as prescribed by ordinance of MOF, and monitor the marine environment on a regular basis.

2. Any Mayor/Do Governor may separately organize marine environmental monitoring networks fit for the waters under his/her jurisdiction, referring to the marine environmental monitoring networks organized by MOF pursuant to paragraph (1). In such cases, when the Mayor/Do Governor intends to organize marine environmental monitoring networks in the waters under his/her jurisdiction or change any details thereof, he/she shall give prior notice thereof to MOF.

1.2.2 Contents of the guidelines of RO Korea

In accordance with the provisions of Article 10 of the Marine Environment Management Act, MOF issued the *Guidelines for Marine Environmental Monitoring* (MOF Notice No. 2018-143, all revisions) on December 5, 2018. Furthermore, the document requires, from January 1, 2019, Minister of Oceans and Fisheries to periodic review the feasibility of the guidelines every three years until December 31, in accordance with the “Regulations regarding the appointment and management of decrees, regulations, etc.". This provision enables the contents of the guidelines to be updated promptly, adapts to the latest technological developments and requirements, and meets the needs of marine environment management to the greatest extent possible.

As a complete technical document, the *Guidelines for Marine Environmental Monitoring* issued in 2018 has four parts, each part corresponds to the monitoring guidelines of seawater, marine sediment, marine biota and marine waste, respectively. In each part, the contents of the guidelines are divided into four chapters: (1) general rules; (2) sample collection and storage; (3) statistical processing and expression method of the analysis data; and (4) analysis methods for each target items. The guidelines are aimed at defining the specification and detailed requirements for maintaining the accuracy, precision and consistency of the sampling, transportation, storage, sample treatment, analysis, data process, quality assurance and quality control in the marine environmental monitoring and assessment. All processes of marine environmental monitoring must be in compliance with the technical requirements in the guidelines. Table 3 presents the parameters and the corresponding analysis methods for seawater as an example.

Table 3. Parameters and the corresponding analysis methods for seawater in the *Specification for Marine Environmental Monitoring*.

No.	Parameter	Analysis method
1	Salinity	Salinometer
		CTD
2	Water temperature	Water thermometer method
3	pH	Glass electrode method
4	Transparency	Disk Method
5	Suspended particulate matter (SPM)	Filtration method
6	Dissolved oxygen (DO)	Iodometric method
		Membrane electrode method
7	Sulfide	Methylene blue spectrophotometric method
8	Chemical oxygen demand	Potassium iodide alkaline Permanganate method
9	Dissolved organic carbon (DOC)	Combustion oxidation nondispersive infrared absorption method
10	Nitrite	N-(1-naphthyl)ethylene diamine dihydrochloride spectrophotometry
		Continuous flow analysis
11	Nitrate	Cadmium column reduction method
		Continuous flow analysis
12	Ammonia	Indophenol blue spectrophotometry
		Continuous flow analysis

No.	Parameter	Analysis method
13	Total nitrogen	Potassium persulfate oxidation spectrophotometry
		Continuous flow analysis
14	Dissolved total nitrogen	Cadmium column reduction method
15	Phosphate	Phosphomolybdenum blue spectrophotometry
		Continuous flow analysis
16	Total phosphorus	Potassium persulfate oxidation spectrophotometry
		Continuous flow analysis
17	Dissolved total phosphorus	Potassium persulfate oxidation spectrophotometry
18	Reactive silicate	Silicon molybdenum blue spectrophotometry
		Continuous flow analysis
19	Cyanide (CN)	Isonicotinic acid-pyrazolone spectrophotometry
20	Fluorine (F)	Fluorine reagents spectrophotometry
21	Cu, Pb, Ni, Zn, Cd, Co, Cr^{6+}, Cr	Graphite Furnace Atomic Absorption Spectro-photometry (GF-AAS)
		Inductively coupled plasma mass spectrometry (ICP-MS)
29	As	Hydride generation atomic absorption spectrophotometry
30	Hg	Cold atomic fluorescent spectrophotometry
		Cold atomic absorption spectrophotometry
31	Methyl mercury	Gas chromatography (GC) - electron capture detector (ECD)
32	Phenol	4-aminoantipyrine spectrophotometry
33	Organophosphorus pesticide	Gas chromatography (GC) - nitrogen phosphorus detector (NPD) or flame photometric detector (FPD)
		Gas chromatography-mass spectrometry (GC-MS)
34	PCBs	Gas chromatography (GC) - electron capture detector (ECD)
35	Organotin	Gas chromatography (GC) - flame photometric detector (FPD)
36	Anionic Surfactants (ABS)	Methylene blue spectrophotometry
37	Volatile organic compounds	Gas chromatography-mass spectrometry (GC-MS)
38	Oil	Fluorescence spectrophotometry
39	Identification of spilled oil	Gas chromatography-flame ionization detector (FID)
		Gas chromatography-mass spectrometry (GC-MS)
		Fluorescent spectrophotometry
		Infrared spectrometry
40	Sulfur compound spilled	Gas chromatography (GC) - flame photometric detector (FPD)
41	Nickel in spilled oil	Graphite Furnace Atomic Absorption Spectro-photometry (GF-AAS)
		Inductively coupled plasma mass spectrometry (ICP-MS)
		Inductively coupled plasma-optical emission spectroscopy (ICP-OES)
42	Vanadium in spilled oil	Inductively coupled plasma mass spectrometry (ICP-MS)
		Inductively coupled plasma-optical emission spectroscopy (ICP-OES)
43	PBDEs	Gas chromatography-mass spectrometry (GC-MS)-negative chemical ionization (NCI)

1.3 Comparison of guidelines between China and RO Korea

Similarities and differences are obvious on the marine environmental monitoring guidelines between China and RO Korea. The main similarity is that the guidelines cover the detailed technical requirements for the whole monitoring process from sampler preparation, sampling, transportation, storage, analysis, quality control to data processing. And these basic technical requirements are relatively consistent in China and RO Korea. Moreover, for most target items, several same monitoring methods are listed in the guidelines of both countries. Annexed Table 5 presents the comparison of monitoring methods of the target monitoring items, among which those in ***bold italics*** are the consistent monitoring methods of both countries.

The differences are mainly reflected in the operation mechanism of the monitoring guidelines.

In general, the guidelines of China consists of different parts: general rules, sampling, transportation, storage, data processing, quality control, and sample analysis, etc. The guideline of monitoring (sample analysis) methods for target items are scattered in different guideline documents, and there are several different analysis methods for most target items. In marine environmental monitoring, one of these analysis methods are selected for implementation according to the specific situation of the laboratory.

In Korea, the Ministry of Oceans and Fisheries (MOF) regularly issues the updated *Guidelines for Marine Environmental Monitoring* before the monitoring. For example, the latest guideline document was issued on December 5, 2018 as MOF Notice No. 2018-143. According to the monitoring tasks and target items, 1-2 monitoring methods are proposed for each item, and other monitoring methods not included in the issued document are not recommended. Most importantly, MOF is required to periodically conduct a review every three years, and update the monitoring methods to meet new technology development and marine environment management needs.

2. Marine environmental quality standards

2.1 Marine environmental quality standards of China

Environmental quality standard refers to the technical regulation of the allowable concentrations of hazardous substances or factors in the environment within a range of time and space. It reflects the comprehensive requirements of the population and ecosystem on environmental quality, as well as the technical possibility and economic affordability of society to control pollution. It is the target value of environmental protection, the basis for the establishment of pollutant emission standards, and the judgment criterion for the assessment of whether pollutant emissions meet the standards. The standard is the concrete embodiment of national environmental policy objectives and an important means of environmental management.

Marine environmental quality standards are the maximum allowable limit for seawater pollution in designated protected areas in accordance with the provisions for the use of seawater for the protection of human health, the safety of marine natural resources and their utilization. The standards are one of the law enforcement measures of marine environmental protection laws and regulations, and they are legally binding. It is the criterion to judge whether the sea is polluted, planning management and the formulation of marine pollutant emission standards.

In China, there are three marine environmental quality standards: seawater quality standard, marine sediment quality standard, and marine biological quality standard. They are the foundation for national or local marine administrative departments to manage the marine environment. Marine environmental protection objectives, inspection and assessment of the marine environmental status are made in accordance with marine environmental quality. The three quality standards of China have been implemented for more than 10 years. The gap is getting bigger between standards and the needs of marine eco-environment management. Taking the seawater quality standard as an example, although there is a total of 35 target items, the limit values of several “getting concerned” pollutants are lacking, such as polycyclic aromatic hydrocarbons, polychlorinated biphenyls, fluorides, nitrates, nitrites, and ammonia nitrogen. Some limit values of pollutants are quite different from international standards or advanced foreign standards. Thus, it is urgent to revise marine environmental quality standards to meet the needs of marine eco-environment management.

2.1.1 Seawater quality standard

2.1.1.1 Overview of the standard

The *Seawater quality standard* (GB 3097-1997) is the current standard of China. It is developed based mainly on the international research achievements on seawater quality criterions. The standard stipulates seawater quality requirements for various functions and applies to all sea areas under China's national sovereignty, as well as the standard stipulates the collection, storage, transportation and pretreatment of seawater samples in accordance with the relevant provisions of specific technical guidelines.

In China, *Fishery water quality standard* (GB 11607-1989) also covers the quality of seawater. The standard is mainly aimed at protecting fishery aquatic resources and aquaculture, and preventing and controlling the harm and damage of water pollution to aquatic resources. It is applicable to fish and shrimp spawning grounds, rodent farms, wintering grounds, migration channels and aquaculture areas of fishing waters including seawater and freshwater.

Compared with the *Seawater quality standard*, the *Fisheries water quality standard* is equivalent to the marine fishery waters in Category I and the mariculture areas in category II of *Seawater water quality standard*. In terms of indicators and index values, both standards are basically similar. The reasons for the differences between them are mainly due to the different purposes of the two standards. The *Seawater quality standard* is a comprehensive standard, while the *Fishery water quality standard* is a single standard, which is established only to protect the quality of fishery products. This is reflected in the facts that the *Fishery water quality standard* focuses more on toxic and harmful substances, while the *Seawater quality standard* focuses on a broader range, such as nutrients, anionic surfactants and radionuclides.

The application field of both *Seawater quality standard* and *Fishery water quality standard* is clear. The *Seawater quality standard* divides the seawater quality into four categories according to the different use and protection objectives of the target sea area, and stipulates the water quality requirements for various use functions of the sea area respectively. While the *Fishery water quality standard* has an obvious target objective: fishery industry. The relationship between them is complementary and mutually reinforcing. The *Seawater quality standard* can be applied to assess the seawater quality, the *Fishery water quality standard* is adopted for the assessment of marine fishery water quality. In the absence of a specific index in the *Fishery water quality standard*, the corresponding classification in the *Seawater quality standard* can be adopted according to the respective characteristics.

2.1.1.2 Classification of seawater quality

According to different use and protection objectives of the target sea area, the seawater quality is sorted into four categories:

Category I: Applicable to marine fishery waters, marine nature reserves, and rare and endangered marine life reserves.

Category II: Applicable to mariculture area, seaside resort, recreational area where human body is directly in contact with seawater, and industrial water supply area directly related to human food.

Category III: Applicable to general industrial water supply area, coastal scenery tourist area.

Category IV: Applicable to marine port waters, marine development and operation area.

2.1.1.3 Index and limit values

The index and their limit values for various categories are listed in Table 4.

Table 4. Seawater quality standard (mg/L) (GB 3097-1997).

No.	Item	Category I	Category II	Category III	Category IV
1	Floatable substance	No oil film, foam and other floating substances on the sea surface			no obvious oil film, floating foam and other f floating substances on the sea surface
2	Color, stink, odor	No different color, stink, odor			No disgusting or unpleasant color, stink, odor
3	Suspended substance	Artificially increased quantity ≤ 10		Artificially increased quantity ≤ 100	Artificially increased quantity ≤ 150
4	Escherichia coli ≤ (number/L)	10,000 water of shellfish culture and proliferation of for human food ≤ 700			—
5	Fecal coliform ≤ (number/L)	2,000 water of shellfish culture and proliferation of for human food ≤ 140			—
6	Pathogen	No pathogens in water of shellfish culture and proliferation of for human food			
7	Human-induced sea water temperature rise	≤ 1°C (summer) ≤ 2°C (other seasons)		≤ 4°C	
8	pH	7.8 ~ 8.5 not exceed 0.2 pH units within the normal range of variation in the sea area		6.8 ~ 8.8 not exceed 0.2 pH units within the normal range of variation in the sea area	
9	Dissolved Oxygen (DO) >	6	5	4	3
10	Chemical oxygen demand (COD) ≤	2	3	4	5
11	Biochemical oxygen demand (BOD5) ≤	1	3	4	5
12	Inorganic nitrogen ≤ (measured in N)	0.20	0.30	0.40	0.50
13	Non-ionic ammonia ≤ (measured in N)	0.020			
14	Labile phosphate ≤ (measured in N)	0.015	0.030		0.045
15	Mercury (Hg) ≤	0.00005	0.0002		0.0005
16	Cadmium (Cd) ≤	0.001	0.005	0.010	
17	Lead (Pb) ≤	0.001	0.005	0.010	0.050

No.	Item		Category I	Category II	Category III	Category IV
18	Cr VI (chromium VI) ≤		0.005	0.010	0.020	0.050
19	Total chromium ≤		0.05	0.10	0.20	0.50
20	Arsenic (As) ≤		0.020	0.030	0.050	
21	Copper (Cu) ≤		0.005	0.010	0.050	
22	Zinc (Zn) ≤		0.020	0.050	0.10	0.50
23	Selenium (Se) ≤		0.010	0.020		0.050
24	Nickel (Ni) ≤		0.005	0.010	0.020	0.050
25	Cyanide ≤		0.005		0.10	0.20
26	Sulfide ≤ (measured in S)		0.02	0.05	0.10	0.25
27	Volatile Phenols ≤		0.005		0.010	0.050
28	Oils ≤		0.05		0.30	0.50
29	Hexachlorocyclohexane (HCH) ≤		0.001	0.002	0.003	0.005
30	DDT ≤		0.00005	0.0001		
31	Malathion ≤		0.0005	0.001		
32	Parathion-methyl ≤		0.0005	0.001		
33	Benzo(a)pyrene ≤ (μg/L)		0.0025			
34	Anionic surfactant (measured in LAS)		0.03	0.10		
35	Radionuclide (Bq/L)	^{60}Co	0.03			
		^{90}Sr	4			
		^{106}Ru	0.2			
		^{134}Cs	0.6			
		^{137}Cs	0.7			

2.1.2 Marine sediment quality standard

2.1.2.1 Overview of the standard

The current standard for marine sediment quality of China is the *Marine sediment quality standard* (GB 18668-2002). The standard is formulated for the purpose of preventing and controlling marine sediment pollution, protecting marine living resources and other marine resources, promoting sustainable utilization of marine resources, maintaining marine ecological balance and safeguarding human health. It stipulates marine sediment quality requirements for various functions and applies to all sea areas under China's national sovereignty. This standard is a basic component of the national marine environmental quality standards and an important technical regulation in marine environmental protection and supervision in China.

2.1.2.2 Classification of marine sediment quality

According to different use and protection objectives of the target sea area, the marine sediment quality is sorted into three categories:

Category I: Applicable to marine fishery waters, marine nature reserves, rare and endangered marine life reserves, mariculture area, seaside resort, recreational area where human body is directly in contact with sediment, and industrial water supply area directly related to human food.

Category II: Applicable to general industrial water supply area, coastal scenery tourist area.

Category III: Applicable to marine port waters, marine development and operation area.

2.1.2.3 Index and limit values

The index and their limit values for various categories are listed in
Table 5.

2.1.3 Marine biological quality standard

2.1.3.1 Classification of marine biological quality

The current standard for marine biological quality of China is *Marine biological quality standard* (GB 18421-2001). The standard takes marine shellfish (bivalves) as environmental monitoring organism and stipulates the quality requirements of marine lives for various functions and applies to all sea areas under China's national sovereignty. It can be used in conjunction with the *Seawater quality standard* (GB 3097-1997) for assessment of marine environmental quality.

According to different use and protection objectives of the target sea area, the marine biological quality is sorted into three categories:

Category I: Applicable to marine fishery waters, mariculture area, marine nature reserves, and industrial water supply area directly related to human food.

Category II: Applicable to general industrial water supply area, coastal scenery tourist area.

Category III: Applicable to marine port waters, marine development and operation area.

Table 5. Marine sediment quality standard.

No.	Item	Category I	Category II	Category III
1	Waste and other	No industrial waste, living waste, large plant debris and animal carcasses		No obvious industrial waste, living waste, large plant debris and animal carcasses
2	Color, stink, structure	No different color, stink, odor		—
3	Coliform (number/g (wet weight)) ≤	200[1,2)]		—
4	Fecal coliform (number/g (wet weight)) ≤	40[3)]		—
5	Pathogen	No pathogens in sediment of shellfish culture and proliferation of for human food		—
6	Mercury (Hg) ($\times 10^{-6}$) ≤	0.20	0.50	1.00
7	Cadmium (Cd) ($\times 10^{-6}$) ≤	0.50	1.50	5.00
8	Lead (Pb) ($\times 10^{-6}$) ≤	60.0	130.0	250.0
9	Zinc (Zn) ($\times 10^{-6}$) ≤	150.0	350.0	600.0
10	Copper (Cu) ($\times 10^{-6}$) ≤	35.0	100.0	200.0
11	Chromium (Cr) ($\times 10^{-6}$) ≤	80.0	150.0	270.0
12	Arsenic (As) ($\times 10^{-6}$) ≤	20.0	65.0	93.0
13	Total organic carbon (TOC) ($\times 10^{-2}$) ≤	2.0	3.0	4.0
14	Sulfide ($\times 10^{-6}$) ≤	300.0	500.0	600.0
15	Oil ($\times 10^{-6}$) ≤	500.0	1000.0	1500.0
16	Hexachlorocyclohexane (HCH) ($\times 10^{-6}$) ≤	0.50	1.00	1.50
17	DDT ($\times 10^{-6}$) ≤	0.02	0.05	0.10
18	polychlorinated biphenyls (PCBs) ($\times 10^{-6}$) ≤	0.02	0.20	0.60

1. Except coliform, fecal coliform and pathogen, other items are measured by dry weight.
2. Sediment of shellfish culture and proliferation of for human food, number of coliform (number/g (wet weight)) ⩽ 14.
3. Sediment of shellfish culture and proliferation of for human food, fecal coliform (number/g (wet weight)) ⩽ 3.

2.1.3.2 Index and limit values

The index and their limit values for various categories are listed in Table 6. The index and limit values are applicable to naturally grown or cultured marine shellfish.

Table 6. Marine biological quality standard (mg/kg fresh weight).

No.	Item	Category I	Category II	Category III
1	Sensory requirements	Growth and activity of shellfish is normal, the shell should not be stained with oil or other foreign matter, no different color, stink, odor		Shellfish can survive, there are no obvious color, stink, odor
2	Fecal coliform (number/kg) ≤	3000	5000	—
3	paralytic shellfish poison (PSP)	0.8		
4	Total mercury ≤	0.05	0.10	0.30
5	Cadmium (Cd) ≤	0.2	2.0	5.0
6	Lead (Pb) ≤	0.1	2.0	6.0
7	Zinc (Zn) ≤	20	50	100 (oyster: 500)
8	Copper (Cu) ≤	10	25	50 (oyster: 100)
9	Chromium (Cr) ≤	0.5	2.0	6.0
10	Arsenic (As) ≤	1.0	5.0	8.0
11	Oil ≤	15	50	80
12	Hexachlorocyclohexane (HCH) ≤	0.02	0.15	0.50
13	DDT ≤	0.01	0.10	0.50
1. Measured in fresh weight of shellfish without the shell. 2. HCH content is the sum of four isomers. 3. DDT content is the sum of four isomers.				

2.1.4 Development of the marine quality standard

As mandatory national standards, the three marine quality standards (for *seawater, marine sediment* and *marine biological quality*) form the national marine environmental quality system, which provides a scientific basis for marine pollution prevention and control, as well as an important technical specification of marine environmental protection and supervision in China.

In recent years, the major changes occurred in the marine environmental status of China. Now, China's marine eco-environmental management is facing severe challenges, such as high pollution pressure, serious pollution of specific sea areas, emerging contaminants constant appearance. Moreover, several new environmental management regulations were implemented step by step, such as the land and sea coordinated marine pollution prevention and control system, the total amount control of pollutants discharge in key sea areas, the red line of ecology. At the same time, the research on marine environmental criteria is getting more and more achievements. Under the new situation, the marine environmental quality standard system of China needs to be continuously developed and improved based on the existing standards revision, standard system improvement, and formulation of zoning quality standards.

2.1.4.1 Revision of existing standards in time

The standard quality is reflected in the technical contents and its form. The easiest way to measure the standard quality is to see whether the standard has good adaptability and operability. Standards are formulated on the premise of certain experiences and cognition, as a result, certain limitation is inevitable. If the standards are not revised in time, the contents of the standards will not keep up with the pace of management requirements and the development of science and technology, or even restrict and hinder the development of specific industry, and become their shackles, completely losing the existence significance of standards.

The three marine environmental quality standards are the products under certain historical conditions and scientific research level. They are the integration of practicality and science, but are not perfect and can be used forever. *Seawater quality standard* (1997) was revised more than 20 years ago. *Marine sediment quality standard* (2002) and *Marine biological quality standard* (2002) have been more than 15 years before present. They are far behind the current situation of social and technical demands.

(1) Limit values need to be improved. At present, China lacks an integrated standard — "environmental quality criteria standard" to scientifically and quantitatively stipulate the type and degree of pollutant hazard effect. The current standard can only judge whether the environmental quality meets the requirements of different quality levels and environmental functions. This simple qualitative judgment is hard to scientifically and quantitatively describe and explain the harm of pollution to the environment, ecology and human health.

(2) The index can't meet the pollution control demand under the new situation. Emerging pollutants are getting more and more concerns. These pollutants have existed in the environment for a long time, but corresponding assessment and management standards lack. The implementation of marine environmental management needs to be combined with these new forms of pollution, which is also inseparable from the study of marine environmental criteria.

(3) Lack of regional or local quality standards. From the ecological point of view, different sea areas have different biological floras. The level of harmless toxicant to one biological flora may have irreversible toxic effects on other biological flora. However, the marine quality standards for regional or local sea areas are missing or scattered.

2.1.4.2 Improvement of the quality standard system

On the whole, China's marine environmental quality standard system is still not perfect. There is still considerable room for improvement in terms of standard formulation principle, classification, index selection and sea area function. Therefore, in the future it is necessary to further improve the quality standard system composed of reference materials, environmental criteria and environmental quality standards.

(1) Establish the marine reference material system. The future development of marine reference material need be based on the requirements of the national marine pollution prevention and control and the principle of complete set, and design the framework structure of China’s marine reference material system combining the specific coastal pollution condition of China.

(2) Carry out the research on marine environmental criteria. Future marine environmental quality standards will inevitably contain more pollutants with stricter limit thresholds. More precise regionalization and rigorous system could also be expected. To achieve the goals of national marine environmental management, more achievements on the research on the marine environmental criteria and quality standards are needed to make China's marine environmental quality standards not only conform to the national conditions, but also keep up with the development of international criteria and quality standards research.

2.1.4.3 Establishment of the quality standards by zoning

In the implementation of quality standards along China's long coastline, there is no distinction between offshore and offshore, urban and township contiguous areas, sensitive areas and non-sensitive areas. The standards has become a ruler that can be applied to various environmental conditions without taking into account the differences and impacts among various fishing waters, biochemistry, ecological system, pollutant sources, loads and residence time, and other factors. As a result, the conclusion of pollution or non-pollution may be inconsistent with the actual situation if simply using the current quality standards to assess these sea areas. Therefore, it is the future objective to establish China’s marine environmental quality standards by zoning based on the natural attributes of various sea areas. In addition, under the management objectives of ecological integrity and sustainable development, it should continue to extend the existing standards from seawater, biology and sediment to the aspects of hydrochemistry, sediment, biology, habitat and toxic substances, and gradually establish regional quality standards system.

2.2 Marine environmental quality standards of RO Korea

2.2.1 Framework for seawater quality standards

The basic law for the environmental management policy of RO Korea is the Framework Act on Environmental Policy, under which water quality standards are established. The major objectives of water environmental management under the Water Quality and Ecosystem Conservation Act are the protection of people’s health and the environment, as well as the preservation of clean water and aquatic ecosystems.

Figure 5 shows the law system chart related to water environmental management of Korea.

Seawater quality standards of Korea is an integral part of their water quality standard system, which is consistent with the structure of the water quality standard system, but with different contents.

There are two kinds of seawater quality standards, the first is standards for protecting human health, and the second is standards for conservation of the living environment. The number of parameters has increased in response to concerns over hazardous chemicals.

The standards for protecting human health concern mainly on the pollutants closely related to human health, including typical heavy metals, organic pollutants, etc., which are not graded for seawater quality and require the concentration of the target pollutants in the seawater to be lower than the limit values. The standards for conservation of the living environment concern mainly on the items that may have an impact on aquatic organisms. The standards are divided into three categories (Category I, II, and III) according to the limit values.

Figure 5. Law system chart for water quality management (source: WEPA, Outlook on water environmental management in Asia 2018).

2.2.2 Seawater quality standards

In order to carry out marine environmental management, RO Korea issued the seawater quality standards in 1998. In accordance with the provisions of Article 8 of the Marine Environment Management Act, the notice No. 2018-10 (2018.1.23, partial revisions) of Ministry of Oceans and Fisheries issued the revised seawater quality standards.

Seawater (coastal water) quality standard for protecting human health consist 19 parameters including trace metals, organic pollutants, anionic surfactants, etc. The specific parameters and their limit values are listed in Table 7.

Seawater quality standard for conservation of the living environment are divided into three classes: Class I, Ⅱ and Ⅲ, each of which correspond to different water quality requirements, respectively. The eight (8) parameters include: pH; chemical oxygen demand (COD); dissolved oxygen (DO); suspended solid (SS), total Coliform, oil, total nitrogen (TN) and total phosphorus (TP). The parameters and their limit values for different class are listed in Table 8.

Table 7. Seawater (coastal water) quality standards for protecting human health

Parameter	Standard value (mg/L)
Cr^{6+}	0.05 or less
As	0.05 or less
Cd	0.01 or less
Pb	0.05 or less
Zn	0.1 or less
Cu	0.02 or less
CN	0.01 or less
Hg	0.0005 or less
PCB	0.0005 or less
Diazinon	0.02 or less
Parathion	0.06 or less
Malathion	0.25 or less
1.1.1- Tritchlorothane	0.1 or less
Ethylene chloride	0.01 or less
Trichloroethyclene (TCE)	0.03 or less
Dichloromethane	0.02 or less
Benzene	0.01 or less
Phenol	0.005 or less
Anionic Surfactants (ABS)	0.5 or less

Table 8. Seawater (coastal water) quality standards for conservation of the living environment.

Class	pH	COD (mg/L)	DO (mg/L)	SS (mg/L)	Total Coliform (MPN/100 mL)	Oil (mg/L)	TN (mg/L)	TP (mg/L)
I	7.8-8.3	1 or less	95 or more	10 or less	200 or less	Not detected	0.05 or less	0.007 or less
Ⅱ	6.5-8.5	2 or less	85 or more	25 or less	1000 or less	Not detected	0.1 or less	0.015 or less
Ⅲ	6.5-8.5	4 or less	80 or more	–	–	–	0.2 or less	0.03 or less

Remarks: 1. In the situation of DO concentration, Class I refers to higher than 6 mg/L, Class II and Class III refer to higher than 5 mg/L.

2. Class I means the water quality is suitable for the habitat, breeding, spawning of aquatic organisms.

3. Class II means the water quality is suitable for sea tour leisure activities, and other living activities of aquatic organisms except for their habitat, breeding, spawning.

4. Class III means the water quality is suitable for the use of industrial water, ship's anchor and other purposes.

5. Total nitrogen refers to the sum of NO_2-N, NO_3-N and NH_3-N.

6. Total phosphorus refers to the form of PO_4-P.

2.2.2 Water quality index (WQI)

To assess the seawater quality status of a certain sea area, MOF issued the seawater quality assessment guideline. The key tool is the Water Quality Index (WQI) in the guideline. On the basis of three basic items and eight heavy metal items, WQI is calculated using 5 reference items: chl-*a*, DIN, DIP, DO, and transparency. Based on the WQI values, the seawater quality is sorted to five categories: I (very good), II (good), III (typical), IV (poor) and V (very poor). In the calculation of WQI, the reference values of the five items are determined according to the five marine ecological zones, and their values are different in each ecological zone. Thus, WQI can reflect the specific seawater quality characteristics of ecological zones.

In *Annual Report on Marine Environment Monitoring in RO Korea*, the status o seawater quality for a certain sea area is described using the WQI. The assessment parameters and their limit values, WQI calculation method, WQI reference values by the different sea areas are listed in Table 9-14.

Table 9. Living environment standards.

Parameter	pH	Total E. coli group (MPN/100 mL)	Oil (mg/L)
value	6.5-8.5	Below 1000	Below 0.01

Table 10. WQI based on ecologically-based seawater quality.

Class	Water Quality Index
I (very good)	below 23
II (good)	24-33
III (typical)	34-46
IV (poor)	47-59
V (very poor)	above 60

Calculation method of Water Quality Index using seawater quality assessment index itemized score is as follows:

Water Quality Index (WQI)

= 10 × [dissolved oxygen (DO)] +6 × [(phytoplankton concentration (Chl-*a*) + transparency (SD))/2] + 4 × [(dissolved inorganic nitrogen (DIN) + dissolved inorganic phosphorus (DIP))/2]

2.2.3 Marine sediment quality standards

According to the ecological quality objectives (EcoQOs), the requirement of the marine sediment quality is “Concentrations of organic pollutants and metals in sediments should not be exceeded the sediment quality guidelines.” MOF issued the marine sediment quality standards [notice No. 2018-10 (2018.1.23, partial revisions)], and two limit values of trace metals are proposed: threshold effects level (TEL) and probable effects level (PEL) (

Table **14**). Moreover, to assess the marine sediment quality, sediment quality guideline (SQG) is proposed. Table 15 lists the marine sediment standards of organic pollutants and trace metals of RO Korea and other countries.

Table 11. Scores of water quality assessment index.

Item Score	Item	
	Chl-a (μg/L), DIN (μg/L), DIP (μg/L)	DO (saturation degree, %) transparency (m)
1	Below base value (BV)	Above base value (BV)
2	< BV + 0.10×BV	> BV - 0.10×BV
3	< BV + 0.25×BV	> BV - 0.25×BV
4	< BV + 0.50×BV	> BV - 0.50×BV
5	≥ BV + 0.50×BV	≤ BV - 0.50×BV

Remark: Per-item reference value applies the sea-specific reference value of the water quality assessment index.

Table 12. Water Quality Index reference values by the different sea areas.

Ecological zone	Chl-*a* (μg/L)	Shallow DO (saturation degree, %)	Surface layer DIN (μg/L)	Surface layer DIP (μg/L)	Transparency (m)
East Sea	2.1		140	20	8.5
Strait	6.3		220	35	2.5
Southwest sea area	3.7	90	230	25	0.5
Middle of West Sea	2.2		425	30	1.0
Jeju	1.6		165	15	8.0

Remark: Shallow is water level up to 1 m from the bottom of the seabed.

Table 13. Marine ecosystem protection standards (unit: μg/L).

Trace Metals	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr^{6+})	Mercury (Hg)	Nickel (Ni)
Short-term criteria*	3.0	7.6	34	9.4	19	200	1.8	11
Long-term standards**	1.2	1.6	11	3.4	2.2	2.8	1.0	1.8

*: Short-term criteria: comparison with once monitoring data.

**: Compared to annual average (minimum four seasons monitoring data).

Table 14. Marine sediment quality standards (unit: mg/kg).

Standards	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Threshold Effects Level (TEL)	14.5	0.75	116	20.6	0.11	47.2	44.0	68.4
Probable Effects Level (PEL)	75.5	2.72	181	64.4	0.62	80.5	119	157

Threshold Effects Level (TEL): Concentrations that are expected to have little negative ecological impact.

Probable Effects Level (PEL): Concentrations that are expected to have high likely negative ecological impact.

Table 15. Sediment quality guideline (SQG) of different countries.

Chemicals	unit	Canada		Australia		United States (NOAA)		Hong Kong		Consensus-based SQGs	
		ISQG	PEL	ISQG-Low	ISQG-High	ERL	ERM	ISQG-Low	ISQG-High	TEC	MEC
PAHs	ng/g dw	764	7071	4000	45000	3500	35000	4022	44792	1610	12205
PCBs	ng/g dw	21.5	189	23		50	400	22.7		60	368
DDTs	ng/g dw	4.48	386.58	1.6	46	3	350	1.58		4.2	33.6
CHLs	ng/g dw	2.26	4.79								
Dieldrin	ng/g dw	0.71	4.3	0.02	8	0.02	8			1.9	32
Endrin	ng/g dw	2.67	62.4	0.02	8	0.02	45			2.2	104.6
TBTs	ng Sn/g dw					60		0.15			
NPs	ng/g dw	1000									
PCDD/Fs	pg-TEQ/g dw	0.85	21.5							0.85	11.2
ΣBHC	ng/g dw									3	62
Cu	mg/kg	18.7	108	65	270	34	270	65	270		
Pb	mg/kg	30.2	112	50	220	46.7	218	75	218		
Zn	mg/kg	124	271	200	410	150	410	200	410		
Cd	mg/kg	0.7	4.2	1.5	10	1.2	9.6	1.5	9.6		
Cr	mg/kg	52.3	160	80	370	81	370	80	370		
Hg	mg/kg	0.13	0.7	0.15	1	0.15	0.71	0.28	1		
As	mg/kg	7.24	41.6	20	70	8.2	70	8.2	70		

2.3 Comparison of quality standards between China and Korea

Seawater quality standards of China and RO Korea are quite different. The differences are mainly as follows:

(1) Kind. The seawater quality standards of China do not reclassify in accordance with the regions or applicable purposes. The seawater quality standards of RO Korea consist of two kinds: one is for the protection of human health, and the other is for conservation of the living environment. The items of standards and quality assessment method are different with the different kinds of seawater quality standards.

(2) Ecological zone. Same to the kind of seawater quality standards, China keeps the standards uniform for all sea areas throughout the country. While Korea divides its all coastal areas into five (5) ecological zones: East Sea Ecological Zone, Korean Strait Ecological Zone, Southwest Sea Ecological Zone, West Sea Central Ecological Zone and Jeju Ecological Zone. Based on the specific different reference values of the five ecological zones, Water Quality Index (WQI) is calculated to assess the seawater quality status in each ecological zone.

(3) Items and their amount. The standards of China have 35 target items (see Table 4), RO Korea has 31 items (see Table 9 to

Table 13). Among them, there are 16 same items: pH, COD, DO, SS, total Coliform, oil, Cr^{6+}, As, Cd, Pb, Zn, Cu, CN, Hg, malathion, anionic surfactants.

(4) Seawater quality category. The seawater quality of China is classified in four (4) categories. In RO Korea, the seawater quality of conservation of the living environment is classified as three (3) categories, while the seawater quality of protection of human health is not classified.

(5) Limit values. The specific limit values of the same items are different, the detailed comparison of the limit values is presented in Table 16.

(6) Identification of seawater quality. Identification of seawater quality in China is based on the specific limit values, as long as any items listed in the standards exceeds the limit value of the category, it is identified to exceed the category. In RO Korea, WQI is calculated by comprehensive calculation of the five (5) items, and seawater quality category is identified according to WQI values in Table 10.

Table 16. Comparison of limit values of the same items in the seawater quality standards of Korea and Chin (unit: mg/L).

No.	RO Korea						China			
	Protecting human health		Conservation of the living environment							
	Item	Limit	Item	Category			Category			
				I	Ⅱ	Ⅲ	I	Ⅱ	Ⅲ	IV
1			pH	7.8-8.3	6.5-8.5		7.8-8.5		6.8-8.8	
2			COD	1 or less	2 or less	4 or less	2 or less	3 or less	4 or less	5 or less
3			DO	6 or more	5 or more		6 or more	5 or more	4 or more	3 or more
4			SS	10 or less	25 or less	–	Artificially increased quantity 10 or less		Artificially increased quantity 100 or less	Artificially increased quantity 150 or less
5			Total Coliform (MPN/100 mL)	200 or less	1000 or less	–	1000 or less Shellfish farming areas 70 or less			–
6			Oil	Not detected	Not detected	–	0.05 or less		0.30 or less	0.50 or less
7	Cr^{6+}	0.05 or less					0.005 or less	0.010 or less	0.020 or less	0.050 or less
8	As	0.05 or less					0.020 or less	0.030 or less	0.050 or less	
9	Cd	0.01 or less					0.001 or less	0.005 or less	0.010 or less	

No.	RO Korea						China			
	Protecting human health		Conservation of the living environment							
	Item	Limit	Item	Category			Category			
				I	Ⅱ	Ⅲ	I	Ⅱ	Ⅲ	IV
10	Pb	0.05 or less					0.001 or less	0.005 or less	0.010 or less	0.050 or less
11	Zn	0.1 or less					0.020 or less	0.050 or less	0.10 or less	0.50 or less
12	Cu	0.02 or less					0.005 or less	0.010 or less	0.050 or less	
13	CN	0.01 or less					0.005 or less	0.005 or less	0.10 or less	0.20 or less
14	Hg	0.0005 or less					0.00005 or less	0.0002 or less	0.0002 or less	0.0005 or less
15	Malathion	0.25 or less					0.0005 or less	0.001 or less		
16	Anionic surfactants (ABS)	0.5 or less					0.03 or less	0.10 or less		

3. Marine environmental monitoring networks

3.1 Marine environmental monitoring networks of China

3.1.1 Monitoring system of China

There are four seas in China: the Bohai Sea; the Yellow Sea; the East China Sea; and the South China Sea. They belong to three administrative sea areas: north sea area (include the Bohai Sea and the north Yellow Sea), east sea area (include the south Yellow Sea and the East China Sea), and south sea area (the South China Sea).

In China, there are two marine environmental monitoring systems: the national system and the local system.

The ***national*** marine environmental monitoring system has four (4) levels: the national monitoring center; the sea area monitoring center; the monitoring central station; and the monitoring station. Currently, there are: (a) one (1) national marine environmental monitoring center; (b) three (3) sea area environmental monitoring centers (hereinafter referred to as the "sea area center"); (c) 16 marine environmental monitoring central stations (hereinafter referred to as the "central station"); and (d) 78 marine environmental monitoring stations (excluding unattended ocean station, hereinafter referred to as the "ocean station"). This system is directly managed by the State Oceanic Administration of China (Figure 6).

The ***local*** marine environmental monitoring system is composed of three-level teams: provincial-level, regional-level and county-level teams. To date, the local system includes 11 provincial-level and 44 municipal-level marine environmental monitoring centers, and 79 county-level marine environmental monitoring stations. The local system is managed and financial supported by the local government.

The national and local teams jointly undertake the marine environmental monitoring tasks. In general, the monitoring tasks beyond 12 nautical miles (NM) offshore are undertaken by the national teams; and tasks within 12 nm offshore by both national and local teams according to the types of monitoring site or monitoring task. Generally, the monitoring of national controlling sites is carried out by the national teams, while other monitoring sites (most are within 12 NM offshore) are charged by the local teams.

Reconstruction of marine ecology and environment monitoring system of China in the new era

In 2018, China launched a new round of national and local institutional reforms. According to the institutional reform plan, the Central Government of China decided to set up the Ministry of Ecology and Environment (MEE), to integrate the responsibilities of scattered ecological and environmental protection, uniformly exercise the responsibilities of ecological and urban and rural pollution emission supervision and administrative law enforcement, strengthen environmental pollution control, protect national ecological security, and build a beautiful China.

When the new MEE was set up, and the functions of marine ecological and environmental protection were transferred from the former State Oceanic Administration (SOA) to the new MEE. According to the unified arrangement of the Central Government of China, National Marine Environment Monitoring Center (NMEMC), part of former SOA, was transferred to the new MEE. However, other monitoring agencies, such as the sea area monitoring centers and the monitoring central stations under SOA, were not transferred to MEE, and these monitoring agencies were still under SOA (SOA is a part of newly formed Ministry of Natural Resources (MNR) during this new round of institutional reform).

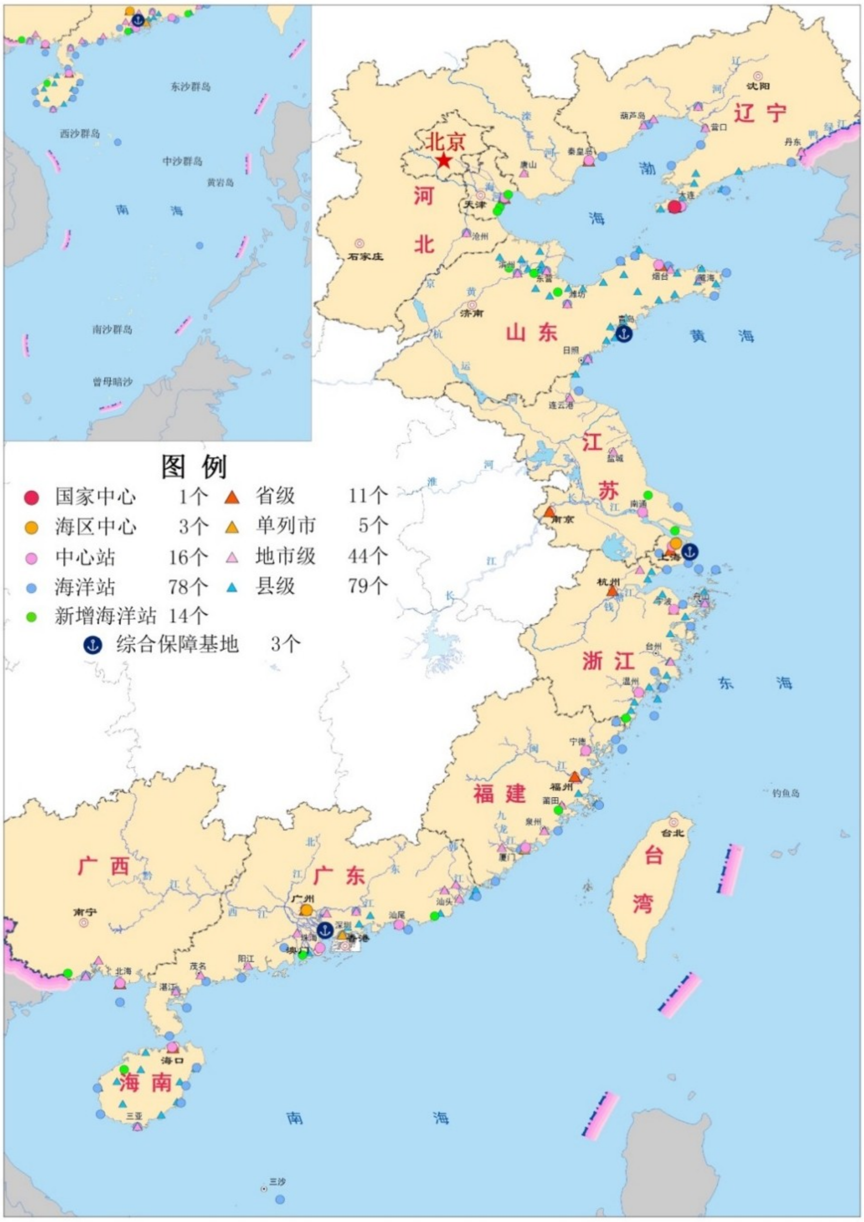


Figure 6. Marine environmental monitoring organizations and stations of China (source: NMEMC, unpublished).

To date, only one monitoring agency (NMEMC) has been transferred to MEE during this round of institutional reform. As result, the current marine ecology and environment monitoring system of China have to reconstruct. The central and local governments are currently taking various measures to rebuild marine ecology and environment monitoring stations.

The current marine ecology and environment monitoring system of China is as follows: NMEMC continues to be the national technical center, and to organize and manage the national marine ecology and environment monitoring. The specific monitoring jobs are carried out by the existing 10 marine sub-stations of MEE. The 10 marine sub-stations are: Dalian, Tianjin, Qingdao, Jiangsu, Zhoushan, Xiamen, Fujian, Shenzhen, Beihai and Hainan.

However, at present, the monitoring abilities of the 10 marine sub-stations are relatively weak, and many of the monitoring jobs are entrusted to other marine environment monitoring stations under SOA.

3.1.2 National marine eco-environmental monitoring program

National marine eco-environmental monitoring program (hereinafter referred to as the "program") is the overall design of the national marine eco-environmental monitoring work. The role of the program is to implement the relevant responsibilities of marine eco-environmental monitoring and protection according to the laws, clarify the tasks and requirements of national marine eco-environment monitoring, guide the formulation of marine eco-environment monitoring programs at different levels, and serve as the basis for supervision of their implementation. The main contents of the national program include the layout of the monitoring station, setting of monitoring item, time and frequency, task assignment and organizational management, data exchange and quality control, etc. Based on the overall requirements of the national program, the oceanic management departments of each sea area and coastal province (autonomous region, and municipality) draw up their respective monitoring programs in accordance with the local characteristics of sea area and management requirements (Table 17).

Based on marine environmental quality trend monitoring and with the guide of pressure–state–response theory, the program has been continuously expanded the optimized monitoring contents; and transformed from the traditional pollution monitoring to the comprehensive monitoring involving the pollution–ecological–functional area monitoring as the main body. Furthermore, the program gradually added several new contents, such as climate change, biodiversity, sea-gas exchange flux of CO_2, seawater intrusion and salinization, and marine radionuclide monitoring.

Under the premise of keeping the total number of monitoring sites basically stable and through the adjustment and optimization of the monitoring sites, the program formed a monitoring site layout that comprehensively covers all sea areas under the jurisdiction and focuses on the coastal waters, heavy pollution areas, typical functional areas and ecologically sensitive areas.

The program also emphasizes on the promotion and application of new and high monitoring techniques. The new techniques, such as satellite remote sensing monitoring and buoy hydrodynamic condition on-line monitoring, have been gradually introduced into the monitoring. For example, the satellite remote sensing monitoring of typical marine ecosystems, video surveillance and monitoring of important objects in marine protected areas, and multi-parameter comprehensive on-line monitoring of major sea areas have been incorporated into the program.

So far, the program framework has been formed containing five categories: marine environmental status monitoring; marine ecological status monitoring; marine environmental supervision monitoring; public service monitoring; and marine environmental and ecological risk monitoring. Table 6 presents the marine eco-environmental monitoring tasks, requirements and objectives of management support of China. Moreover, to meet the requirements of policies of marine environment real-time online monitoring and assessment of marine resources and environmental carrying capacity, the marine environment online monitoring and the marine resources and environmental carrying capacity monitoring and warning were also added into the national program. Taking the year 2014 as an example, the national program sets up a total of 8,759 monitoring sites, with a total of over 780 monitoring index, and monitoring frequency ranges from 1 time per year to 6 times per year. In some key sea areas, the seawater quality has been continuously monitored online (Figure 7).

Figure 7. Seawater monitoring sites of China (source: NMEMC, unpublished).

Table 17. Marine eco-environmental monitoring tasks, requirements and objectives of management support

Category	No.	Monitoring contents	Monitoring tasks and requirements	Objectives of management support
Marine environmental status monitoring	1	Seawater	Grasp the distribution, pollution levels and variation of main pollutants in the sea.	To accurately grasp and objectively assess the comprehensive situation of the national marine ecological and environmental quality, and to meet the requirements of the assessment of coastal water quality.
	2	Sediment	Grasp the types of marine sediment, and the distribution, pollution levels and variation of main pollutants.	
	3	Atmosphere	To evaluate the atmospheric deposition of major pollutants.	
	4	Carbon dioxide	Obtain the CO_2 partial pressure data of the sea area, and evaluate the CO_2 exchange flux and the spatial and temporal pattern at the sea-air interface.	To determine the pattern of carbon sink in the sea areas under our jurisdiction, and provide basic data for addressing climate change in the marine field.
Marine ecological status monitoring	5	Marine biodiversity	Figure out the species, quantity, distribution and changes of marine organism.	Services for marine ecological protection, rehabilitation and restoration.
	6	Typical marine ecological system	Figure out the ecological health status of the ecological monitoring area.	
	7	Integrated marine ecological monitoring demonstration	Grasp the current situation and changing trend of economic development, resource intensive utilization, ecological protection construction, and security system construction in the integrated marine ecological monitoring demonstration areas.	Provide basic data and technical support for evaluating and supervising the construction of marine ecological civilization demonstration area.
	8	Marine natural/special protection areas	Grasp the status and changes of the protected objects, habitat, and biodiversity of marine nature/special protection zones.	Provide the basis for evaluating the management effectiveness and making the management plan for the marine nature/special protection zones and coastal wetlands.
	9	Coastal wetlands	Grasp the status and changes of the natural conditions, protected objects, habitat, and biodiversity of coastal	

Category	No.	Monitoring contents	Monitoring tasks and requirements	Objectives of management support
			wetlands.	
Marine environment supervision monitoring	10	Drain outlet into the sea	Acquire the status of main sewage discharges into the sea and its impacts on the adjacent marine environment.	Monitor the discharge status of terrestrial pollutants, evaluate their impacts on the marine ecological environment, and provide support for prevention and control of pollution in coastal waters.
	11	Rivers into the sea	Acquire the types, amounts and trends of pollutants entering the sea by rivers.	
	12	Marine litter and microplastics	Acquire the types, quantity and sources of marine debris, as well as their impacts on the marine ecological environment.	
	13	Marine dumping site	Evaluate the conformity of dumping activities with the permit conditions; compliance with environmental requirements of functional areas; change of submarine topography; the ecological impact on the dumping area and the surrounding sea area; the continuous use of the dumping area and the dumping area that should be focused on.	Grasp the impacts of ocean dumping activities and marine development activities on the surrounding marine ecological environment, and provide a basis for rational planning, adjustment of the scale and layout of marine development related activities.
	14	Offshore oil exploration and development zone	Identify major pollution sources in the oil and gas region, grasp the potential impacts of the development and operation activities on the environmental quality of the surrounding sea area and other sea functions, and provide basis and effective support for the decision-making of the management department.	
	15	Marine engineering construct zone	Evaluate the status of pollutant discharge from the sea and its impacts on the marine ecological environment during the construction and operation period of marine engineering projects, and provide a basis for reasonable planning and adjustment of the scale layout of marine engineering.	
Monitoring for	16	Bathing beach	Acquire the environmental quality status of the bathing	Provides support for the protection of public

Category	No.	Monitoring contents	Monitoring tasks and requirements	Objectives of management support
public service			beach.	recreational activities and human health in coastal communities and the strengthening of environmental supervision in major mariculture areas.
	17	Coastal tourist resort	Acquire the environmental quality status of the coastal tourism resort.	
	18	Mariculture zone	Grasp the status and changing trend of environmental quality in mariculture areas, evaluate the impact of mariculture activities and the potential sustainable utilization risk.	
Environmental and ecological risk monitoring	19	Oil spill	Grasp the variation of residual and drift of spilled oil in the marine environment, and understand the medium and long-term influence of spilled oil on the quality of seawater, sediment, marine organism, ecosystem and marine functional area.	Provide the technical support for disaster management and risk assessment of oil spill, hazardous chemicals leakage and radioactive materials leakage accidents, and assess their impacts on marine environment and ecosystem.
	20	Hazardous chemicals	Acquire the residues and drift in marine environment after the hazardous chemicals leakage accident, and understand their impacts on the seawater, sediment, marine organism, ecosystem and the surrounding marine functional area.	
	21	Radionuclide	Track, monitor the environmental impact and risk warning of the Fukushima nuclear accident on the western Pacific Ocean and the sea areas under the jurisdiction, monitor the radioactive level and assess their potential impacts on adjacent sea areas with nuclear power plants (nuclear facilities).	
	22	Harmful algal blooms	Carry out early warning and monitoring of red tide (green tide) disasters, and mitigate the loss of red tide (green tide) disasters.	
	23	Saltwater intrusion	Acquire the status and change trends of saltwater intrusion	Acquire the coastal geological disaster

Category	No.	Monitoring contents	Monitoring tasks and requirements	Objectives of management support
		and soil salinization	and soil salinization.	information and provide information services and decision-making basis for disaster prevention and reduction in coastal areas.
	24	Coastal erosion	Evaluate the status and change trends of coastal erosion.	
	25	Ocean acidification	Understand the current status, regulatory mechanism, development trend of ocean acidification in the sea areas under the jurisdiction, and evaluate the potential impact of ocean acidification on marine ecological environment.	Provide the support of the management policy and solution on the global climate changes, industrial policy and implementation of international convention.
	26	Low oxygenated zone	Acquire the spatial and temporal distribution of the typical low-oxygen areas of China, and the status of benthic biological resources in the low-oxygen areas.	

New program of national marine eco-environment monitoring after the institutional reform in 2018

After the institutional reform in 2018, the responsibility of marine eco-environmental protection was adjusted to the newly established Ministry of Ecology and Environment (MEE). The task of national marine eco-environment monitoring is therefore carried out by the newly formed MEE instead of the former SOA from the year of 2019.

In 2019, the marine eco-environment monitoring program no longer is issued separately by SOA, but is issued by MEE as a part of the national eco-environment monitoring program. Moreover, due to the institutional reform and functional adjustment, as well as the limitation of funds and monitoring abilities, compared with the monitoring program in 2018, the monitoring contents in 2019 were partially reduced and some monitoring contents were also deleted. It should be noted that, in order to better support one of the country's important tasks, the integrated Bohai Sea management, special monitoring of environmental quality of Bohai Sea was added to the monitoring program of 2019. In addition, in order to further strengthen the land-sea coordination in marine eco-environmental protection, the monitoring work of rivers and sewage outlets into the sea was strengthened in 2019.

Table 18. Monitoring items for seawater quality.

Type	Item
Seawater	salinity, pH, dissolved oxygen, chemical oxygen demand (COD), active phosphate, active silicate, nitrite, nitrate, ammonia, petroleum, chlorophyll a, suspended substance, total nitrogen, total phosphorus, heavy metals (copper, zinc, chromium, mercury, cadmium, lead, arsenic)
Seawater (only for summer)	floatable substance, color stink odor, suspended substance, Escherichia coli, fecal coliform, sea water temperature, pH, dissolved oxygen, COD, biochemical oxygen demand (BOD_5), inorganic nitrogen, non-ionic ammonia, labile phosphate, mercury (Hg), cadmium (Cd), lead (Pb), chromium VI (Cr VI), total chromium, arsenic (As), copper (Cu), zinc (Zn), selenium (Se), nickel (Ni), cyanide, sulfide, volatile Phenols, oils, hexachlorocyclohexane (HCH), DDT, malathion, parathion-methyl, benzo(a)pyrene, anionic surfactant (33 items + salinity)

The marine eco-environment monitoring program of 2019 includes the following contents: seawater quality, special monitoring of environmental quality of Bohai Sea, marine ecosystem health, bathing beach water quality of coastal city, the seawater radioactivity, marine debris and microplastics, marine environment quality of areas for marine dumping and marine oil and gas development zone.

A total of 1,434 water quality monitoring sites were set up, including 1,257 monitoring sites in coastal areas and 177 monitoring sites in offshore areas.

The monitoring frequency of seawater quality for coastal areas is three times per year, which is carried out in spring (April-May), summer (July-August) and autumn (October-November). On the basis of three times per year, sea water quality monitoring of Bohai Sea is conducted once more in winter (February-March). Once monitoring of all items (33 items) for seawater quality (Table 18) (according to *Seawater quality standard* (GB 3097-1997), except for radionuclides and pathogens) is arranged in summer. Monitoring frequency in offshore areas is once per year, which should be carried out in summer in principle.

The monitoring of marine ecosystem health is carried out once per year (in August in principle, adjusted according to the characteristics of community flora). The types of marine ecosystem include estuary, bay, beach wetland, coral reefs, mangroves, seaweed bed. There are 18 typical monitoring areas in 2019.

3.1.3 Marine environmental monitoring program in the Yellow Sea of China

3.1.3.1 Organization and implementation

The Yellow Sea is one of the marginal seas in the western Pacific, and lies between the Chinese mainland and the Korean peninsula. It is a typical semi-enclosed sea area with north-south direction. The Yellow Sea bounded in the northwest by the Laotieshan corner at the southern tip of Liaodong Peninsula to the Penglai corner on the northern bank of Shandong Peninsula. In the south, the dividing line is from Qidong mouth on the north bank of the Yangtze River Estuary of China to the southwest corner of Jeju Island of RO Korea. The average depth of the Yellow Sea is 90 meters, and most of the water depth near the shore is 60 meters. The narrowest sea area of the Yellow Sea occurs between Chengshan corner of Shandong Peninsula and Long Mountain Chain of north of Korea. Traditionally, the line from Chengshan corner to Long Mountain Chain divides the Yellow Sea into the north Yellow Sea and the south Yellow Sea. The north Yellow Sea covers about 81,000 km^2 and the south Yellow Sea covers about 409,000 km2. In the northwest of the Yellow Sea, it is connected with the Bohai Sea through the Bohai Strait. In the east, it is connected with the Korea Strait by the Jeju Strait, and in the south, it is connected with the East China Sea from the Qidong corner on the northeast bank of the Yangtze River Estuary to the southwest corner of Jeju Island.

On the Chinese side of the Yellow Sea, there are three provinces (Liaoning Province, Shandong Province and Jiangsu Province), including nine coastal cities (Dandong, Dalian, Weihai, Yantai, Qingdao, Rizhao, Nantong, Yancheng and Lianyungang). Figure 8 presents the seawater quality monitoring sites of the Yellow Sea. The sites are categorized into two types: the national site (blue circle) and local sites (green triangle). In general, the monitoring tasks of national sites are charged by the national level teams: North Sea Environmental Monitoring Center (the north and middle Yellow Sea, sea areas of Liaoning Province and Shandong Province) and the East Sea Environmental Monitoring Center (the south Yellow Sea, sea area of Jiangsu Province), respectively. The monitoring tasks of local sites are carried out by the local marine environmental monitoring teams: three provincial and nine municipal-level marine environmental monitoring centers.

3.1.3.2 Monitoring sites

To date, there have been 284 national sites for seawater quality monitoring (203 sites in the north YS and 81 sites in the south YS), 125 national sites for sediment quality monitoring (85 sites in the north YS and 40 sites in the south YS), and 97 national sites for marine biodiversity monitoring (56 sites in the north YS and 41 sites in the south YS) (Figure 8).

All the local sites are within 12 NM offshore. The location and number of sites are determined by the local provincial or municipal marine environmental management departments according to the local specific situation and requirements, and presented in the local monitoring program.

The determination principles of local sites are:

— In principle, the number of local sites is not less than the number of the national sites within the jurisdictions, and are not overlap with the national sites;

— Improving the coverage of monitoring sites in the bays. The local environmental management department supplements the monitoring sites at the bay with over 50 km^2 and less than three national sites, and supplements at least one site at the bay with less than 50 km^2 and without national site.

— According to the latest provincial sea area function division, the sites are added at the main functional area and/or the functional area with high environmental quality (category I and II).

— Each coastal county is required to set up the monitoring site.

Figure 8. Seawater quality monitoring sites of the Yellow Sea of China (source: NMEMC, unpublished)

3.1.3.3 Monitoring contents

The contents of marine environmental monitoring in the Yellow Sea of China are listed inTable 19:

Table 19. Monitoring contents in the Yellow Sea of China.

Type	Index
Seawater	salinity, pH, dissolved oxygen, chemical oxygen demand (COD), active phosphate, active silicate, nitrite, nitrate, ammonia, petroleum, chlorophyll a, suspended substance, total nitrogen, total phosphorus, heavy metals (copper, zinc, chromium, mercury, cadmium, lead, arsenic)
Sediment	sulfide, organic carbon, particle size, heavy metals (mercury, cadmium, lead, arsenic, copper, zinc, chromium), petroleum, DDT (containing monomer) and polychlorinated biphenyls (containing monomer)
Bivalve	heavy metals (copper, zinc, chromium, total mercury, cadmium, lead, arsenic), petroleum
Atmospheric dry	total suspended particulate (TSP), mercury, chromium, copper, lead,

Type	Index
deposition	cadmium, zinc, arsenic, nitrate, nitrite, ammonia, phosphate
Wet deposition	mercury, chromium, copper, lead, cadmium, zinc, arsenic, nitrate, nitrite, ammonia, phosphate, rainfall, precipitation conductivity, precipitation pH
Hydrological and meteorological elements	wind direction, wind speed, weather phenomenon, water temperature, water color, water depth, transparency, sea condition
Hydrodynamic monitoring elements	water level, sea current profile, temperature, salinity and depth of the layer where the instrument is located

3.1.3.4 Monitoring frequency

The sea water quality monitoring frequency of offshore monitoring is four times per year, which is carried out in February, May, August and October, respectively. The monitoring frequency of sea water outside the coastal areas is twice a year (May and August). The monitoring frequency of the selected high-frequency monitoring sites for seawater quality is six times per year, which is carried out in February (or March), May, July, August, October and November, respectively.

The frequency of marine sediment and bivalve quality monitoring is once per year (August).

Atmospheric dry deposition: the monitoring frequency is four times per year, which is implemented in February, May, August and October. The continuous monitoring is carried out for at least one month each time. Every atmospheric dry deposition sample is collected every three days, and total ten samples are collected every month. When affected by weather such as rain and wind, the sampling time can be extended.

Wet deposition: rain samples are collected every precipitation in each sampling month (February, May, August and October). The precipitation from 8 am on the sampling day to 8 am on the next day is taken as a sample (> 20 mL).

Remote sensing monitoring period is the whole year. The remote sensing bio-optical field monitoring is carried out synchronously with national sea water quality monitoring.

The hydrodynamic monitoring is carried out in the representative months of the seasons. The monitoring of each representative month of the four seasons are finished in four years.

4.1.3.5 Monitoring guidelines

The monitoring guidelines are listed in Table 20.

Table 20. Guidelines of the marine environmental monitoring in the Yellow Sea of China.

No.	Guidelines	Guideline No.
1	Specification for marine monitoring—part 1: general rules	GB 17378.1-2007
2	Specification for marine monitoring—part 2: data processing and quality control of analysis	GB 17378.2-2007
3	Specification for marine monitoring—part 3: sample collection, storage and transportation	GB 17378.3-2007
4	Specification for marine monitoring—part 4: seawater analysis	GB 17378.4-2007
5	Specification for marine monitoring—part 5: sediment analysis	GB 17378.5-2007
6	Specification for marine monitoring—part 6: organism analysis	GB 17378.6-2007
7	Specification for marine monitoring—part 7: ecological survey for offshore pollution and biological monitoring	GB 17378.7-2007
8	Code of practice for marine monitoring technology—Part 1: seawater	HY/T 147.1-2013
9	Code of practice for marine monitoring technology—Part 2: sediment	HY/T 147.2-2013
10	Code of practice for marine monitoring technology—Part 3: organism	HY/T 147.3-2013
11	Code of practice for marine monitoring technology—Part 4: atmosphere	HY/T 147.4-2013
12	Regulation for offshore environmental monitoring	HJ 442-2008

New program of national marine eco-environment monitoring in the Yellow Sea after the institutional reform in 2018

After the institutional reform in 2018, as a part of the national marine eco-environment monitoring, the program of marine eco-environment monitoring in the Yellow Sea was adjusted along with the changes of national marine eco-environment monitoring program.

In 2019, total 332 sites are set to monitor the seawater quality in the Yellow Sea. Of which, 287 sites are in coastal areas, and 45 sites are outside of coastal areas.

The monitoring frequency of seawater quality for 287 sites in coastal areas of the Yellow Sea is three times per year too, which is carried out in spring (April-May), summer (July-August) and autumn (October-November). Once monitoring of all items for seawater quality (according to *Seawater quality standard* (GB 3097-1997), except for radionuclides and pathogens) is arranged in summer. Monitoring frequency for 45 sites for offshore areas is once per year, which should be carried out in summer in principle (

Table 21).

The monitoring of marine ecosystem health is carried out in two areas (Yalu Estuary in Liaoning Province and Subei shoal in Jiangsu Province) in 2019, and the monitoring frequency is once per year (in August in principle).

Table 21. Monitoring items for seawater quality in the Yellow Sea.

Type	Item
Seawater	salinity, pH, dissolved oxygen, chemical oxygen demand (COD), active phosphate, active silicate, nitrite, nitrate, ammonia, petroleum, chlorophyll a, suspended substance, total nitrogen, total phosphorus, heavy metals (copper, zinc, chromium, mercury, cadmium, lead, arsenic)
Seawater (only for summer)	floatable substance, color stink odor, suspended substance, Escherichia coli, fecal coliform, sea water temperature, pH, dissolved oxygen, COD, biochemical oxygen demand (BOD_5), inorganic nitrogen, non-ionic ammonia, labile phosphate, mercury (Hg), cadmium (Cd), lead (Pb), chromium VI (Cr VI), total chromium, arsenic (As), copper (Cu), zinc (Zn), selenium (Se), nickel (Ni), cyanide, sulfide, volatile Phenols, oils, hexachlorocyclohexane (HCH), DDT, malathion, parathion-methyl, benzo(a)pyrene, anionic surfactant (33 items + salinity)

3.2 Marine environmental monitoring networks of Korea

3.2.1 Overview of marine environmental monitoring network

There are three coastal seas in Korea: East Sea, South Sea and West Sea. They are divided into five ecological areas: East Sea Ecological Zone, Korean Strait Ecological Zone, Southwest Sea Ecological Zone, West Sea Central Ecological Zone and Jeju Ecological Zone (Figure 9).

Marine environmental monitoring network (MEMN) of RO Korea is set and conducted based on the Article 9 (MEMN) of the Marine Environment Management Act. MEMN conducts regular monitoring of coastal marine environmental quality and pollution sources investigation to collect the primary and necessary data for assessment of the marine ecology and environment status, and the development of marine environmental management and protection policies in RO Korea. In general, the data and assessment results are provided to the general public through the National Marine Environment Information Integrated System (www.meis.go.kr).

In 2017, according to the different environmental quality standards and environment management targets for various marine environment management zones, the coastal area of RO Korea was divided into 31 marine monitoring areas. The construction and regroup of MEMN adapted for the influence range (salinity < 30) of rivers into the sea, river discharge, coastal current and marine environmental policy needs. The detailed information of operation and service can be found in the MEMN System and Operation Plan (Notice of MOF No. 2017-39) (

Figure 10).

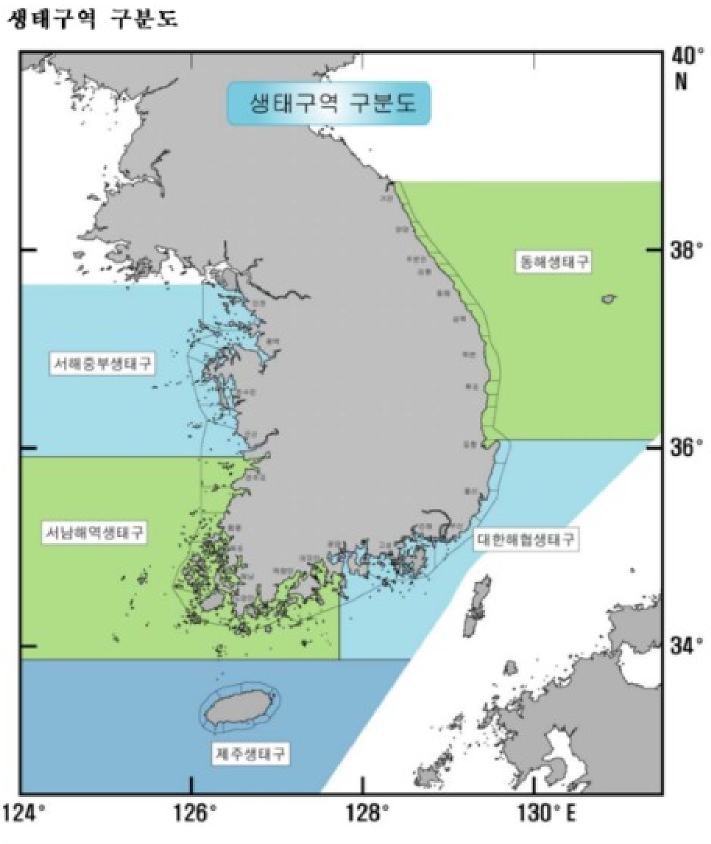


Figure 9. Marine environment monitoring areas of RO Korea (source: Marine environment standards in accordance with the Marine Environment Management Act, MOF, RO Korea 2011-972)

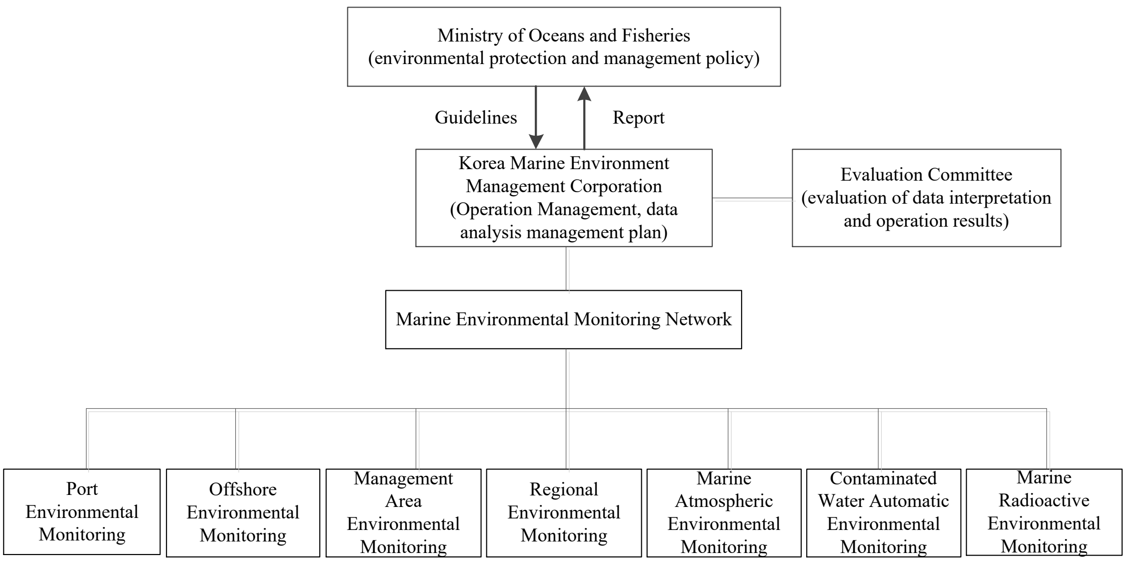


Figure **10. Operating scheme of marine environment monitoring network (source: Annual report on marine environment monitoring in** RO **Korea 2018)**.

MEMN has been operated by integrating the marine pollution monitoring network and the coastal fisheries pollution investigation from the year 1997. In 1999, the monitoring environmental media included seawater (surface and bottom), marine biota and sediment. From 2004, MEMN began to operate based on the different purpose of sea area use, such as port, offshore, environmental management area, bay (estuary, river influence), etc.

3.2.2 National marine environmental monitoring program

3.2.2.1 Monitoring sites

According to the marine environment management targets, MEMN is divided into three parts: port environmental monitoring network, bay and river influence environmental monitoring network, and offshore environmental monitoring network, which consist of a total of 425 monitoring sites (Table 22).

Table 22. Marine environment measurement network by sea station research (source: Operating plan for the construction of marine environment measurement network, 2017).

Monitoring net	Ecological zone name	Number of sites (total sites of the regions)
Port environmental monitoring network	**Subtotal**	31 (50)
	Middle of the West Sea ecological zone	3 (3)
	Southwest sea ecological zone	2 (3)
	Strait ecological zone	12 (22)
	East Sea ecological zone	10 (15)
	Jeju ecological zone	4 (7)
Bay and river influence environmental monitoring network	**Subtotal**	21 (230)
	Middle of the West Sea ecological zone	4 (73)
	Southwest sea ecological zone	5 (28)
	Strait ecological zone	6 (114)
	East Sea ecological zone	6 (15)
Offshore environmental monitoring network	**Subtotal**	5 (145)
	Middle of the West Sea ecological zone	1 (10)
	Southwest sea ecological zone	1 (25)
	Strait ecological zone	1 (44)
	East Sea ecological zone	1 (47)
	Jeju ecological zone	1 (19)

The port environmental monitoring network consist of 50 monitoring sites covering the 31 main ports. There are 3 sites in 3 ports in the middle of the West Sea, 3 sites in 2 ports in the southwest sea, 22 sites in 12 ports in the Strait ecological zone, 15 sites in 10 ports in the East Sea, 7 sites in 4 ports in the Jeju ecological zone.

The bay and river influence environmental monitoring network consist of 230 monitoring sites in the 21 regions. Of which there are 73 sites in the 4 regions of the West Sea ecological zone, 28 sites in the 5 regions in the southwest sea ecological zone, 114 sites in the 6 regions in the Strait ecological zone, 15 sites in the 6 regions in the East Sea ecological zone.

The offshore environmental monitoring network consist of 145 monitoring sites in the 5 ecological zones. They are: 10 sites in the West Sea ecological zone; 25 sites in the southwest sea ecological zone; 44 sites in the Strait ecological zone; 47 sites in the East Sea ecological zone; and 19 sites in the Jeju ecological zone.

3.2.2.2 Monitoring frequency

The monitoring frequency is twice a year in February and August for the port environmental measurement network, four times a year in February, May, August and November for the bay and river influence environmental monitoring network, and offshore environmental monitoring network, respectively. Several influence factors need to be considered when samples are collected, such as the changes in freshwater inflow caused by tides, tidal currents, meteorological conditions, rainfall and other factors in the monitoring sea area, sampling sites and the construction conditions in the nearby sea area.

3.2.2.3 Monitoring items

Sample collection, storage and analysis are carried out based on *Marine Environmental Monitoring Specification* in accordance with the provision of Article 10 of the Marine Environment Management Act. The main monitoring target items are: temperature; salinity; pH; dissolved oxygen (DO); chemical oxygen demand (COD); NH_4^+; NO_2^-; NO_3^-; dissolved inorganic nitrogen (DIN); total nitrogen (TN); dissolved inorganic phosphate (DIP); $Si(OH)_4$; suspended particulate matter (SPM); and chlorophyll *a* (Chl *a*) (Table 23 to

Table 25).

Table 23. Monitoring items and time of the port environment monitoring network.

Category		Item	Time	Number of sites
Seawater	General items (16)	Water temperature, Salinity, pH, DO, COD, TN, DIN (NO_3^-, NO_2^-, NH_4^+), TP, DIP (PO_4^{3-}), $Si(OH)_4$, SPM, transparency, Chlorophyll-a, oil	February August	50 sites
	Trace metal (8)	Cu, Pb, Zn, Cd, Cr^{6+}, total mercury, As, CN	February August	26 sites
Marine sediment	General items (4)	Particle size, organic carbon, sulfide, COD	February	26 sites
	Trace metal (13)	Cu, Pb, Zn, Cd, Cr, total mercury, As, Ni, Co, Al, Li, Fe, Mn	February	26 sites
Marine biota	Trace metal (7)	Cu, Pb, Zn, Cd, Cr, total mercury, As	February	23 sites

Remarks: · Seawater includes surface and low layer samples; however, oil and trace metals are only analyzed in the surface seawater samples.
· Oil is monitored only in the port monitoring sites; and the monitoring of trace metals is referenced by monitoring network.
· Monitoring sites of trace metals in seawater are the same to the sediment sites.
· Reference marine biota is oysters.

Table 24. Monitoring items and time of the bay and river influence environmental monitoring network.

Category		Item	Time	Number of sites
Seawater	General items (16)	Water temperature, Salinity, pH, DO, COD, TN, DIN (NO_3^-, NO_2^-, NH_4^+), TP, DIP (PO_4^{3-}), $Si(OH)_4$, SPM, transparency, Chlorophyll-a	February May August November	230 sites
		Oil	February May August November	81 sites
	Trace metal (8)	Cu, Pb, Zn, Cd, Cr^{6+}, total mercury, As, CN	February August	139 sites
Marine sediment	General items (4)	Particle size, organic carbon, sulfide, COD	February	139 sites
	Trace metal (13)	Cu, Pb, Zn, Cd, Cr, total mercury, As, Ni, Co, Al, Li, Fe, Mn	February	139 sites
Marine biota	Trace metal (7)	Cu, Pb, Zn, Cd, Cr, total mercury, As	February	22 sites

Remarks: · Seawater includes surface and low layer samples; however, oil and trace metals are only analyzed in the surface seawater samples.

· Oil is monitored only in the port monitoring sites; and the monitoring of trace metals is referenced by monitoring network.

· Monitoring sites of trace metals in seawater are the same to the sediment sites.

· Reference marine biota is oysters.

· Masan Bay, Busan Coast, Shihwa Lake - Incheon Coast are monitored additional twice in June and July (total 6 times in a year).

· Kumgang Estuary, Yeongsan Estuary, Jinhae Bay, Yeongilman are monitored additional twice in June and July (total 6 times in a year).

Table 25. Monitoring items and time of the offshore environmental monitoring network.

Category		Item	Time	Number of sites
Seawater	General items (16)	Water temperature, Salinity, pH, DO, COD, TN, DIN (NO_3^-, NO_2^-, NH_4^+), TP, DIP (PO_4^{3-}), $Si(OH)_4$, SPM, transparency, Chlorophyll-a	February May August November	145 sites
		Oil	February May August November	29 sites
	Trace metal (8)	Cu, Pb, Zn, Cd, Cr^{6+}, total mercury, As, CN	February August	33 sites
Marine sediment	General items (4)	Particle size, organic carbon, sulfide, COD	February	33 sites
	Trace metal (13)	Cu, Pb, Zn, Cd, Cr, total mercury, As, Ni, Co, Al, Li, Fe, Mn	February	33 sites
Marine biota	Trace metal (7)	Cu, Pb, Zn, Cd, Cr, total mercury, As	February	5 sites

Remarks: · Seawater includes surface and low layer samples; however, oil and trace metals are only analyzed in the surface seawater samples.

· Oil is monitored only in the port monitoring sites; and the monitoring of trace metals is referenced by monitoring network.

· Monitoring sites of trace metals in seawater are the same to the sediment sites.

· Reference marine biota is oysters.

3.3 Comparison of marine environmental monitoring network between China and RO Korea

3.3.1 Administrative department

Until 2018, marine environmental monitoring of China was in charge of the former State Oceanic Administration (SOA) of China. In 2018, China implemented a new round of institutional reform and shifted the responsibilities of marine environmental protection to the newly established Ministry of Ecology and Environment (MEE). From 2019, as the administrative department of national ecology and environment, MEE began to be in charge of marine environmental monitoring of China. National Marine Environment Monitoring Center (NMEMC) was authorized to be responsible for organizing and implementing the annual marine environmental monitoring work.

Marine environmental monitoring of RO Korea is under the administration of the Ministry of Oceans and Fisheries (MOF), which issues national monitoring programs and guidelines. Korea Marine Environment Management Corporation (KOEM) is authorized to carry out the operation management of marine environmental monitoring network (MEMN) and data analysis management plan.

3.3.2 Task-taking body

The national monitoring tasks in China are charged by the sea area monitoring center (North Sea Environmental Monitoring Center (the north and middle Yellow Sea, sea areas of Liaoning Province and Shandong Province) and East Sea Environmental Monitoring Center (the south Yellow Sea, sea area of Jiangsu Province)) and 3 provincial and 9 municipal-level marine environmental monitoring centers.

In RO Korea, several marine environment monitoring institutions are responsible for carrying out the monitoring tasks. They are national research institutions under MOF, universities, and government-funded research institutions, each of which are responsible for marine environment, fishery survey, ocean survey, ocean observation, navigation survey and other tasks (Table 26).

Table 26. Main marine environmental monitoring institutions of RO Korea.

Institutions	Responsibilities
Korea Marine Environment Management Corporation (KOEM)	Affiliated to Ministry of Oceans and Fisheries, aiming to effectively promote the protection, management and improvement of marine environment
National Institute of Fisheries Science (NIFS)	monitoring and research on the marine environment and fisheries
Coast Guard	Independent department under Ministry of Oceans and Fisheries, responsible for marine environmental management law enforcement and carrying out oil pollution accidents and other marine environmental monitoring tasks
Korea Hydrographic and Oceanographic Agency (KHOA)	Marine investigation and basic research
Korean Institute of Ocean Science & Technology (KIOST)	Government-funded marine research institutions under the Ministry of science and technology, responsible for marine environmental monitoring and development of marine environmental management technologies
National and private universities	Carry out marine environmental investigation, monitoring and research

3.3.3 Monitoring program

Monitoring program of China is issued as official document every year by MEE (by SOA before 2018) as a part of national ecological and environmental monitoring program. In the program, several requirements, such as the monitoring ranges (sites), monitoring items, frequency (time), organization and implementation, data reporting, quality control, are set.

Monitoring program of RO Korea is issued every year by MOF as notice (Marine Environment Monitoring Network System and Operation Plan). The main contents are similar with the program of China.

3.3.4 Monitoring sites

To date, there have been 284 national sites for seawater quality monitoring (203 sites in the north YS and 81 sites in the south YS), 125 national sites for sediment quality monitoring (85 sites in the north YS and 40 sites in the south YS), and 97 national sites for marine biodiversity monitoring (56 sites in the north YS and 41 sites in the south YS). It should be noted that, by 2020, the national sites for seawater quality monitoring will adjust to 335 (coastal area sites 290 and offshore sites 45) according to the reviewing plan.

In RO Korea, according to the marine environment management targets, MEMN is divided into three parts: port environmental monitoring network; bay and river influence environmental monitoring network; and offshore environmental monitoring network. The number of monitoring sites for each environmental monitoring network is presented in Table 27, and the total number of monitoring sites are 425. West Sea central ecological zone, Southwest sea ecological zone and Jeju ecological zone can be considered as the side of the Yellow Sea of RO Korea, and the number of monitoring sites in these three ecological zones are 168.

Table 27. Monitoring sites for the three environmental monitoring networks of RO Korea.

Ecological zone	Port environmental monitoring network	Bay/river influence environmental monitoring network	Offshore environmental monitoring network	Total
West Sea central	3	73	10	86
Southwest sea	3	28	25	56
Jeju	7	0	19	26
Strait	22	114	44	180
East Sea	15	15	47	77
Total	50	230	145	425

Remark: West Sea central ecological zone, Southwest sea ecological zone and Jeju ecological zone are considered as the side of the Yellow Sea of RO Korea.

3.3.5 Target item, time and frequency

The detailed comparison information of RO Korea and China marine environmental monitoring items, time (frequency), number of sites in the side of the Yellow Sea of both countries is presented in Table 28.

Table 28. Comparison of monitoring items, time and number of sites in the side of the Yellow Sea of RO Korea and China.

Korea			China		
Item	Time	Site	Item	Time	Site
water temperature, salinity, pH, dissolved oxygen, chemical oxygen demand, total nitrate, dissolved inorganic nitrogen (NO^{3-}, NO^{2-}, NH^{4+}), total phosphorus, dissolved inorganic phosphate (PO_4^{3-}), $Si(OH)_4$, suspended particulate matter, transparency, chlorophyll-*a*, oil	February May August November	168	salinity, pH, dissolved oxygen, chemical oxygen demand (COD), active phosphate, active silicate, nitrite, nitrate, ammonia, petroleum, chlorophyll-*a*, suspended substance, total nitrogen, total phosphorus, Cu, Pb, Zn, Cd, Cr, Hg, As	May August October	335
Cu, Pb, Zn, Cd, Cr^{6+}, total mercury, As, CN	February August	33			

Remark: Monitoring sites in the side of the Yellow Sea of Korea consist the sites of the West Sea central ecological zone, Southwest sea ecological zone and Jeju ecological zone.

4. Draft marine environmental monitoring framework

4.1 Monitoring sites

On one hand, the joint monitoring sites of China and Korea in the Yellow Sea in the project are selected based on the existing national marine environmental monitoring sites according to both countries' monitoring program, instead of selecting new sites for monitoring. In this way, it not only maintains the consistency between the monitoring contents of the project and the monitoring programs of the respective countries, but also makes full use of the existing historical monitoring data of the sites to ensure the authority and continuity of the monitoring sites and data.

On the other hand, some new monitoring sites are added to connect the existing monitoring sites of both countries. Then, the existing sites and new sites can be connected into an integrated monitoring web system, and more comprehensive comparative research can be carried out based on the new monitoring system in the Yellow Sea. Figure 11 shows the proposed monitoring sites of draft marine environmental monitoring. A total of 42 monitoring sites are set up with 5 sections.

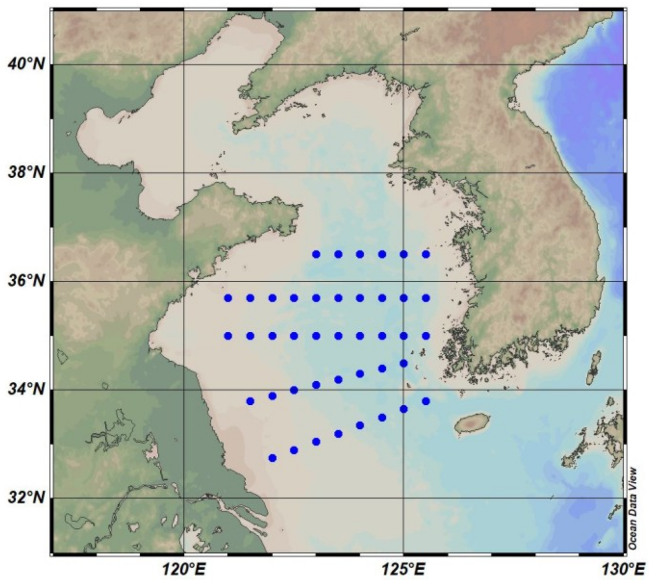


Figure 11. Proposal of monitoring sites of draft marine environmental monitoring of the Yellow Sea.

4.2 Monitoring contents

The contents of marine environmental monitoring in the Yellow Sea are determined according to the same monitoring contents in the monitoring programs of both countries. Furthermore, several specific target items, such as POPs, are also added. The detailed monitoring contents are listed in Table 29.

Table 29. Proposal monitoring contents of draft marine environmental monitoring of the Yellow Sea.

Media	Contents
Seawater	water temperature, salinity, pH, dissolved oxygen, chemical oxygen demand (COD), active phosphate, active silicate, nitrite, nitrate, ammonia, petroleum, chlorophyll-a, suspended substance, total nitrogen, total phosphorus, Cu, Pb, Zn, Cd, Cr, Hg, As
	PAHs, PBDEs, OCPs, organophosphorus pesticide, microplastics
Sediment	sulfide, organic carbon, particle size, heavy metals (mercury, cadmium, lead, arsenic, copper, zinc, chromium), petroleum

4.3 Monitoring time and frequency

The monitoring time of China is in May, August and October, and the monitoring time of Korea is in February, May, August and October. Based on the same monitoring time of both countries' monitoring programs, August is selected as the monitoring time. The monitoring frequency is determined as once a year (August).

4.4 Monitoring methods

There are one or different monitoring methods for each specific item. To unify the monitoring methods of each item between both countries and make the monitoring data comparable, it is necessary to select one monitoring method within various methods that both countries have. The detailed monitoring methods of each item are listed in Table 30.

Table 30. Proposal monitoring methods of target items in seawater and sediment.

No.	Media	Item	Method
1	Sea water	water temperature	Water thermometer method
2		salinity	Salinometer
			CTD
3		pH	Glass electrode method
4		dissolved oxygen	Iodometric method
5		chemical oxygen demand	Potassium iodide alkaline Permanganate method
6		active phosphate	Continuous flow analysis
			Phosphomolybdenum blue spectrophotometry

No.	Media	Item	Method
7		active silicate	Silicon molybdenum blue spectrophotometry
			Continuous flow analysis
8		nitrite	N-(1-naphthyl)ethylene diamine dihydrochloride spectrophotometry
			Continuous flow analysis
9		nitrate	Cadmium column reduction method
			Continuous flow analysis
10		ammonia	Indophenol blue spectrophotometry
			Continuous flow analysis
11		petroleum	Fluorescence spectrophotometry
12		chlorophyll-a	Fluorescence spectrophotometry
13		suspended substance	Filtration method
14		total nitrogen	Potassium persulfate oxidation spectrophotometry
			Continuous flow analysis
15		total phosphorus	Potassium persulfate oxidation spectrophotometry
			Continuous flow analysis
16		Cu, Pb, Zn, Cd, Cr	Inductively coupled plasma mass spectrometry
17		Hg	Cold atomic fluorescent spectrophotometry
18		As	Hydride generation atomic absorption spectrophotometry
19		PAHs	Gas chromatography-mass spectrometry
20		PBDEs	Gas chromatography-mass spectrometry
21		OCPs	Gas chromatography
22		organophosphorus pesticide	Gas chromatography
23		microplastics	
24	Sediment	sulfide	Sulfide -Methylene blue spectrophotometric method
25		organic carbon	Potassium dichromate oxidation method
26		particle size	Laser diffraction method
27		Cu, Pb, Zn, Cd, Cr	Inductively coupled plasma mass spectrometry
28		Hg	Cold atomic fluorescent spectrophotometry
29		As	Hydride generation atomic absorption spectrophotometry
30		petroleum	Fluorescence spectrophotometry

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Annexed Table 1. Monitoring guidelines for target pollutants in seawater.

Target pollutants		Method	Standard No.
POPs	DDT	Gas chromatography	GB 17378.4-2007 HY/T 147.1-2013
	PCBs	Gas chromatography	GB 17378.4-2007 HY/T 147.1-2013
	Dieldrin	Gas chromatography	GB 17378.4-2007 HY/T 147.1-2013
	Endrin	Gas chromatography	HY/T 147.1-2013
	Chlordane	Gas chromatography	HY/T 147.1-2013
	Mirex	Gas chromatography	V
	Aldrine	Gas chromatography	HY/T 147.1-2013
	Heptachlor	Gas chromatography	HY/T 147.1-2013
	Endosulfan	Gas chromatography	HY/T 147.1-2013
	PAHs (Bap)	Gas chromatography-mass spectrometry	GB/T 26411-2010
Heavy metal	Cu	Flameless atomic absorption spectrometry	GB 17378.4-2007
		Anodic stripping voltammetry	GB 17378.4-2007
		Flame Atomic Absorption Spectrophotometry	GB 17378.4-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.1-2013
	Pb	Flameless atomic absorption spectrometry	GB 17378.4-2007
		Anodic stripping voltammetry	GB 17378.4-2007
		Flame Atomic Absorption Spectrophotometry	GB 17378.4-2007

Target pollutants		Method	Standard No.
		Inductively coupled plasma mass spectrometry	HY/T 147.1-2013
	Zn	Flame Atomic Absorption Spectrophotometry	GB 17378.4-2007
		Anodic stripping voltammetry	GB 17378.4-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.1-2013
	Cd	Flameless atomic absorption spectrometry	GB 17378.4-2007
		Anodic stripping voltammetry	GB 17378.4-2007
		Flame Atomic Absorption Spectrophotometry	GB 17378.4-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.1-2013
	Hg	Atomic fluorescence spectrometry	GB 17378.4-2007
		Cold atomic absorption spectrophotometry	GB 17378.4-2007
		Gold capture cold atomic absorption spectrometry	GB 17378.4-2007
	Cr^{6+}	Portable spectrometer method	HY/T 147.1-2013
	Total Cr	Flameless atomic absorption spectrometry	GB 17378.4-2007
		1,5-Diphenylcarbonylhydrazide spectrophotometric method	GB 17378.4-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.1-2013
	As	Atomic fluorescence spectrometry	GB 17378.4-2007 HY/T 152-2013
		Spectrophotometric method with arsenic hydride and silver nitrate	GB 17378.4-2007
		Hydride generation atomic absorption spectrophotometry	GB 17378.4-2007
		Catalytic polarography	GB 17378.4-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.1-2013
	Se	Fluorescence spectrophotometry	GB 17378.4-2007

Target pollutants		Method	Standard No.
		3,3'-Diaminobenzidine spectrophotometric method	GB 17378.4-2007
		Catalytic polarography	GB 17378.4-2007
	Ni	Inductively coupled plasma mass spectrometry	HY/T 147.1-2013
Emerging contaminants	Microplastics	-	-
	Organophosphorus pesticide (malathion, methyl parathion)	Gas chromatography	HY/T 147.1-2013
	Phthalate ester	Gas chromatography	HY/T 147.1-2013
		Gas chromatography-mass spectrometry	HY/T 147.1-2013
	Chloromycetin	High performance liquid chromatography / tandem mass spectrometry	HY/T 147.1-2013
	Sulfa-type antibiotics	High performance liquid chromatography / tandem mass spectrometry	HY/T 147.1-2013

Annexed Table 2 Monitoring guidelines for target pollutants in marine sediment

Target pollutants	Target pollutants	Method	Standard No.
POPs	DDT	Gas chromatography	GB 17378.5-2007
	PCBs	Gas chromatography	GB 17378.5-2007
	Dieldrin	Gas chromatography	GB 17378.5-2007
	PBDEs	Gas chromatography-mass spectrometry	HY/T 147.2-2013
	PAHs (Bap)	Gas chromatography-mass spectrometry	HY/T 147.2-2013
		Gas chromatography	HY/T 147.2-2013
		High performance liquid chromatography	HY/T 147.2-2013
Heavy metal	Cu	Flameless atomic absorption spectrometry	GB 17378.5-2007
		Flame Atomic Absorption Spectrophotometry	GB 17378.5-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.2-2013 GB/T 20260-2006
		Inductively coupled plasma atomic emission spectrometry	GB/T 20260-2006
	Pb	Flameless atomic absorption spectrometry	GB 17378.5-2007
		Flame Atomic Absorption Spectrophotometry	GB 17378.5-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.2-2013 GB/T 20260-2006
	Zn	Flame Atomic Absorption Spectrophotometry	GB 17378.5-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.2-2013 GB/T 20260-2006
		Inductively coupled plasma atomic emission spectrometry	GB/T 20260-2006
	Cd	Flameless atomic absorption spectrometry	GB 17378.5-2007

Target pollutants	Target pollutants	Method	Standard No.
		Flame Atomic Absorption Spectrophotometry	GB 17378.5-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.2-2013 GB/T 20260-2006
	Total Hg	Atomic fluorescence spectrometry	GB 17378.5-2007
		Cold atomic absorption spectrophotometry	GB 17378.5-2007
		Thermal decomposition cold atomic absorption spectrometry	HY/T 147.2-2013
		Cold-vapour atomic fluorescence spectrometry	GB/T 20260-2006
	Total Cr	Flameless atomic absorption spectrometry	GB 17378.5-2007
		1,5-Diphenylcarbonylhydrazide spectrophotometric method	GB 17378.5-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.2-2013 GB/T 20260-2006
	As	Atomic fluorescence spectrometry	GB 17378.5-2007
		Arsenical molybdate-crystal violet spectrophotometric method	GB 17378.5-2007
		Hydride generation atomic absorption spectrophotometry	GB 17378.5-2007
		Catalytic polarography	GB 17378.5-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.2-2013
		Hydride generation-atomic fluorescence spectrometry	GB/T 20260-2006
	Se	Fluorescence spectrophotometry	GB 17378.5-2007
		3,3'-Diaminobenzidine spectrophotometric method	GB 17378.5-2007
		Catalytic polarography	GB 17378.5-2007
		Hydride generation-atomic fluorescence spectrometry	GB/T 20260-2006
	Ni	Inductively coupled plasma mass spectrometry	HY/T 147.2-2013
		Atomic Absorption Spectrophotometry	HY/T 206-2016

Target pollutants	Target pollutants	Method	Standard No.
			GB/T 20260-2006
		Inductively coupled plasma atomic emission spectrometry	GB/T 20260-2006
Emerging contaminants	Microplastics		
	Organophosphorus pesticide (malathion, methyl parathion)	Gas chromatography	HY/T 147.2-2013
	Phthalate ester	Gas chromatography-mass spectrometry	HY/T 147.2-2013
		Gas chromatography	HY/T 147.2-2013
	Organotin	Gas chromatography	HY/T 147.2-2013

Annexed Table 3 Monitoring guidelines for target pollutants in marine organism

Target pollutants		Method	Standard No.
POPs	DDT	Gas chromatography	GB 17378.6-2007
	PCBs	Gas chromatography	GB 17378.6-2007
	Dieldrin	Gas chromatography	GB 17378.6-2007
	PBDEs	Gas chromatography-mass spectrometry	HY/T 147.3-2013
	PAHs (Bap)	Gas chromatography-mass spectrometry	HY/T 147.3-2013
		Gas chromatography	HY/T 147.3-2013
		High performance liquid chromatography	HY/T 147.3-2013
Heavy metal	Cu	Flameless atomic absorption spectrometry	GB 17378.6-2007
		Flame atomic absorption spectrophotometry	GB 17378.6-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.3-2013
	Pb	Flameless atomic absorption spectrometry	GB 17378.6-2007
		Flame atomic absorption spectrophotometry	GB 17378.6-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.3-2013
	Zn	Flame atomic absorption spectrophotometry	GB 17378.6-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.3-2013
	Cd	Flameless atomic absorption spectrometry	GB 17378.6-2007
		Flame atomic absorption spectrophotometry	GB 17378.6-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.3-2013
	Total Hg	Atomic fluorescence spectrometry	GB 17378.6-2007
		Cold atomic absorption spectrophotometry	GB 17378.6-2007
		Thermal decomposition cold atomic absorption spectrometry	HY/T 147.3-2013

Target pollutants		Method	Standard No.
	Total Cr	Flameless atomic absorption spectrometry	GB 17378.6-2007
		1,5-Diphenylcarbonylhydrazide spectrophotometric method	GB 17378.6-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.3-2013
	As	Atomic fluorescence spectrometry	GB 17378.6-2007
		Arsenical molybdate-crystal violet spectrophotometric method	GB 17378.6-2007
		Hydride generation atomic absorption spectrophotometry	GB 17378.6-2007
		Catalytic polarography	GB 17378.6-2007
		Inductively coupled plasma mass spectrometry	HY/T 147.3-2013
	Se	Fluorescence spectrophotometry	GB 17378.6-2007
		3,3'-Diaminobenzidine spectrophotometric method	GB 17378.6-2007
		Catalytic polarography	GB 17378.6-2007
	Ni	Inductively coupled plasma mass spectrometry	HY/T 147.3-2013
		Atomic absorption spectrophotometry	HY/T 206-2016
Emerging contaminants	Microplastics	-	-
	Organophosphorus pesticide (malathion, methyl parathion)	Gas chromatography	HY/T 147.3-2013
	Phthalate ester	Gas chromatography-mass spectrometry	HY/T 147.3-2013
		Gas chromatography	HY/T 147.3-2013
	Organotin	Gas chromatography	HY/T 147.3-2013

Annexed Table 4 Monitoring guidelines for target pollutants in atmosphere

Target pollutants		Method	Standard No.
POPs	PCBs	Gas chromatography	HY/T 147.4-2013
	PAHs (Bap)	High performance liquid chromatography	HY/T 147.4-2013
Heavy metal	Cu	Inductively coupled plasma mass spectrometry	HY/T 147.4-2013
	Pb	Inductively coupled plasma mass spectrometry	HY/T 147.4-2013
	Zn	Inductively coupled plasma mass spectrometry	HY/T 147.4-2013
	Cd	Inductively coupled plasma mass spectrometry	HY/T 147.4-2013
	Cr	Inductively coupled plasma mass spectrometry	HY/T 147.4-2013
	As	Inductively coupled plasma mass spectrometry	HY/T 147.4-2013

Annexed Table 5. Comparison of monitoring methods of the target monitoring items, among which the bold italics are the consistent monitoring methods of both countries

Item	Guideline of China	Standard No.	Guideline of Korea
Salinity	Salinometer	GB 17378.4-2007	Salinometer
	CTD	GB 17378.4-2007	CTD
Water temperature	Water thermometer method	GB 17378.4-2007	Water thermometer method
pH	Glass electrode method	GB 17378.4-2007	Glass electrode method
Transparency	Transparent disc method	GB 17378.4-2007	Transparent disc method
Suspended particulate matter (SPM)	Filtration method	GB 17378.4-2007	Filtration method
Dissolved oxygen (DO)	Iodometric method	GB 17378.4-2007	Iodometric method
			Membrane electrode method
Sulfide	Methylene blue spectrophotometric method	GB 17378.4-2007	Methylene blue spectrophotometric method
	Ion selective electrode method	GB 17378.4-2007	
Chemical oxygen demand (COD)	Potassium iodide alkaline Permanganate method	GB 17378.4-2007	Potassium iodide alkaline Permanganate method
Dissolved organic carbon (DOC)			Combustion oxidation nondispersive infrared absorption method
Nitrate	Cadmium column reduction method	GB 17378.4-2007	Cadmium column reduction method
	Zinc-cadmium reduction method	GB 17378.4-2007	Continuous flow analysis
	Cadmium copper column reduction method	GB/T 12763.4-2007	
	Zinc-cadmium reduction method	GB/T 12763.4-2007	
	Continuous flow analytical method	HY/T 147.1-2013	
	Portable spectrography	HY/T 147.1-2013	
	Gas phase molecular absorption spectroscopy	HJ/T 198-2005	
Nitrite	N-(1-naphthyl)ethylene diamine spectrophotometry	GB 17378.4-2007	N-(1-naphthyl)ethylene diamine dihydrochloride spectrophotometry
	Continuous flow analytical method	HY/T 147.1-2013	Continuous flow analysis
	Portable spectrography	HY/T 147.1-2013	
	Diazo - azo method	GB/T 12763.4-2007	
	Gas phase molecular absorption spectroscopy	HJ/T 197-2005	
Ammonia	Indophenol blue photometric method	GB 17378.4-2007	*Indophenol blue* spectrophotometry
	Hypobromite oxidation method	GB 17378.4-2007	Continuous flow analysis
	Sodium hypobromite oxidation method	GB/T 12763.4-2007	
	Indophenol blue method	GB/T 12763.4-2007	
	Continuous flow analytical method	HY/T 147.1-2013	
	Portable spectrography	HY/T 147.1-2013	

Item	Guideline of China	Standard No.	Guideline of Korea
	Gas phase molecular absorption spectroscopy	HJ/T 195-2005	
Phosphate	Phosphomolybdenum blue spectrophotometric method	GB 17378.4-2007	Phosphomolybdenum blue spectrophotometry
	Phosphomolybdenum blue extraction spectrophotometric method	GB 17378.4-2007	Continuous flow analysis
	Continuous flow analytical method	HY/T 147.1-2013	
	Portable spectrography	HY/T 147.1-2013	
	Ascorbic acid reduction phosphorus molybdenum blue method	GB/T 12763.4-2007	
Active silicate	Silicon molybdenum blue method	GB17378.4-2007	Silicon molybdenum blue spectrophotometry
	Silicon molybdenum yellow method	GB17378.4-2007	Continuous flow analysis
	Silicon molybdenum blue method	GB/T 12763.4-2007	
	Silicon molybdenum yellow method	GB/T 12763.4-2007	
	Continuous flow analytical method	HY/T 147.1-2013	
Total phosphorus	Potassium persulfate oxidation method	GB 17378.4-2007	Potassium persulfate oxidation spectrophotometry
	Potassium persulfate oxidation method	GB/T 12763.4-2007	Continuous flow analysis
	Continuous flow analytical method	HY/T 147.1-2013	
Total nitrogen	Potassium persulfate oxidation method	GB 17378.4-2007	Potassium persulfate oxidation spectrophotometry
	Potassium persulfate oxidation method	GB/T 12763.4-2007	Continuous flow analysis
	Continuous flow analytical method	HY/T 147.1-2013	
Dissolved total nitrogen			Cadmium column reduction method
Dissolved total phosphorus			Potassium persulfate oxidation spectrophotometry
Cyanide (CN)			Isonicotinic acid-pyrazolone spectrophotometry
Fluorine (F)			Fluorine reagents spectrophotometry
Methyl mercury			Gas chromatography (GC) - electron capture detector (ECD)
Phenol			4-aminoantipyrine spectrophotometry
Anionic Surfactants (ABS)			Methylene blue spectrophotometry
Volatile organic compounds (VOCs)			Gas chromatography-mass spectrometry (GC-MS)
Oil	Fluorescence spectrophotometry	GB 17378.4-2007	Fluorescence spectrophotometry
	Ultraviolet Spectrophotometry	GB 17378.4-2007	
	Gravimetric method	GB 17378.4-2007	
Identification of spilled oil			Gas chromatography-flame ionization detector (FID)
			Gas chromatography-mass spectrometry (GC-MS)
			Fluorescent spectrophotometry
			Infrared spectrometry

Item	Guideline of China	Standard No.	Guideline of Korea
Sulfur compound spilled			Gas chromatography (GC) - flame photometric detector (FPD)
Nickel in spilled oil			Graphite Furnace Atomic Absorption Spectro-photometry (GF-AAS)
			Inductively coupled plasma mass spectrometry (ICP-MS)
			Inductively coupled plasma-optical emission spectroscopy (*ICP-OES*)
Vanadium in spilled oil			Inductively coupled plasma mass spectrometry (ICP-MS)
			Inductively coupled plasma-optical emission spectroscopy (ICP-OES)
DDT	Gas chromatography	GB 17378.4-2007 HY/T 147.1-2013	
PCBs	Gas chromatography	GB 17378.4-2007 HY/T 147.1-2013	Gas chromatography (GC) - electron capture detector (ECD)
Dieldrin	Gas chromatography	GB 17378.4-2007 HY/T 147.1-2013	
Endrin	Gas chromatography	HY/T 147.1-2013	
Chlordane	Gas chromatography	HY/T 147.1-2013	
Mirex	Gas chromatography	HY/T 147.1-2013	
Aldrine	Gas chromatography	HY/T 147.1-2013	
Heptachlor	Gas chromatography	HY/T 147.1-2013	
PBDEs			Gas chromatography-mass spectrometry (GC-MS)-negative chemical ionization (NCI)
Endosulfan	Gas chromatography	HY/T 147.1-2013	
PAHs (Bap)	Gas chromatography-mass spectrometry	GB/T 26411-2010	
Cu	Flameless atomic absorption spectrometry	GB 17378.4-2007	Graphite Furnace Atomic Absorption Spectro-photometry (GF-AAS)
	Anodic stripping voltammetry	GB 17378.4-2007	Inductively coupled plasma mass spectrometry (ICP-MS)
	Flame Atomic Absorption Spectrophotometry	GB 17378.4-2007	
	Inductively coupled plasma mass spectrometry	HY/T 147.1-2013	
Pb	Flameless atomic absorption spectrometry	GB 17378.4-2007	Graphite Furnace Atomic Absorption Spectro-photometry (GF-AAS)
	Anodic stripping voltammetry	GB 17378.4-2007	Inductively coupled plasma mass spectrometry (ICP-MS)
	Flame Atomic Absorption Spectrophotometry	GB 17378.4-2007	
	Inductively coupled plasma mass spectrometry	HY/T 147.1-2013	
Zn	Flame Atomic Absorption Spectrophotometry	GB 17378.4-2007	Graphite Furnace Atomic Absorption Spectro-photometry (GF-AAS)
	Anodic stripping voltammetry	GB 17378.4-2007	Inductively coupled plasma mass spectrometry (ICP-MS)
	Inductively coupled plasma mass spectrometry	HY/T 147.1-2013	
Cd	Flameless atomic absorption spectrometry	GB 17378.4-2007	Graphite Furnace Atomic Absorption Spectro-photometry (GF-AAS)
	Anodic stripping voltammetry	GB 17378.4-2007	Inductively coupled plasma mass spectrometry (ICP-MS)
	Flame Atomic Absorption Spectrophotometry	GB 17378.4-2007	

Item	Guideline of China	Standard No.	Guideline of Korea
	Inductively coupled plasma mass spectrometry	HY/T 147.1-2013	
Hg	Atomic fluorescence spectrometry	GB 17378.4-2007	Cold atomic fluorescent spectrophotometry
	Cold atomic absorption spectrophotometry	GB 17378.4-2007	Cold atomic absorption spectrophotometry
	Gold capture cold atomic absorption spectrometry	GB 17378.4-2007	
Cr^{6+}	Portable spectrometer method	HY/T 147.1-2013	Graphite Furnace Atomic Absorption Spectro-photometry (GF-AAS)
			Inductively coupled plasma mass spectrometry (ICP-MS)
Total Cr	Flameless atomic absorption spectrometry	GB 17378.4-2007	Graphite Furnace Atomic Absorption Spectro-photometry (GF-AAS)
	1,5-Diphenylcarbonylhydrazide spectrophotometric method	GB 17378.4-2007	Inductively coupled plasma mass spectrometry (ICP-MS)
	Inductively coupled plasma mass spectrometry	HY/T 147.1-2013	
As	Atomic fluorescence spectrometry	GB 17378.4-2007 HY/T 152-2013	Hydride generation atomic absorption spectrophotometry
	Spectrophotometric method with arsenic hydride and silver nitrate	GB 17378.4-2007	
	Hydride generation atomic absorption spectrophotometry	GB 17378.4-2007	
	Catalytic polarography	GB 17378.4-2007	
	Inductively coupled plasma mass spectrometry	HY/T 147.1-2013	
Se	Fluorescence spectrophotometry	GB 17378.4-2007	
	3,3'-Diaminobenzidine spectrophotometric method	GB 17378.4-2007	
	Catalytic polarography	GB 17378.4-2007	
Ni	Inductively coupled plasma mass spectrometry	HY/T 147.1-2013	Graphite Furnace Atomic Absorption Spectro-photometry (GF-AAS)
			Inductively coupled plasma mass spectrometry (ICP-MS)
Co			Graphite Furnace Atomic Absorption Spectro-photometry (GF-AAS)
			Inductively coupled plasma mass spectrometry (ICP-MS)
Organophosphorus pesticide	Gas chromatography	HY/T 147.1-2013	Gas chromatography (GC) - nitrogen phosphorus detector (NPD) or flame photometric detector (FPD)
			Gas chromatography-mass spectrometry (GC-MS)
Phthalate ester	Gas chromatography	HY/T 147.1-2013	
	Gas chromatography-mass spectrometry	HY/T 147.1-2013	
Organotin			Gas chromatography (GC) - flame photometric detector (FPD)
Chloromycetin	High performance liquid chromatography / tandem mass spectrometry	HY/T 147.1-2013	
Sulfa-type antibiotics	High performance liquid chromatography / tandem	HY/T 147.1-2013	

Item	Guideline of China	Standard No.	Guideline of Korea
	mass spectrometry		