UNDP/GEF PROJECT ENTITLED "REDUCING ENVIRONMENTAL STRESS IN THE YELLOW SEA LARGE MARINE ECOSYSTEM"

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# Report of Pollution Regional Data Synthesis

The results from the activity to collect national pollution data and information from China and Republic of Korea were compiled to create a regional synthesis. This work was carried out from February to September 2006. The results of the regional synthesis will contribute to the Pollution Chapter of the Transboundary Diagnostic Analysis (TDA).

A consultant from Pukyong National University, Korea, was contracted to prepare the regional synthesis, and the draft final report is attached hereafter. During the 3rd RWG-P Meeting, the consultant will present his results-to-date, highlight the regional status and trends of importance, and show the pollution data gaps.

After reviewing the report and presentations, participants will discuss the information presented, and suggest how certain notable data and information could be included in the pollution section of the TDA.

Due to the delay in receiving national reports on data and information collection, the preparation of the regional synthesis was also delayed, which in turn, negatively impacted the preparation schedule of the regional TDA.

# Regional Synthesis Report of the Yellow Sea

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# Ⅰ. Introduction

The principal activities to be implemented in the Yellow Sea Large Marine Ecosystem (YSLME) are including four main objectives; i) regional strategies for sustainable management of fisheries, and mariculture, ii) effective regional initiatives for biodiversity protection, iii) actions to reduce stress to the ecosystem, improve water quality and protect human health, and iv) development of regional instructions and capacities. Of which, actions to reduce stress to the ecosystem, improve water quality and protect human health is the target of this regional synthesis report. However, it must be coordinated to the objectives of the other activities for sustainable fisheries and stable biodiversity in the Yellow Sea.

The procedure is designed to collect environmental data through national reports and special investigations for the regional assessment and to set critical spots for transboundary environmental issues in the region during the Transboundary Diagnostic Analysis (TDA) process. It is to identify corrective measures and a long-term strategies including investment strategies for remediation, establish a contaminant and ecological monitoring system for the long-term success of strategic action plan (SAP) and NAP implementation (Sherman, 2001).

Taking into account this situation, the synthesis regional report must describe present status of degradable and conservative pollutant including their atmospheric and terrestrial sources in the Yellow Sea precisely. Then, the risk assessment should be made to determine Yellow Sea's critical pollution spots and their priorities. The most important thing is to collect all kind of available data and information enough to assess the pollution levels and their effects on the productivity and diversity of the ecosystem.

As we are aware, marine pollution and depletion of living resources threaten the Yellow Sea ecosystem and commercial fisheries resources. Most Chinese and Korean marine scientist and policy decision-makers generally know how the status of pollution in the Yellow Sea is and that it is a bad thing, but for a scientific examination of marine pollution, value evaluation of this kind have to be quantified. In what way is it? How bad? To answer these questions, we must know what kind of atmospheric and terrestrial pollutants are discharged into Yellow Sea. And where they come from especially non-point sources? It was found that the excess additions of degradable wastes into the Yellow Sea caused harmful algal blooms frequently in the summer season. Furthermore, we should determine the conservative pollutants such as heavy metals and persistent organic pollutants in the seawater and marine organisms. They are not subject to bacterial attack and are not dissipated, but are reactive and harmful in various ways with marine organisms. Acknowledging the seriousness of those persistent pollutants, we must consider their impacts on the marine environment and commercially important plants and animals living there. In this regard, it needs to clarify the implications of these effects for food resources, human health, and amenities of marine ecosystems. All of them are initiatives and responsibilities for sustainable fisheries and balanced biodiversity of marine ecosystem

The main purpose of this regional synthesis report is to containe a scientifically-sound assessment of the national pollution data and information collected from China and Korea. Then, it should provide a regional picture of pollutants in the Yellow Sea. Based on all findings and assessment of pollution level, justify the determination of marine pollution hot spots and sensitive areas. Some recommendations for TDA will be provided for the integrated management of the Yellow Sea Large Marine Ecosystem. Furthermore, this regional report has to make comprehensive risk assessments on present status of marine pollution and national policies. It can not only establish appropriate management and mitigation strategies but also provide basis for TDA in order to conserve the wildlife Yellow Sea ecosystem. We must find what can be done and what should be done to reduce or to remove the pollution and impacts in the Yellow Sea marine ecosystem.

# Ⅱ. Methodology for the synthesis report

## 2. Targets and approaches

The purpose of this regional synthesis report is to provide scientific justifications for the sustainable productivity and balanced biodiversity in the Yellow Sea marine ecosystem. There are generally three steps; identification of the suspected agent, identification of the target, and implementation of the risk assessment. Environmental data and information will be collected and compiled from the national report, cooperative cruises report, direct interviews, and archives on oceanographic and environmental changes. After the harmonization all data and information, this regional synthesis report will be prepared for publication after approval. For more details and efficiency, a business travels has been conducted to collect actual data and management policy through direct interviews with relevant scientists and decision-makers from China and Korea.

### 1.1. Target area – The Yellow Sea

LMEs are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margins of the major current systems (Sherman and Duda, 1999). They are relatively large regions on the order of 200,000㎢ or greater, characterized by distincts : i) bathymetry, ii) hydrography, iii) productivity, iv) and trophically dependent populations. The Yellow Sea borders China and Korea. It extends to around 40° N to the north and joins the East China Sea 31°N to the south. The horizontal scale is approximately 400㎞x1,000㎞ with northern boundary at Bohai Bay and southern boundary approximately along the 200m iso-line of water depth in the northern slope of Okinawa trench, where strong feature of Kuroshio separates with the complicated feature of the Yellow Sea . The southern boundary between the Yellow Sea and the East China Sea runs from the mouth of the Yangtze river (Chang Jiang) to Jeju Island. . It was known that the sea bottom is shallow and relatively flat. The mean and maximum depth are 44m and 103m, respectively, and the area of the Yellow Sea excluding the Bohai Bay is 404,000㎢. Its volume is about 120,000㎦ of seawater (Yoo et al., 2001).

As we are well aware of, the Yellow Sea has historically been the marine silk roads of cultural and commercial exchanges and an affluent fishing grounds for sustaining the life of fishermen in China and Korea. It is a semi-closed sea between mainland China and Korean peninsula in mid latitude of the northwestern Pacific region (Yoo et al., 2001). It borders the Republic of Korea (hereafter Korea) and the Democratic People's Republic of Korea (hereafter North Korea) on the east, and the People's Republic of China (hereafter China) on the north and west. An elongated trough in north-south direction is found in the central part of the Yellow Sea. This semi-enclosed the Yellow Sea is an epicontinental shelf sea whose sediments are derived primarily from the rivers and estuaries along its margin. Each river has a distinctive flow regime and sediment discharge determined primarily by the size and geological characteristics of its drainage basin and by the climate (Schubel, 1986).

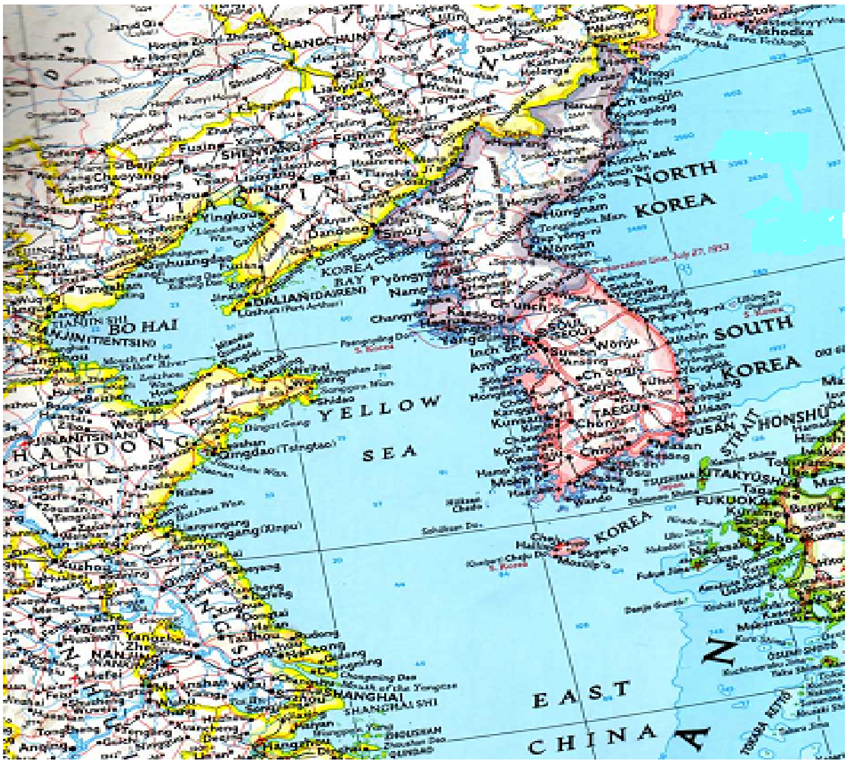



Fig. Ⅱ-1. The Yellow Sea and bordering land (Source : NATIONAL GEOGRAPHIC, Atlas of the world, sixth edition, 1990).

The topography of the Yellow sea is marked by a north-south oriented trough that is near to Korea than to China. The trough is the landward extension of a canyon formation that begins in deep waters west of Kyushu. It is well known that the Kuroshio reaches these waters before it exits the East China Sea through the Tokara Strait (Nakao, 1977). The canyon thus provides the Yellow Sea with an access to the heat and salt carried by the Kuroshio warm current.

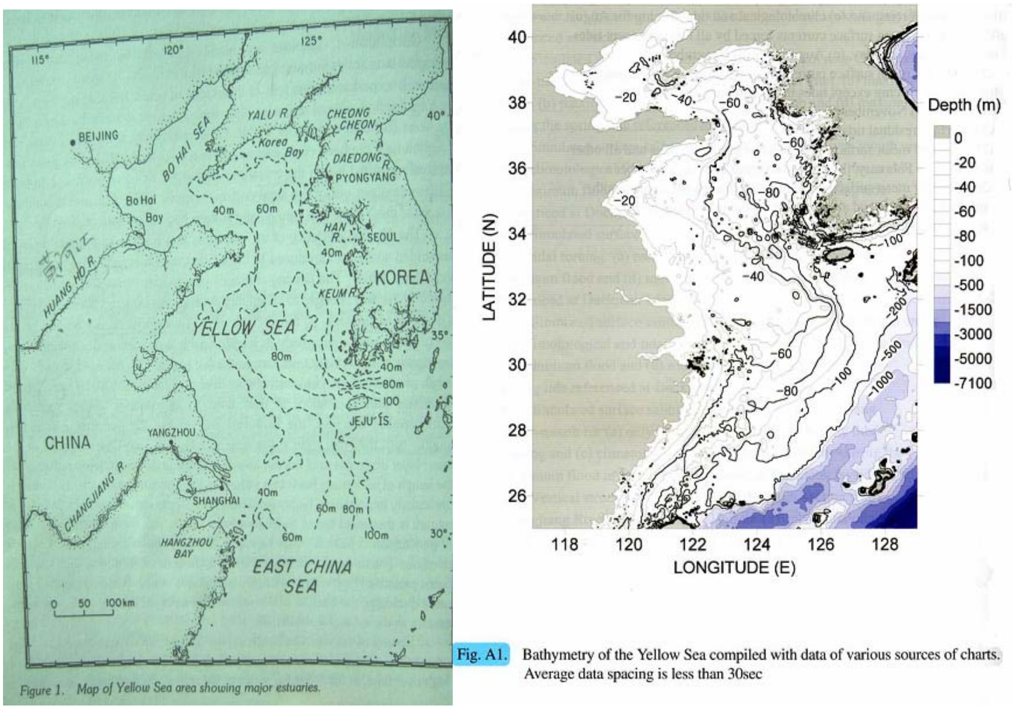



Fig. Ⅱ- 2. Map of the Yellow Sea areas showing major estuaries (Schubel et al., 1986) and bathymetry ( Kim et al., 2003).

## 1.2. Sources of data and information

Most of the data and information have been collected through the followings;

○ National reports of two countries

○ Data and information from the regular monitoring from both countries

○ Archives on oceanographic and environmental changes

○ Report of the Yellow Sea environment cooperative research between Korea and China since 1999

○ Socio-economic data and policy

All collected data and information are compiled and analyzed to assess the pollution level of the Yellow Sea. The final goal of this synthesis report is to implement risk assessment in order to determine the critical pollution factors to be utilized to establish baseline of environmental criteria.

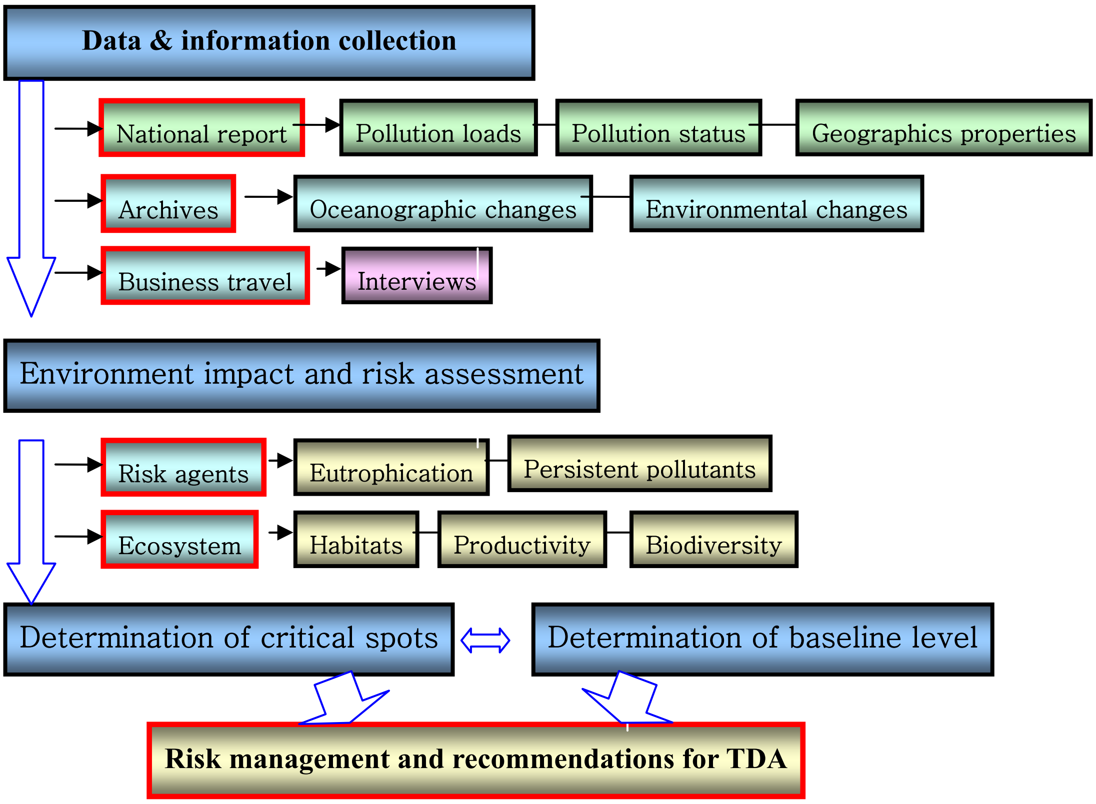



Fig. Ⅱ-3. Work procedures establishing the framework of syntheses report.

### 1.3. Business travels to the oceanographic and fisheries institutions

Chinese institutions such as National Marine Data and Information Service/State Oceanic Administration (NMDIS/SOA), Offshore Environmental Monitoring Center, State Environmental Protection Administration(OEMC/SEPA), Key Laboratory of Marine Ecology and Environmental Sciences/Institute of Oceanology, Chinese Academy of Sciences (KLMEES/IOCAS), and Yellow Sea Fisheries Research Institute under Chinese Academy of Fisheries Science.

Korean institutions include Korean Oceanographic Data Center in National Fisheries and Development Institute (KODC/NFRDI), Korea Ocean Research and Development Institute (KORDI). Ministry of Maritime Affairs and Fisheries(MOMAF) and Inha University

## 2. Synthesis report of the Yellow Sea

This report is to provide scientific basis for pollution chapter of TDA and ecosystem based management of the Yellow Sea marine ecosystem. It should include the status of pollution, risk assessments, and recommendations for the highly qualified environment and sustainable fisheries in the Yellow Sea. This can be achieved by the well designed framework of the report including assessment of pollution and its impacts which can introduce pertinent cooperative management system. All kinds of scientific and administrative understandings and integrated synthesis report of Yellow Sea ecosystem can provide new scientific and action plans for transboundary diagnostic analysis essential to establish practical regional management system for the sustainable fisheries, stable biodiversity and safety of marine food. It must include the overall status of marine pollution and risk assessment.

The main description will include atmospheric and terrestrial pollutants into the Yellow Sea, and the status of pollution based on the state of some seas such as Bohai Sea, the central part of Yellow Sea, the southern part of Yellow Sea if possible. The main component of this report has been described on chapter Ⅲ-Ⅹ.

## 2.1. Environment Risk assessment (ERA)

ERA is to assess the pollution level which introduce subsequent or potential changes in productivity, biomass, and species diversity of Yellow Sea marine ecosystem, and then search for the levels of pollution that minimize harm. It provides a basis for environmental management that balances the responsibilities to protect mankind and the environment with economic realism. Prospective risk assessment will be carried out in this report.

### 2.1.1. Prospective risk assessment based on compiled data from national report

a. What is the suspected impact and risk agent on environment?

The suspected agents will be chemical, biological, physical or a combination of the three.

b. What are the sources of the risk agent?

There are many non-point sources. It may be necessary to take more details and develop appropriate regulatory and management strategies. The likely routes of exposure also described herein.

c. What are the exposure and critical levels for living organisms?

Taking the variability in measured environmental concentrations into account, quantify the risk quotients (RQs) by using common Monte Carlo Simulation (GEF/UNDP/IMO, 1999). Otherwise, the level of eutrophication and conservative pollutants are measured using selected indicator species of plankton. Finally estimate risks on the targer.

d. What are appropriate baseline and recommendation for TDA?

Analyses and assessments based on information from the national report and interview are used to recommend governance action to improve the long-term sustainability of coastal resources and to achieve greater socioeconomic benefits.

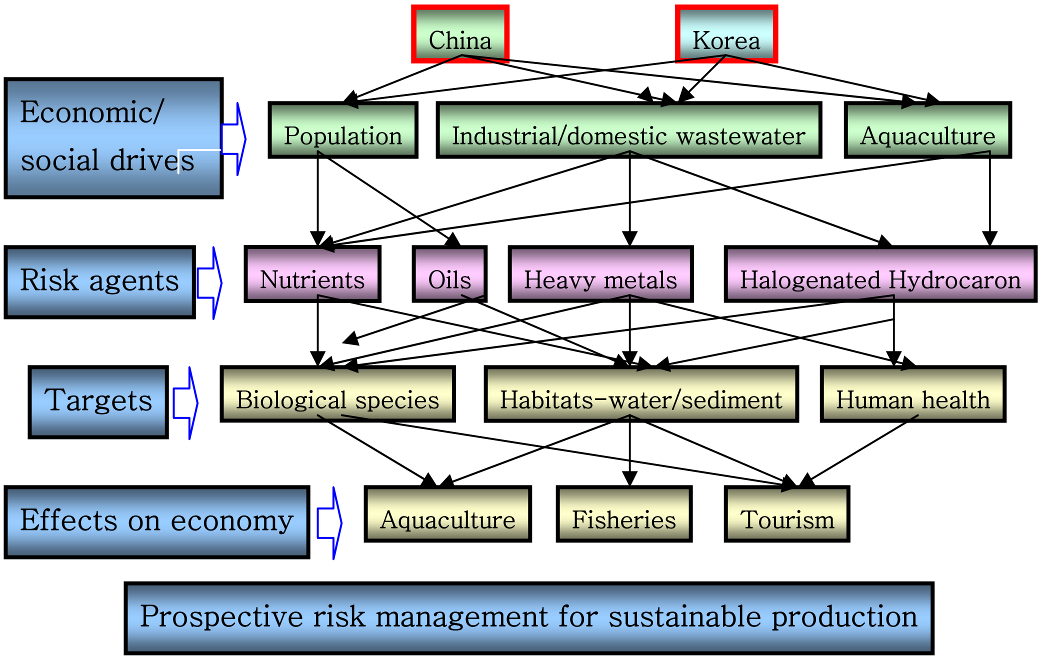



Fig. Ⅱ-4. Simplified risk assessment pathways for the Yellow Sea

**2.1.2. Baseline level and determination critical pollution spots and ranking**

The baseline contamination level for the marine ecosystem is the level not to disturb health and sustainability of ecosystem. Health and sustainable marine ecosystem can maintain its metabolic activity level and its internal structure and function, and must resist external stress over time and space scales relevant to the ecosystem. In assessing the maintenance of ecosystem, five indices such as biodiversity, stability, yields, productivity, and resilience are being considered as experimental measures of changing ecosystem states and health. Therefore, the baseline level must be determined based on these five indices. In case of biodegradable pollution, the critical pollution spots and ranking can be decided by eutrophic index such as oligotrophic, eutrophic, saprobic, and polysaprobic. Contamination level of conservative pollutant is to be ranked based on the toxicity of the pollutants estimated from median lethal concentration($LC_{50}$) and physiologically based toxicokinetic models if possible (Mckim and Nichols, 1993). ). Each water quality criteria will be recommended for baseline level of critical pollution spots.

# Ⅲ. Marine pollution loads

Marine pollution originates in many sources, such as dumping and discharges through the atmosphere, rivers, estuaries, outfalls and pipelines. GESAMP(1990) made a rough estimate of the relative contribution of all potential pollutants from various human activities is as follows; land-based sources 44%, maritime transportation 12%, dumping at sea 10%, offshore production 1%t, and atmosphere 33%. The most important inputs are the terrestrial disposal of waste waters and industrial sewage into coastal waters through river and direct inputs in the Yellow Sea. Taking into account the quantitative features, it needs to describe the discharges through atmospheric and terrestrial deposition and dumping in the Yellow Sea. In addition to the sources of the pollutants, the nature and major constituents of the wastewater and sewages should be clarified where possible.

## 1. Atmospheric deposition

Nutrients, heavy metals and persistent organic pollutants in aerosol are transported from the land to the sea. The wind direction and speed is playing an important role on the atmospheric transportation. It was known that the dominant wind over the Yellow Sea is north- northwestern wind, and south-southeastern wind in the summer season (Lee,1992). Therefore the Chinese atmospheric deposition into the Yellow Sea is more important than that of Korea. Refer to POMRAC report.

### 1.1. Into Chinese coast

According to the incomplete Chinese statistics in the mid 1990s, 230 million tons of fertilizers were applied in the coastal areas of the Yellow Sea; the average applying intensity was about 27Kg/mu (Chinese unit of area equal 1/15 of a hectare). Among them, the applying percentages of nitrogen fertilizers, phosphate fertilizers, compound fertilizers and others fertilizers were about 58%, 20%, 16% and 6% respectively. 14 million tons of pesticides were used in the coastal areas of the Yellow Sea, and the average applying intensity was about 1.75Kg/mu. Among them, the applying percentages of organic phosphorus pesticides and organochlorine pesticides were about 92% and 7.5%. According to statistical estimates, the area of aquiculture zones distributed along the coastline of the Yellow Sea was about 117 million mu, and the wastewater from aquiculture discharged into the sea was 400 million tons in every year.

Table Ⅲ-1. Variation tendencies of the atmospheric quality in four representative sea areas of China (2002-2005)

| Elements | Average value | Range |
|---|---|---|
| Cu | 0.23 | 0.057-0.60 |

| | | |
|---|---|---|
| Cd | 0.04 | 0.011-0.11 |
| Pb | 1.92 | 0.38-4.94 |
| Zn | 2.91 | 0.62-6.74 |

| Sea areas | Atmospheric deposition flux | | | | contents of pollutants in aerosols | | | |
|---|---|---|---|---|---|---|---|---|
| | TSP | Cu | Pb | Cd | TSP | Cu | Pb | Cd |
| Dalian Sea area | - | ↗ | ↗ | ⇔ | ⇔ | ↗ | ↗ | + |
| Qingdao Sea area | + | ↗ | - | ⇔ | ↗ | ↗ | ↘ | ⇔ |
| Coastal area of the Changjiang Estuary | - | ⬈ | ⬈ | + | - | ⬈ | ⬈ | ↗ |
| All national sea areas | ⇔ | ⬈ | ↗ | + | ⇔ | ⬈ | ↗ | + |

| | |
|---|---|
| ⬈ | upwards (α=0.01) |
| ↗ | upwards (α=0.1) |
| + | Not significant upwards |
| ⇔ | No change over time |
| - | Not significant downwards |
| ⬊ | downwards (α=0.01) |

Note: TSP refers to all particles in atmosphere.

### 1.2. Into Korean coast

Table Ⅲ-2. Variation tendencies of the atmospheric quality in four representative sea areas of Korea

## 2. Terrestrial deposition (River and direct inputs)

The most important terrestrial inputs in the Yellow Sea are river discharge and direct inputs. The Changjiang (Yangtze), Huang Ho (Yellow), Yalu (Aprock), Han, and Keum rivers are the most important river entering Yellow Sea. The Chinese rivers on the west coast have large water discharges, larger sediment loads and smaller tidal ranges. According to Schubel et al.(1986), the Chinese rivers make much greater contributions of sediment to the Yellow Sea than do the Korean rivers because of their much larger sediment discharges and, to a lesser extent, because of the lower filtering efficiencies of their estuaries.

Table Ⅲ-3. Major rivers entering Yellow Sea (Schubel et al., 1986)

| Characteristics | Changjiang | Huang Ho | Yalu | Han | Keum |
|---|---|---|---|---|---|
| Length (㎞) | 6,300 | 5,464 | 800 | 488 | 401 |
| Drainage area(㎢) | $1.8 x 10^6$ | $0.752 x 10^6$ | $6.1 x 10^4$ | $2.6 x 10^4$ | $1.0 x 10^4$ |
| River discharge(㎦/y) | 924 | 44.28 | 34.7 | 25 | 6.4 |
| Suspended sediment discharge (metric tons/y) | $486 x 10^6$ | $1.1 x 10^9$ | $2.04 x 10^6$ | $2 x 10^{6(est.)}$ | $1.3 x 10^6$ |

## 2.1 Land-based sources (point sources)

Land-based sources of pollution such as municipal, industrial and agricultural wastes and run-off account for as much as 80% of all marine pollution (UNEP, 2000). They are mainly composed of sewage and waste water, persistent organic pollutants, heavy metals, oils, nutrients and sediments, and brought by rivers or discharged directly into coastal waters.

### 2.1.1. Into Chinese coast

The area of polluted waters was rising unceasingly due to the increasing amount of pollutants discharged into the sea. Disorderly, excessive and gratuitous resource exploitation was the main cause of the damages to marine ecology. Since the 1990s the volume of sewage discharged into the coastal waters has been rising gradually in China. The total amount of wastewater discharged from coastal industries into the sea is about 3.98 billion tons, accounting for 19.9% of the total amount of industrial wastewater in China, 19.0% of which enters the Yellow Sea.

According to the survey and incomplete statistics in the mid 1990s, there were over 90 different kinds of pollutants discharge outlets to the Yellow Sea. Annual discharge load to the sea amounted to about 700 million tons. The amount of river runoff was about 30 billion $m^3$ per year. The results of the treatment and discharge of industrial wastewater in the coastal area of the Yellow Sea in 1996 were showed in Table Ⅲ-2. Although industrial wastewater treatment rate in the area had reached 70%, the rate in accordance with the discharging standards for industrial wastewater was below 35%. At the same time, a large amount of sewage that wasn't purified from densely populated areas and wastewater produced by well-developed agriculture was discharged into the sea, so the discharge load (amount per sq. km) to the Yellow Sea was much more than the national average discharge load. The amount of four kinds of such pollutants as COD, oils, inorganic nitrogen and inorganic phosphate discharged into the sea accounted for 99.8% of the overall discharge load of pollutants.

In the mid 1990s, the number of pollutants discharge outlets directly to the Yellow Sea accounted for 62% of the total number of land-based coastal discharge outlets to the Yellow Sea. The amount of wastewater from the discharge outlets directly to the Yellow Sea accounted for 40% of the total amount of land-based wastewater discharged into the Yellow Sea. The amount of pollutants from the discharge outlets directly to the Yellow Sea accounted for 2.8% of the total amount of land-based pollutants discharged into the Yellow Sea. The amount of three kinds of such pollutants as COD, oils and inorganic nitrogen directly discharged into the sea accounted for 99.9% of the total amount of pollutants from the discharge outlets directly to the Yellow Sea.

The number of the complex discharge outlets to the Yellow Sea accounted for 13% of the total number of land-based coastal discharge outlets to the Yellow Sea. The amount of wastewater from the complex discharge outlets to the Yellow Sea accounted for 59% of the total amount of land-based wastewater discharged into the Yellow Sea. The amount of pollutants from the complex discharge outlets to the Yellow Sea accounted for 11% of the total amount of land-based pollutants discharged into the Yellow Sea. The amount of four kinds of such pollutants as COD, oils, inorganic nitrogen and inorganic phosphate discharged into the sea accounted for 99.9% of the total amount of pollutants from the complex discharge outlets.

The number of the municipal sewage outfalls to the Yellow Sea accounted for 26% of the total number of land-based coastal discharge outlets to the Yellow Sea. The amount of wastewater from municipal sewage outfalls to the Yellow Sea accounted for 19.9% of the total amount of land-based wastewater discharged into the Yellow Sea. The amount of pollutants from the municipal sewage outfalls to the Yellow Sea accounted for 2% of the total amount of land-based pollutants discharged into the Yellow Sea. The amount of four kinds of such pollutants as COD, oils, inorganic nitrogen and inorganic phosphate discharged into the sea accounted for 99.9% of the total amount of pollutants from the municipal sewage outfalls.

The number of the rivers entering the Yellow Sea accounted for 26% of the total number of land-based coastal discharge outlets to the Yellow Sea. The amount of pollutants discharged into the Yellow Sea carried by the rivers accounted for 19.9% of the total amount of land-based pollutants discharged into the Yellow Sea. The amount of three kinds of such pollutants as COD, oils and inorganic nitrogen discharged into the sea accounted for 99.9% of the total amount of pollutants from the rivers.

In 1999, the amount of industrial wastewater discharged from 11 coastal provinces (autonomous regions, municipalities directly under the Central Goverment) into the sea amounted to 10.02 billion tons. Among them, the amount of industrial wastewater discharged directly into the seas was about 36.7 million tons, with a decrease of 310 million tons (decrease rate was 7.8%) compared with 1998, the amount of industrial wastewater discharged directly into theYellow Sea was about 710 million tons. In the same year, the amount of the sewage discharged from 11 coastal provinces (municipalities) was 10.81 billion tons. Among them, the amount of the sewage discharged directly into the seas was about 3.95 billion tons million tons, the amount of the sewage discharged directly into the Yellow Sea was about 760 million tons, accounting for 15.4% of total discharging amount.

The results of the monitoring conducted in in 2005 indicated that the phenomenon of standard-exceeding pollutants discharge in the coastal area of the Yellow Sea was still very serious (shown in Table Ⅲ-5). The environmental quality of the waters adjacent to dominant pollutants discharge outlets was at poor condition (shown in Table Ⅲ-6).

Table Ⅲ-4. Discharge and treatment of industrial wastewater in the coastal area of the Yellow Sea in China (Unit: 10 thousand tons)

| Region | Total discharging amount of industrial wastewater | Discharging amount to the sea without treatment | Industrial wastewater | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | treated Industrial wastewater | treatment rate（%） | Discharging amount in accordance with the discharging standard for industrial wastewater | Rate in accordance with the discharging standard for industrial wastewater（%） | Discharging amount in accordance with discharging standard for Industrial wastewater after treatment | Rate in accordance with the discharging standard for Industrial wastewater after treatment（%） |
| Liaoning | 124544 | 23896 | 155617 | 85.60 | 84184 | 67.6 | 35394 | 22.7 |
| Jiangsu | 219677 | 3478 | 139416 | 74.95 | 151859 | 69.1 | 46618 | 33.4 |
| Shandong | 101018 | 7873 | 204184 | 85.03 | 47849 | 47.4 | 24459 | 12.0 |

Source: China Ocean Statistical Yearbook (1997). Beijing: China Ocean Press.

TableⅢ-5. Statistics on the standard-exceeding pollutants discharge outlets to the sea in the coastal area of the Yellow Sea in 2005

| Province (Autonomous Region, Municipality) | Number of monitoring pollutants discharge outlets | Number of standard-exceeding pollutants discharge outlets | Proportion of standard-exceeding pollutants discharge outlets（%） |
|---|---|---|---|
| Liaoning | 83 | 54 | 65.1 |
| Shandong | 78 | 75 | 96.2 |
| Jiangsu | 52 | 45 | 86.5 |

Table Ⅲ-6. Grades of the eco-environment quality in the waters adjacent to some dominant pollutants discharge outlets to the sea (2005)

| Name and location of pollutants discharge outlets | | Dominant functional zones | Required water quality Categories | Actual water quality categories | Grades of ecological environment quality |
|---|---|---|---|---|---|
| Liaoning | Pollutants discharge outlets of Dalian Chemical Industry Company | Port zones | CategoryⅣ | Surpassed CategoryⅣ | Better |
| | Pollutants discharge outlets of the cooling Water of Huaneng Dandong Power plant | Mariculture zones | CategoryⅡ | Surpassed CategoryⅣ | Worst |
| | Daling River estuary into the sea | Mariculture zones | CategoryⅡ | Surpassed CategoryⅣ | Worst |
| Shandong | Pollutants discharge outlets of Qingdao Soda Ash Industrial Company Ltd | Prohibitive mariculture zones | CategoryⅢ | Surpassed CategoryⅣ | Bad |
| | Pollutants discharge outlets of Tuandao sewage treatment plant | Prohibitive mariculture zones | CategoryⅢ | Surpassed CategoryⅣ | Bad |
| | Pollutants discharge outlets of Xiaomaidao sewage treatment plant | Travelling resort | CategoryⅡ | CategoryⅣ | Bad |
| | Pollutants discharge outlets of Shandong Marine Chemical Group | Mariculture zones | CategoryⅡ | CategoryⅢ | Better |
| | Yu River estuary into the sea | Mariculture zones | CategoryⅡ | Surpassed CategoryⅣ | Worst |

| | | | | | |
|---|---|---|---|---|---|
| | Pollutants discharge outlets of Zhanhua Power plant | Multiplying regions | Category Ⅱ | Surpassed Category Ⅳ | Worst |
| | Pollutants discharge outlets of Shandong Lubei Group | Mariculture zones | Category Ⅱ | Surpassed Category Ⅳ | Worst |
| Jiangsu | Linhong River estuary into the sea | Mariculture zones | Category Ⅱ | Surpassed Category Ⅳ | Worst |
| | Zhongshan River estuary into the sea | Mariculture zones | Category Ⅱ | Surpassed Category Ⅳ | Worst |

**2.1.1. Into Korean coast**

Table Ⅲ-7.

## 2.2 Non-point source pollutants

### 2.2.1. Population

According to the global population profile 2002(www.census.gov/ipc/www/world.html), global population surpassed 6 billion in 1999. At midyear 2002, it stood at 6.2 billion and just over two people were being added each second. The population clocks in 2006 August, 9 stands at 6.533 billion. In 2002, China was not only the most populous country in the world, it was also more populous than most of the world's regions.

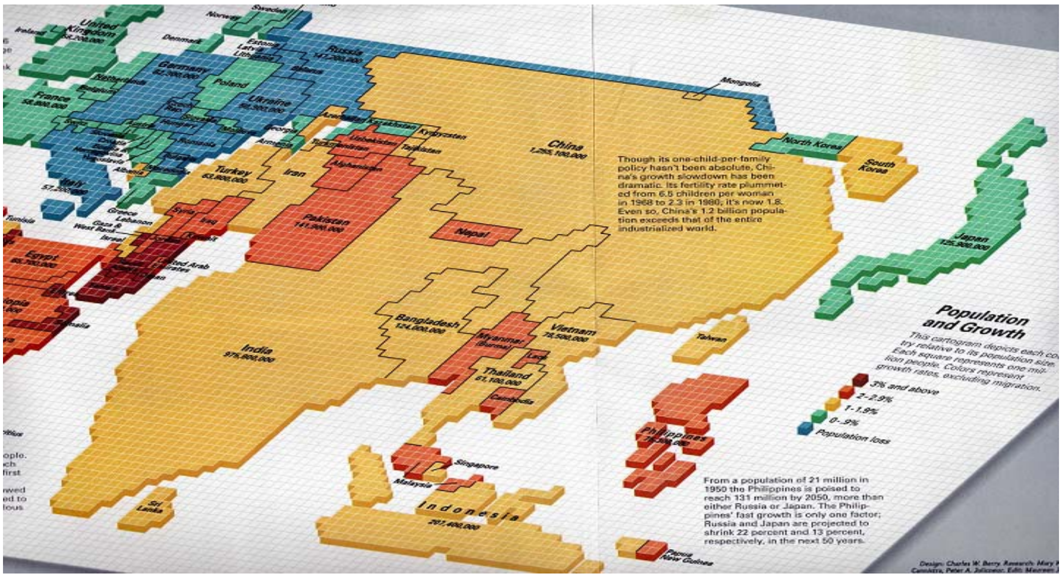



Fig. Ⅲ-1. This cartogram depicts each country relative to its population size. Each square represents one million people. Colors represent growth rates, excluding migration (Supplement to NATIONAL GEOGRAPHIC, October 1998).

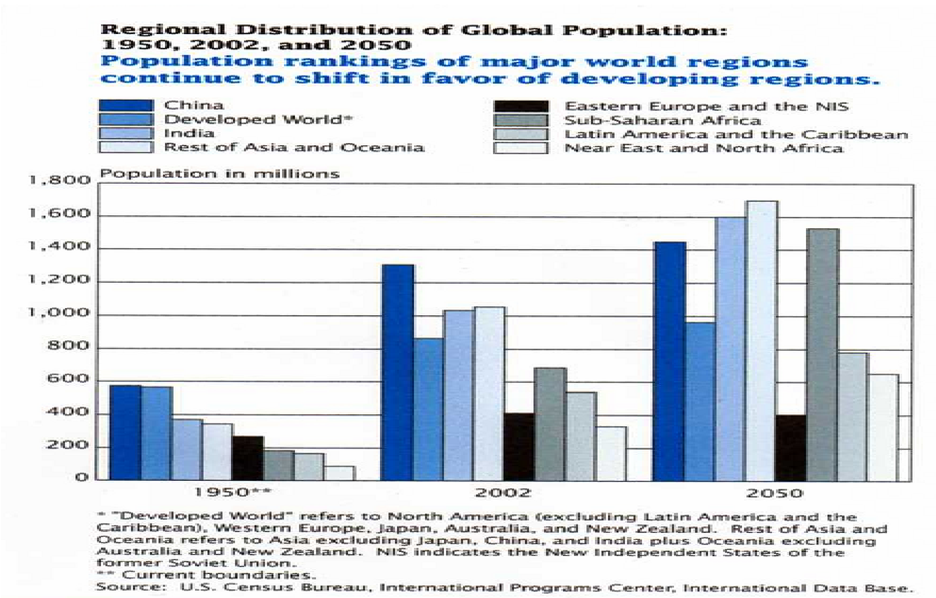



Fig. Ⅲ-2. Regional distribution of global population : 1950, 2002, and 2050 ( Source : U.S. Census bureau, Global Population Profile : 2002).

The annual average growth rate was approximately 1.2 percent in 2002, down from a high of 2.2 percent in 1963-64. It is expected that this slowdown in population growth will continue into the foreseeable future. In 2010, Chinese population will be 1,374 million with fertility rate of 1.8 percent. South and north Korean population of 70 million in 2002 will increase to 73 million in 2010 with fertility rate of 1.6 to 1.9 percent (TableⅢ-8 ).

Table Ⅲ-8. Total population and fertility rate 1980-2010 (Unit : million)

| Year | Demography | China | South Korea | North Korea |
|---|---|---|---|---|
| 1980 | Population | 1,007 | 38 | 17 |
| | Fertility rate | - | - | - |
| 1990 | Population | 1,165 | 43 | 20 |
| | Fertility rate | 2.2 | 1.6 | 2.5 |
| 2002 | Population | 1,309 | 48 | 22 |
| | Fertility rate | 1.7 | 1.6 | 2.3 |
| 2010 | Population | 1,374 | 50 | 23 |
| | Fertility rate | 1.8 | 1.6 | 1.9 |

( Source : U.S. Census bureau, Global Population Profile : 2002)

In China, Liaoning, Shandong and Jiangsu play very important roles in the north of China because of the population and the rapid development of their economy. The overall tendency of the population of these three provinces around the Yellow Sea is increasing. The population growth of the cities and counties in the coastal areas of Liaoning is slow. The population of the cities in the coastal areas of Shandong increases rapidly, especially in some cities at the county level, where the population increases rapidly after upgrade. The population of counties in the coastal areas of Shandong also increased rapidly, the population increased by about 4,000 thousands from 1996 to 2004. The population growth of cities and counties in the coastal areas of Jiangsu is slow. Table Ⅲ-9 shows the Population change in these three provinces.

Table Ⅲ-9 . Population change in these three provinces.

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|---|---|---|---|---|---|---|---|---|---|
| Liaoning Province | | | | | | | | | |
| Population in coastal cities | 609 | 616.4 | 622.3 | 626.9 | 640.5 | 646.85 | 651.47 | 672.18 | 676.68 |
| Dandong | 69 | 69.7 | 70.1 | 70.2 | 76.3 | 76.18 | 76.01 | 75.67 | 75.22 |
| Dalian | 257.2 | 259.7 | 262.4 | 264.2 | 267.8 | 270.68 | 273.23 | 274.78 | 278.09 |
| Population in coastal areas | 572.4 | 675.2 | 677 | 678.56 | 681.4 | 682.24 | 684.07 | 1087.32 | 613.94 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Changhai | 8.8 | 8.9 | 8.8 | 8.84 | 8.9 | 8.92 | 8.95 | 8.98 | 8.92 |
| Pulandian | 81.8 | 81.9 | 82.1 | 82.1 | 82.5 | 82.69 | 82.61 | 83.06 | 82.34 |
| Zhuanghe | 88 | 88.1 | 88 | 87.9 | 89.7 | 89.61 | 90.09 | 90.29 | 89.9 |
| Donggang | 65.1 | 65.4 | 65.5 | 65.48 | 63.8 | 63.83 | 64.08 | 64.05 | 64.06 |
| Shandong Province | | | | | | | | | |
| Population in coastal cities | 726 | | 892.1 | 921.2 | 1689.3 | 1495.2 | 956.9 | 3194.35 | 3305.19 |
| Yantai | 151.2 | 898.7 | 156.7 | 159.3 | 161.5 | 162.8 | 168.5 | 556.9 | 646.82 |
| Weihai | 46.1 | 154.4 | 49.6 | 50.8 | 246.9 | 247.2 | 55.2 | 247.63 | 248.39 |
| Qingdao | 223.9 | 227.2 | 229.6 | 232.2 | 706.7 | 504.3 | 241.7 | 720.68 | 731.12 |
| Rizhao | 111.2 | 272 | 274 | 275.4 | 268.8 | 276.8 | 277.6 | 278.48 | 280.48 |
| Population in coastal areas | 1224.4 | 1220.8 | 1223.7 | 1231.9 | 1167.7 | 1393.1 | 1231.7 | 1627.81 | 1624.28 |
| Jiaozhou | 74.1 | 74.7 | 75.1 | 75.4 | 75.8 | 237.7 | 76.4 | 76.45 | 76.95 |
| Jimo | 105.4 | 105.7 | 106.1 | 106.3 | 106.6 | 106.9 | 107.5 | 107.51 | 108.22 |
| Jiaonan | 83.3 | 83.5 | 83.7 | 83.6 | 83.6 | 83.7 | 83.7 | 83.8 | 80.8 |
| Changdao | 4.4 | 4.4 | 4.6 | 4.6 | 4.5 | 4.5 | 4.6 | 4.47 | 4.42 |
| Wendeng | 67 | 66.7 | 66.7 | 66.5 | 66.2 | 66 | 65.6 | 64.99 | 64.6 |
| Rongcheng | 68.5 | 68.3 | 68.3 | 68.1 | 68.1 | 67.9 | 67.4 | 67.03 | 66.75 |
| Rushan | 61.7 | 61.6 | 61.2 | 60.8 | 60.5 | 60 | 59.4 | 58.67 | 58.12 |
| Jiangsu Province | | | | | | | | | |
| Population in coastal cities | 177.31 | 180.8 | 183.5 | 187.4 | 190.6 | 207.33 | 210.94 | 2041.96 | 2040.88 |
| Nantong | 62.21 | 63.2 | 63.9 | 64.6 | 65.1 | 79.54 | 81.23 | 777.62 | 773.79 |
| Lianyungang | 58.17 | 59.4 | 59.7 | 61.7 | 62.5 | 63.86 | 64.74 | 467.83 | 468.81 |
| Yancheng | 56.93 | 58.2 | 59.9 | 61.1 | 63 | 63.93 | 64.97 | 796.51 | 798.28 |
| Population in coastal areas | 1228.76 | 1412.2 | 1419.2 | 1419.7 | 1427.1 | 1413.68 | 1413.92 | 1478.66 | 1408.49 |
| Haian | 99 | 99.2 | 98.9 | 98.5 | 98.2 | 79.76 | 97.27 | 96.54 | 95.98 |
| Rudong | 113.2 | 112.9 | 112.6 | 112.1 | 111.5 | 110.89 | 110.11 | 109.36 | 108.46 |
| Haimen | 103.46 | 103.2 | 104.9 | 103.7 | 103.6 | 103.13 | 102.75 | 102.33 | 108.32 |
| Qidong | 113.2 | 116.8 | 116.6 | 116.6 | 116.2 | 115.67 | 115.13 | 114.38 | 113.4 |
| Tongzhou | 145.57 | 145.7 | 145.2 | 144.7 | 144.3 | 130.19 | 129.21 | 128.13 | 127.14 |
| Ganyu | 100.89 | 101.6 | 102.6 | 102.6 | 104.8 | 105.83 | 106.83 | 107.91 | 107.09 |
| Guanyun | 98.44 | 99.2 | 101.3 | 102.3 | 104.2 | 104.88 | 106.26 | 107.23 | 107.25 |
| Xiangshui | 54.64 | 55 | 55.5 | 55.7 | 56.5 | 56.79 | 56.91 | 57.21 | 57.53 |
| Binhai | 106.68 | 107.2 | 106.6 | 106.8 | 107 | 107.3 | 108.03 | 108.57 | 108.64 |
| Shexiang | 102.31 | 103 | 104.2 | 104.8 | 105.5 | 105.3 | 105.07 | 104.7 | 104.34 |
| Dafeng | 74 | 74.2 | 74.1 | 74 | 74.1 | 74.07 | 73.77 | 73.37 | 73.05 |
| Dongtai | 117.37 | 117.2 | 117.6 | 117.6 | 117.3 | 116.8 | 116.38 | 116.24 | 114.43 |

The population of the coastal cities of Jiangsu province changed in 2003 and 2004 because of different statistical methods

In order to estimate anthropogenic pollutants, the population residing coastal zone should be estimated to quantify the non-point source of terrestrial pollutants. UNEP(2000) report that seven out of 10 people around the globe live within 80㎞ of the shoreline. Almost half the world's cities with a population of over one million are sited near tide-washed river mouths. Along the coast of the Yellow Sea, more than seven cities such as Dalian, Tianjin, Quindao, Shanghai to the western Chinese coast and Pyongyang, Incheon to the eastern Korean coast have a population of over one million. Taking into account the difficulties in population census, when estimate 30 to 70 percent of the total population is residing in the coastal area in 2002, it will be 413.7 – 965.3 million. Based on this situation, the demographic non-point pollution load is ranged from ----.

#### 2.2.2. Livestock

## 2.3. Discharge and treatment of wastewater in the coastal areas

With China's rapid economic growth, the production of important industrial raw materials such as steel, electrolysis aluminum, cement, etc. increases substantially, and the supply of energy such as coal, electric power etc. falls short of demand. The rapid growth of heavy-pollution and high-energy-consumption industries brings great pressure on the environment, the environment pollution by the rapid growth of some industries have exceeds the capacity of environmental protection efforts. The discharging amount of wastewater and pollutants from three provinces around the Yellow Sea doesn't change over time. The discharge and treatment of wastewater is at a medium level, as shown in Table Ⅲ-10 to Table Ⅲ-13.

Table Ⅲ-10. Statistics on total amount of pollutants discharged into the Yellow Sea in recent years

| Year | Waste water (10 million tons) | | | COD (10 thousand tons) | | | Ammoniac nitrogen (10 thousand tons) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | Industry | Domestic | Total | Industry | Domestic | Total | Industry | Domestic |
| 2002 | 5.9 | 2.7 | 3.2 | 16.2 | 4.3 | 11.9 | 1.8 | 0.3 | 1.5 |
| 2003 | 5.9 | 2.6 | 3.3 | 15.2 | 4.1 | 11.1 | 1.6 | 0.3 | 1.3 |
| 2004 | 5.8 | 2.6 | 3.2 | 15.4 | 4.2 | 11.2 | 1.5 | 0.2 | 1.3 |

Table Ⅲ-11. Discharge and treatment of land-based industrial wastewater into the sea in recent years

| Year | region | Counted Number of Industrial Enterprises | Total discharging amount of industrial wastewater (10 thousand tons) | Discharging amount to the Sea Without Treatment (10 thousand tons) | Amount in compliance with the discharging standard for Industrial Wastewater (10 thousand tons) | Wastewater treatment facilities (sets) | Running Cost of Facilities in the Year (10 thousand Yuan) |
|---|---|---|---|---|---|---|---|
| 2002 | Liaoning | 139 | 665 | 311 | 585 | 78 | 1210.4 |
| | Jiangsu | 958 | 18857 | 1049 | 18652 | 484 | 9653.7 |
| | Shandong | 448 | 7849 | 5233 | 7848 | 388 | 12607.2 |
| | Total | 1545 | 27372 | 6593 | 27085 | 950 | 23471.3 |
| 2003 | Liaoning | 128 | 1083 | 433 | 1004 | 70 | 933.3 |
| | Jiangsu | 829 | 17846 | 798 | 17846 | 465 | 11446.0 |
| | Shandong | 454 | 7141 | 2225 | 7075 | 393 | 13683.2 |
| | Total | 1411 | 26070 | 3456 | 25925 | 928 | 260062.5 |
| 2004 | Liaoning | 92 | 439 | 25 | 405 | 55 | 648.4 |
| | Jiangsu | 779 | 16782 | 440 | 16615 | 469 | 8756.1 |
| | Shandong | 444 | 8171 | 2257 | 7900 | 381 | 16939.7 |
| | Total | 1315 | 25392 | 2722 | 24920 | 905 | 26344.2 |

Table Ⅲ-12. Discharge and treatment of land-based industrial wastewater into the sea in recent years

(Unit: ton)

| Year | region | Discharging amount of pollutants in industrial wastewater | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hg | Cd | $Cr^{6+}$ | Pb | As | Volatile phenolic compounds | Cyanide | COD | Oils | Ammoniac nitrogen |
| 2002 | Liaoning | | | 0.009 | 0.038 | 0.006 | | 0.1 | 1476.5 | 0.0 | 627.0 |
| | Jiangsu | | 0.003 | 0.745 | 0.012 | 0.645 | 3.391 | 0.6 | 25185.4 | 16.5 | 2199.7 |
| | Shandong | | | 0.110 | 0.001 | 0.039 | 1.008 | 0.2 | 16262.4 | 14.8 | 338.0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | | 0.003 | 0.864 | 0.051 | 0.690 | 4.399 | 0.9 | 42924.3 | 31.3 | 3164.6 |
| 2003 | Liaoning | | | 0.003 | | 0.006 | | | 2130.2 | | 635.8 |
| | Jiangsu | | 0.011 | 1.201 | 0.009 | 0.645 | 3.444 | 0.3 | 22141.9 | 17.9 | 2345.8 |
| | Shandong | | | 0.117 | | 0.040 | 0.633 | 0.4 | 16779.8 | 18.0 | 397.8 |
| | Total | | 0.011 | 1.321 | 0.010 | 0.691 | 4.077 | 0.7 | 41051.9 | 35.9 | 3379.4 |
| 2004 | Liaoning | | | 0.002 | | 0.006 | | | 886.0 | | 10.7 |
| | Jiangsu | | | 1.325 | 0.135 | 0.672 | 3.351 | 0.5 | 17148.0 | 17.2 | 1385.0 |
| | Shandong | | | 0.107 | 0.001 | | 0.883 | 0.2 | 24314.3 | 17.3 | 606.5 |
| | Total | | 0.010 | 1.434 | 0.136 | 0.678 | 4.234 | 0.7 | 42348.3 | 34.4 | 2002.1 |

Table Ⅲ-13. Discharge and treatment of land-based industrial wastewater into the sea in recent years

(Unit: ton)

| Year | region | Discharging amount of pollutants in industrial wastewater | | | | |
|---|---|---|---|---|---|---|
| | | Volatile phenolic compounds | Cyanide | COD | Oils | Ammoniac nitrogen |
| 2002 | Liaoning | | 0.8 | 3056.7 | | 66.5 |
| | Jiangsu | 5.6 | 17.5 | 93326.9 | 14.7 | 539.3 |
| | Shandong | 24.7 | 3.1 | 152241.5 | 104.7 | 705.6 |
| | Total | 30.3 | 21.4 | 248625.2 | 119.4 | 1311.5 |
| 2003 | Liaoning | | | 6803.0 | | 32.2 |
| | Jiangsu | 19.6 | 11.3 | 81605.0 | 1.7 | 824.2 |
| | Shandong | 21.1 | 3.5 | 157763.5 | 97.3 | 731.5 |
| | Total | 40.7 | 14.8 | 246171.6 | 99.1 | 1587.8 |
| 2004 | Liaoning | | | 2137.6 | | 0.2 |
| | Jiangsu | 7.3 | 15.8 | 44275.1 | 3.9 | 10945.7 |
| | Shandong | 20.6 | 3.5 | 194624.1 | 63.5 | 394.3 |
| | Total | 27.9 | 19.4 | 241036.7 | 67.4 | 11340.3 |

## 3. Ocean dumping

Ocean dumping is one of directs inputs. The most important materials dumped at sea are dredged material, industrial wastes, sewage sludge and radioactive wastes. It was known that China and Korea have designated one dumping site in the Yellow Sea (Yang, 2000).

### 3.1. What is dumped at sea

On the global statistics, about 80-90% of the material dumped at sea results from dredging. Between 1980 and 1985 the reports provided to IMO show an average of 215 million tones of dredged material dumped at sea annually (IMO, 1991). Both China and Korea have designated one dumping site in the Yellow Sea. Chinese dumping site of 3,850 ㎢ is located in 31˚-31˚N, 122˚-124˚E off Qingdao (Hong et al., 1999). It was reported that the main dumping materials were dredging materials (Yang et al., 2000). Meanwhile, annual Chinese total amount of dumping disposal into the Yellow Sea was composed of 8.7x$10^9$㎥/y of domestic waste water and 1.47x$10^6$㎥/y of industrial and municipal wastes (Yang et al., 2000). However in recent, I have no details of dumping disposal in this sea. Korean dumping site of 3,165 ㎢ is located in 35˚27´-36˚12´N, 124˚13´-124˚38´E off Kunsan (Yang et al., 2000). The amount of dumping 0.547x$10^6$㎥/y in 1988 has been increased to 2,380x$10^6$㎥/y in 1999. Generally speaking, most of the industrial wastes consist of acid and alkaline waste, coal ash, flue gas desulpurization sludges, scrap metal waste and fish processing waste. The sewage sludge resulting from sewage treatment operations consists of nutrients. However, Chinese dumping disposal are different from Korean owing to the industries and life status of the people.

### 3.2. The problems involved in dumping materials.

Current dumping at sea comprised mostly industrial wastes, sewage sludge, and dredging materials (IMO, 1991). The important environmental problems associated with disposal are human health risks from the presence of pathogens, eutrophication due to nutrients and organics, and toxic effects on marine organisms and/or man caused by various chemicals.

# Ⅳ. Oceanographic properties of the Yellow Sea

## 1. Seawater movement and currents

### 1.1. General circulation

It was known that there are five major water masses identified in the Yellow Sea : the Yellow Sea Warm Current (YSWC), the Yellow Sea Bottom Cold Water (YSBCW), the Korean Coastal Water, The China Water and the Changjiang Diluted Water (Su and Weng, 1994). The circulation pattern of the Yellow Sea is not yet far from clear understanding, or no prominent feature of circulation might be present in the

Yellow Sea. However based on analysis of the temperature and salinity data, the Yellow Sea circulation can be characterized into two types (Lee et al., 2002). In winter, it has been believed that the northward Yellow Sea Warm Current (YSWC) appears in the interior and two southward coastal flows develop along China and Korea coasts. In summer, there is a southward China coastal current (CCC), a northward Korean coastal flow (KCC) and a cyclonic flow system between them.

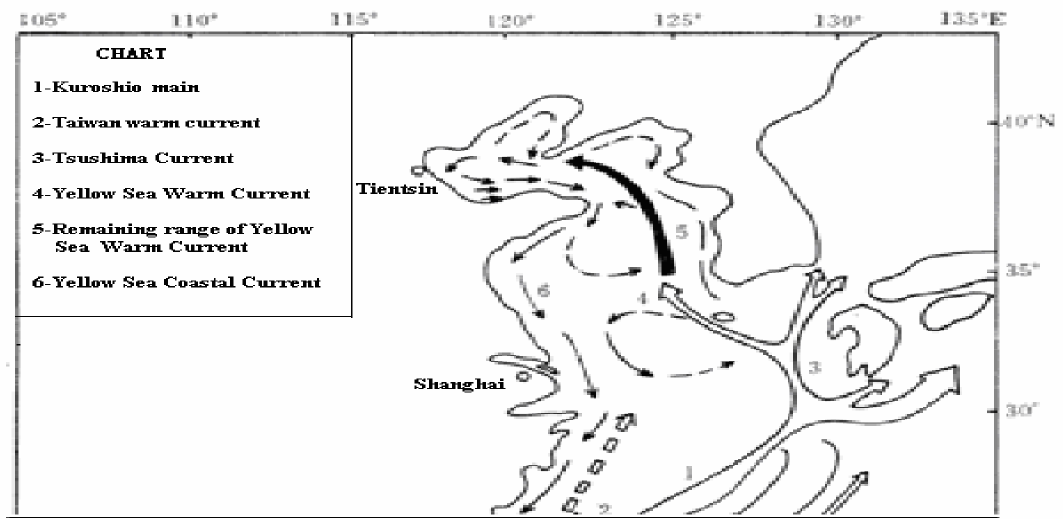



Fig. Ⅳ-1. Chart showing the currents of the Yellow Sea

## 1.2. Tidal current

The Yellow Sea is a semi-closed sea, its frangibility of environment is determined by its dynamical environmental characteristics, including semi-closed sea area, the great dependence of species on the natural habitats and the strong influence of rivers flowing into the Yellow Sea. The Yellow Sea Coastal Current is a diluent current that flows into the Changjiang river estuary from the Bohai Bay across the Shandong peninsula and the coastal area of JiangSu (shown in Fig. Ⅳ-2), the direction of this current remains steadily all of the years. This area has lower salinity and wider range temperature, so the biota is dominated by the wide-temperature and low-salinity species. The species varies greatly between summer and winter, the number of species increases gradually from the north to the south. That is the basic ecosystem characteristic of the coastal shallow areas of the Yellow Sea.

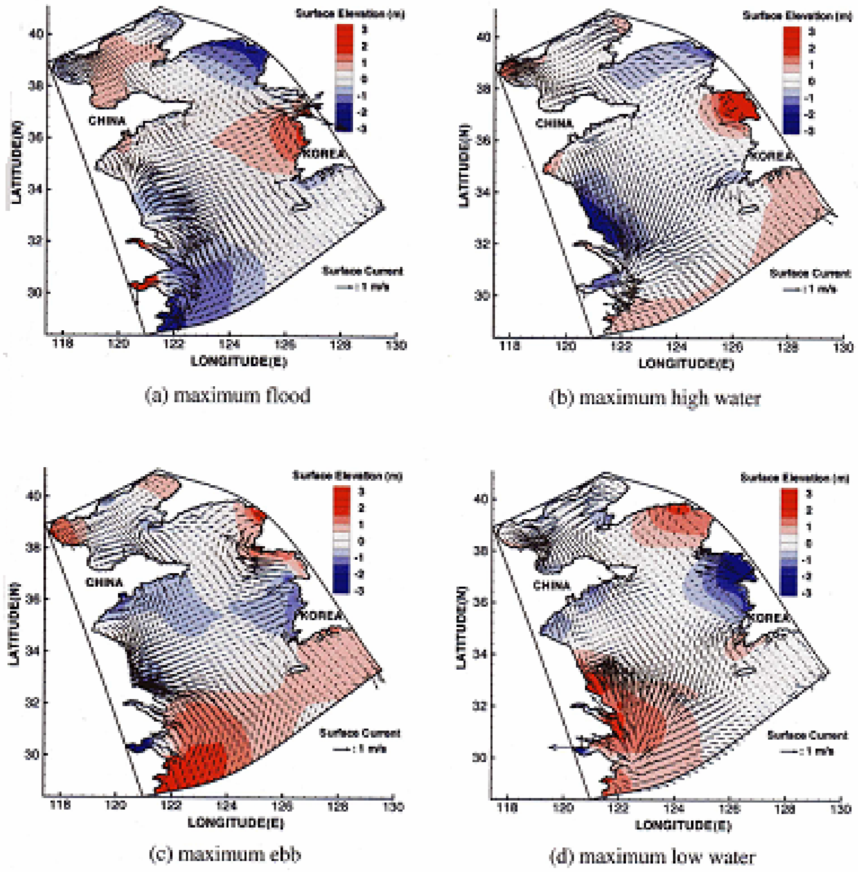



Fig. A13. Simulated surface elevation and surface current under the climatological forcing and tides. (a) maximum flood, (b) maximum high water, (c) maximum ebb and (d) maximum low water during the spring tide referenced at Duckjeok Island

Fig. Ⅳ-2. simulated surface elevation and surface current under the climatological forcing and tides. (a) maximum flood, (b) maximum high water, (c) maxiumum ebb and (d) maxiumum low water during the spring tide referenced at Duckjeok Island.

The tide, tidal range, and the residual currents in the coastal areas (shown in Fig. Ⅳ-3) indicate that the dynamical environment of the Yellow Sea is in the condition of regular movement

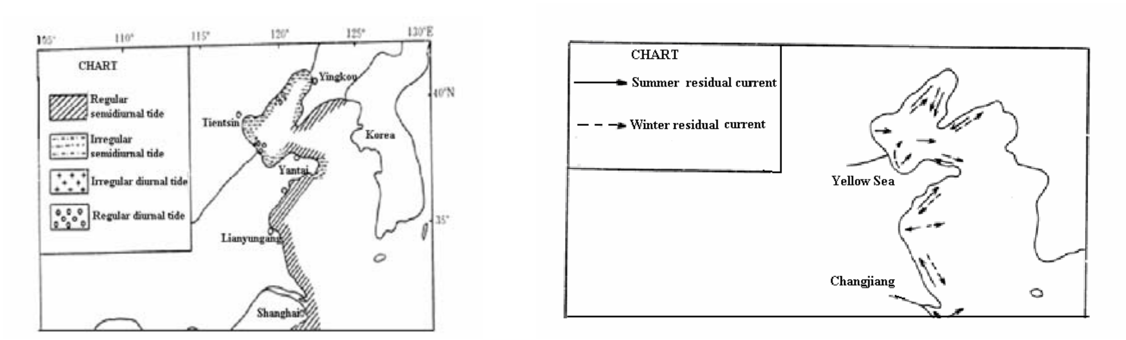



Fig. Ⅳ-3. Tide and the residual currents in coastal areas of the Yellow Sea

## 1.2. Temperature

The simulated SST field shows an evident seasonal variation (Kim et al.,2003). The initial condition of Levitus shows the isotherm lines running nearly in parallel with the latitude in the basin interior of the Yellow Sea, except near the coastal area where iso-lines are following the shape of the coastal line due to the land effects. In winter, the SST ranges approximately from 15℃ in the south to 3℃ in the north. This winter distribution shows a northward intrusion of warm waters into the central basin of the Yellow Sea, yielding a tongue-shape isotherm lines. In summer, the SST in the south is around 27℃ and also relatively high up to 24-26 ℃in north and coastal waters.

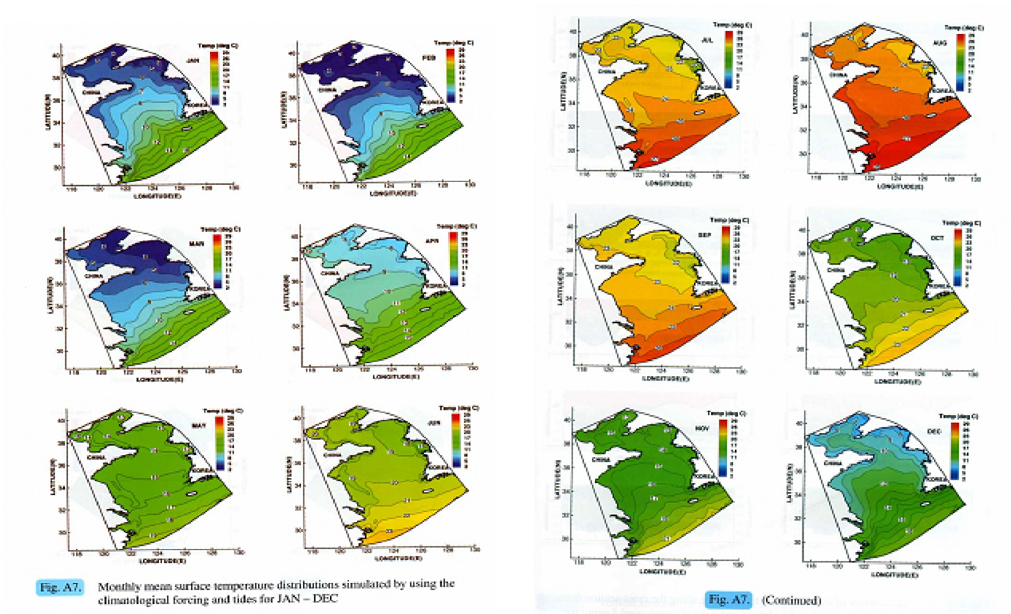



Fig. Ⅳ-4. Monthly mean surface temperature distribution simulated by using the climatological forcing and tides for January -December (source, Kin et al., 2003).

And, the simulated SSt field is nearly coincide with the initial ones as shown in Fig.Ⅳ-4. In terms of inter-annual SST distribution, the horizontal temperature gradient is not significantly shown, except in coastal waters where local tidal fronts frequently observed.

## 1.3. Salinity

The simulated monthly sea surface salinity (SSS) field shows low saline waters along the continental coastal area, particularly along the Chinese coastal line. The distribution of climatological surface salinity shows higher saline waer in the Korean coastal area than the Chinese coast. The annual range of surface salinity change in the Yellow Sea basin is approximately 5psu. The maximum salinity occurs at above 34.0psu in the south in winter, while northern water shows lower than 30.0 psu in winter. As the fresh water discharge from the major rivers around the Yellow Sea increases in summer, the salinity in the coastal waters along Chinese waters dramatically gets lowered due to the fresh water dilution, particularly around the Changjiang river estuary.

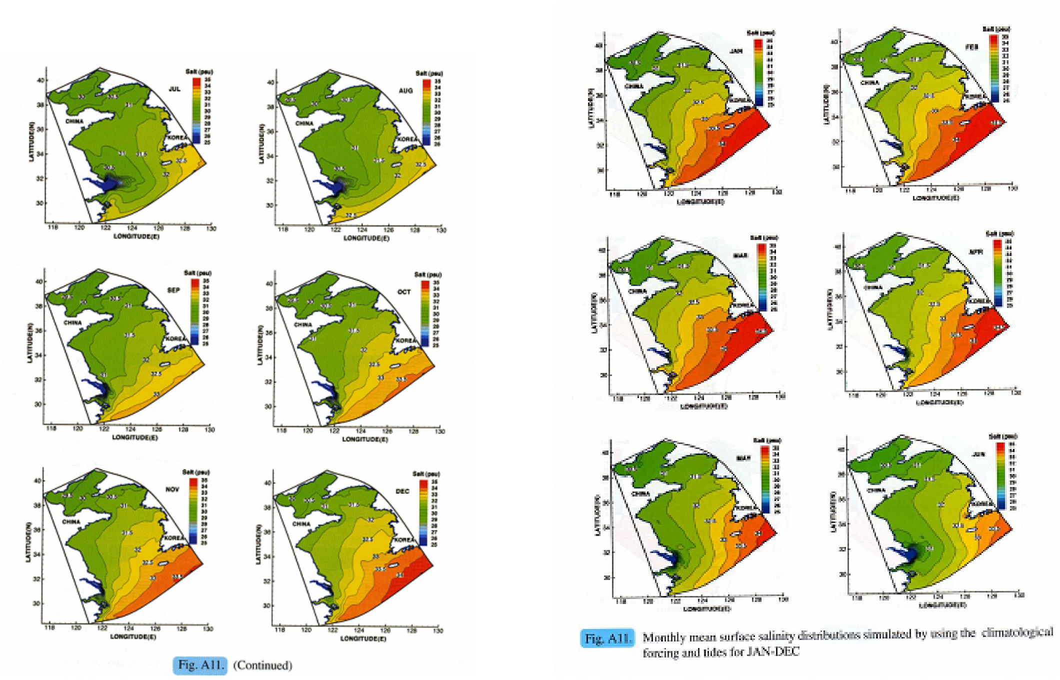



Fig.Ⅳ-5.Monthly mean surface salinity distribution simulated by using the climatological forcing and tides for January –December (source, Kin et al., 2003).

The salinity at the south open boundary is about 32.5 psu while the salinity around the Changjiang river estuary is as low as below 30.0psu. As in the simulated inter-annual surface distribution, the low saline water originated from the Changjiang river estuary expands to east reaching to at least 125˚ E.

Variations of salinity in the section located in thirty and four degrees north latitude in the Yellow Sea are shown in Fig. Ⅳ-6 and Ⅳ-7.

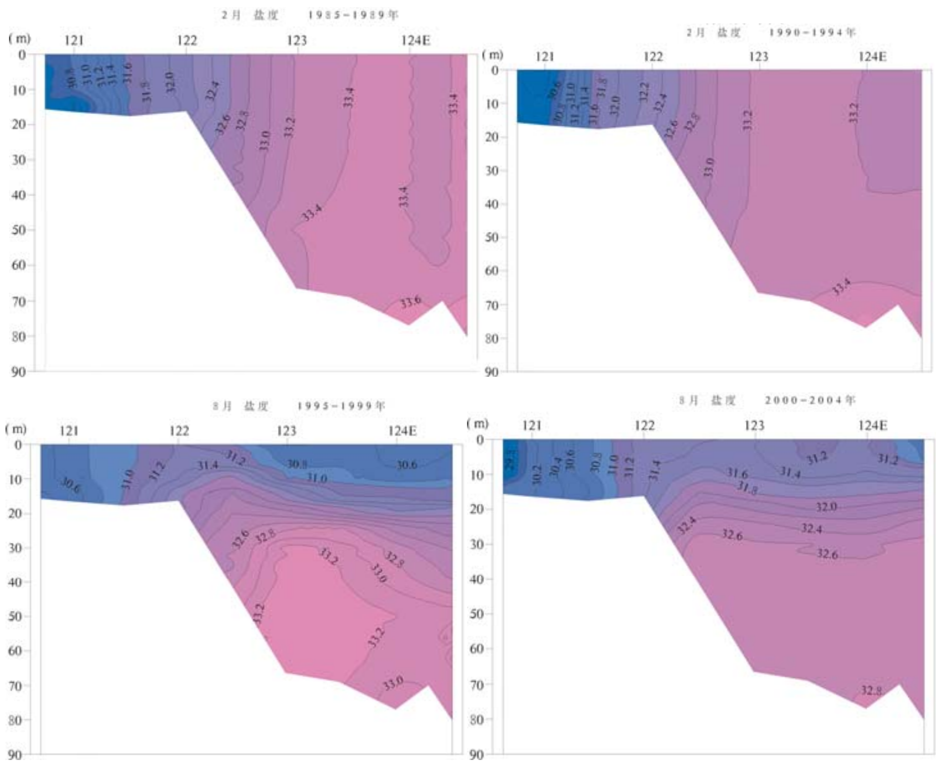



Fig. Ⅳ-6. Variations of salinity in the Yellow Sea in recent 20 years (February)

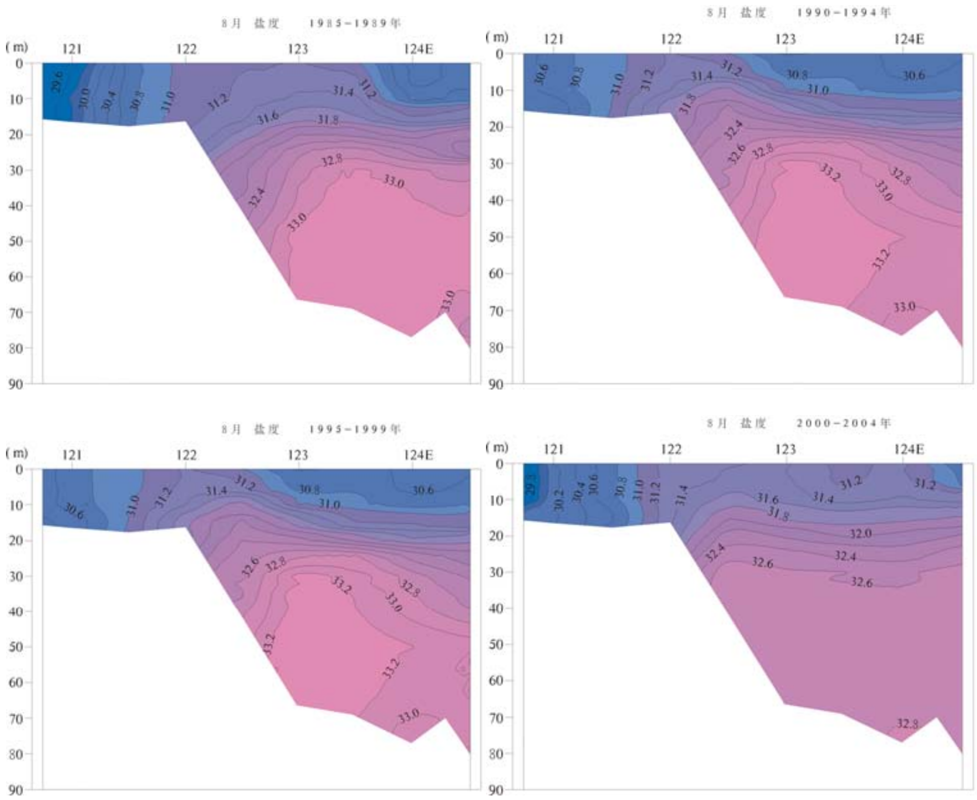
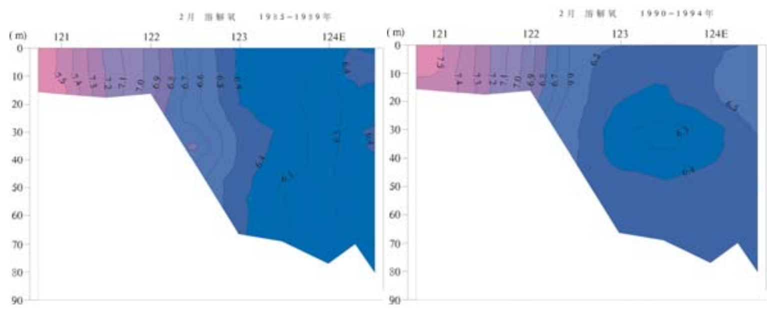



Fig. Ⅳ-7. Variations of salinity in the Yellow Sea in recent 20 years (August)

### 1.3. Dissolved oxygen

Variations of dissolved oxygen content in the section located in thirty and four degrees north latitude in the Yellow Sea are shown in Fig. Ⅳ-8 and Ⅳ-9.



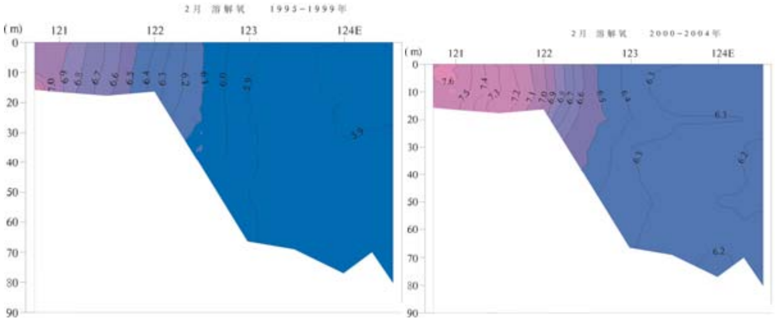


Fig. Ⅳ-8. Variations of dissolved oxygen content in the Yellow Sea in recent 20 years (February)

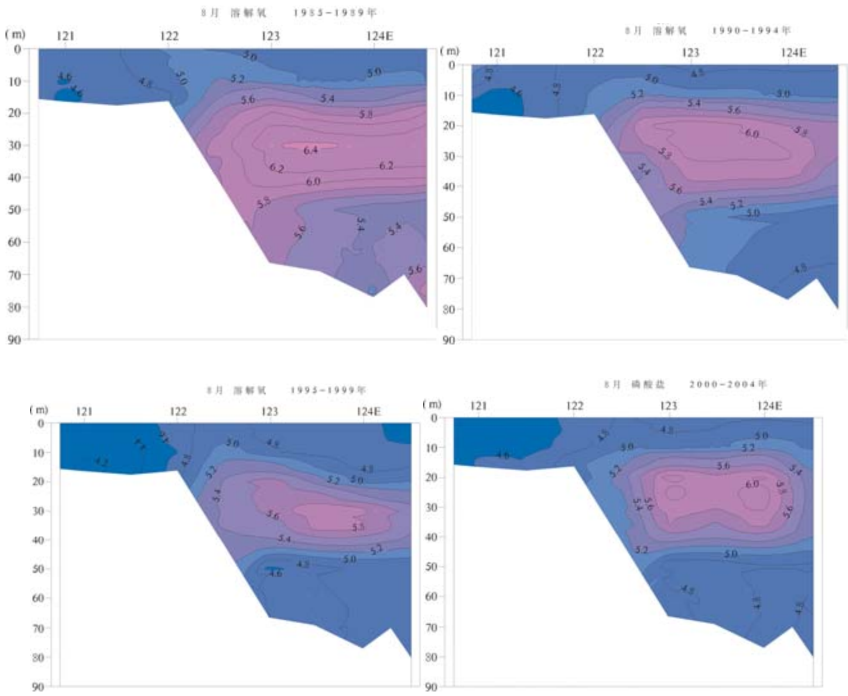


Fig. Ⅳ-9. Variations of dissolved oxygen content in the Yellow Sea in recent 20 years (August)

## 1.4. pH value

Recent tendency of pH value in the Chinese coastal waters of the Yellow Sea is shown in Fig. Ⅳ-10. The pH value had changed in some degrees in the coastal waters of Shangdong. A comparison made between the monitoring results of 1981and 1998 indicated: pH values ranged from 7.50 to 8.65 in spring 1998, with the range of 1.15, and pH values ranged from 7.10 to 8.50 in autumn 1998, with the range of 1.40. The pH value ranged from 7.89 to 8.48 in spring 1981, with the range of 0.59, the pH value ranged from 8.01 to 8.53 in autumn 1981, with the range of 0.52. It was evident that the range of the pH values in spring and autumn 1998 was wider than that in the same period of 1981. The increase of the range of pH values showed that the instability of environmental conditions was increasing in this area.

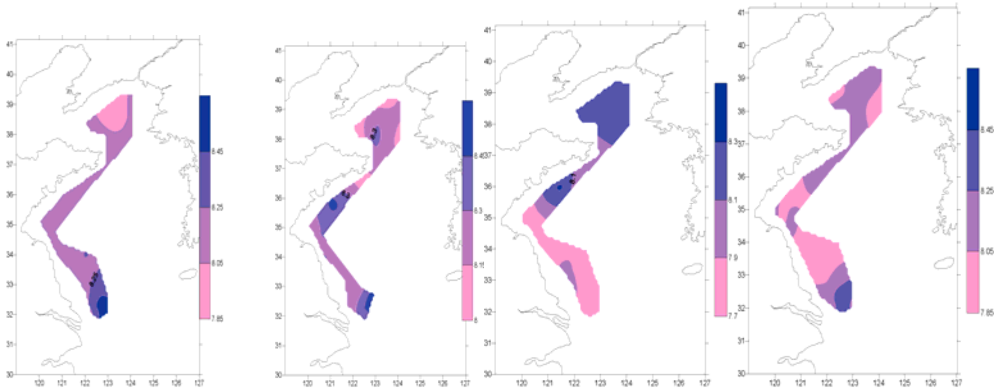


Fig. Ⅳ-10. Distribution of pH value in the coastal waters of the Yellow Sea, China (Aug., 2002- 2005)

# Ⅴ. Present status of marine pollution

## 1. Eutrophication and nutrient dynamics

### 1.1. Nutrients dynamics

#### 1.1.1. Ammonium

Variations of ammonium content in the section located in thirty and four degrees north latitude in The Yellow Sea are shown in Fig. Ⅴ-1 and Ⅴ-2 in recent 15 years. Distribution of ammonium content in the seawater of the Yellow Sea in autumn 2000 and spring 2001 is shown in Fig. Ⅴ-3.

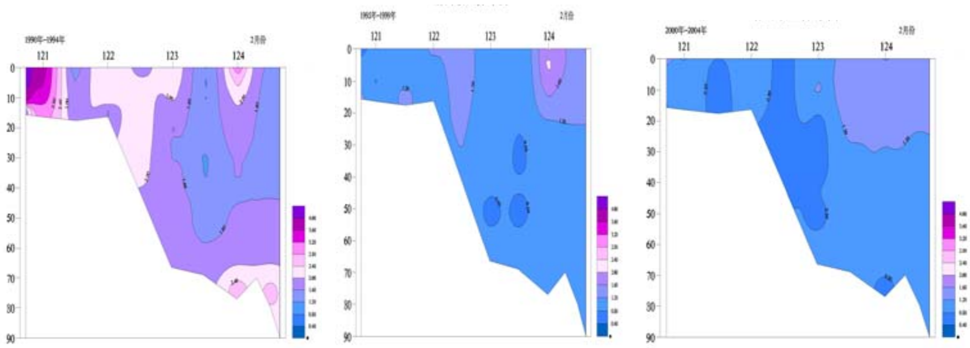


Fig. Ⅴ-1. Variations of ammonium content in seawater of the Yellow Sea for the recent 15 years

(February)

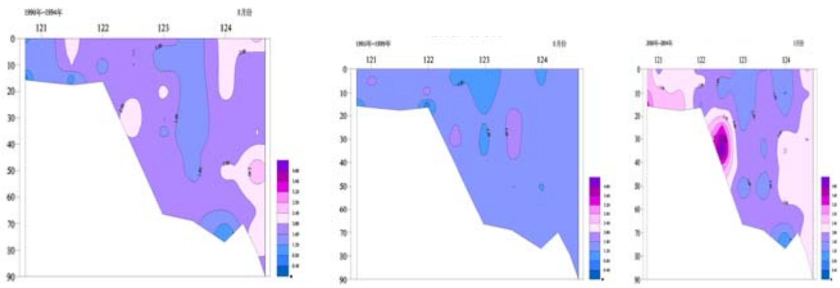


Fig. Ⅴ-2. Variations of ammonium content in seawater of the Yellow Sea for the recent 15 years (August)

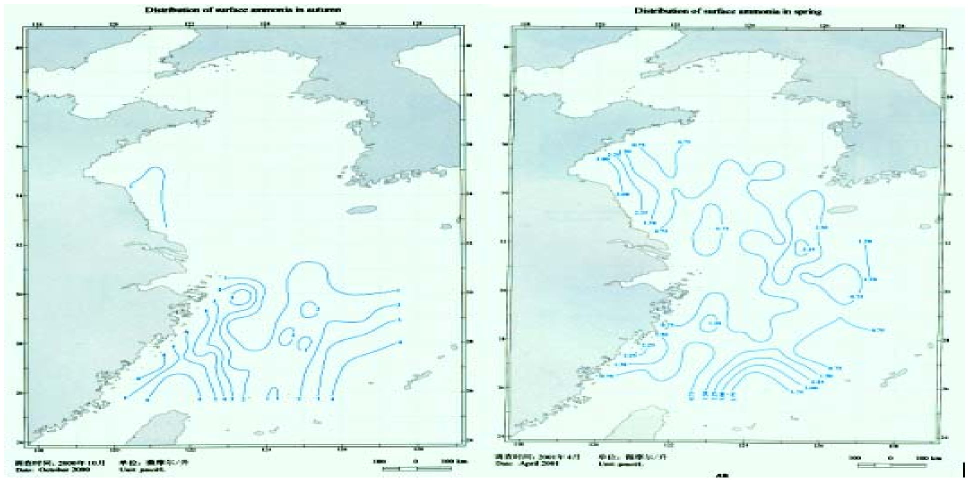



Fig. Ⅴ-3. Distribution of ammonium content in seawater of the Yellow Sea (left: autumn 2000, right: spring 2001)

**1.1.2. Nitrite**

Variations of 20 years of nitrite content in the section located in thirty and four degrees north latitude in the The Yellow Sea are shown in Fig.Ⅴ-4 and Ⅴ-5. Distribution of nitrite content in the seawater of the Yellow Sea in autumn 2000 and spring 2001 is shown in Fig.Ⅴ-6. Variations of nitrite content in the coastal waters of the The Yellow Sea in recent years are shown in Fig.3-2-13-Fig.3-2-16.

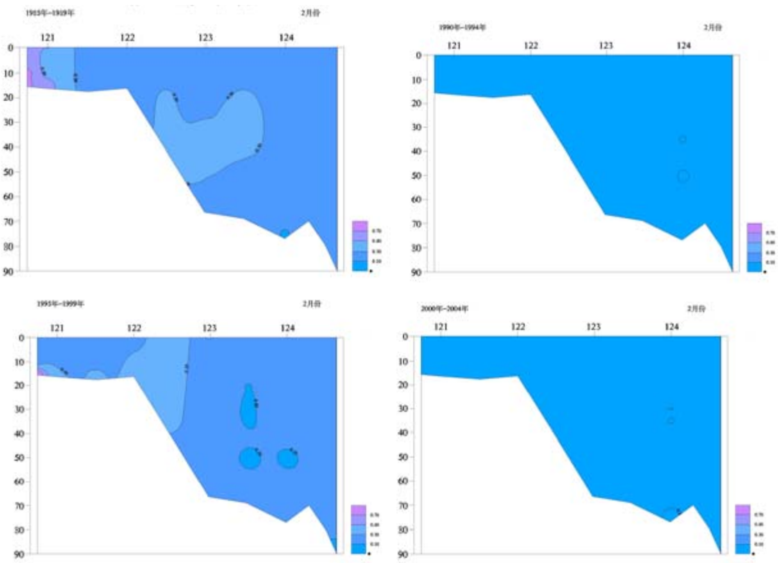
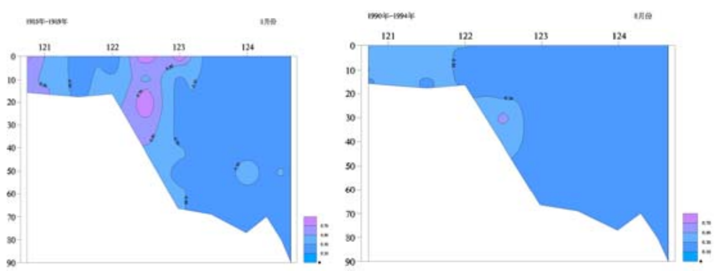


Fig. Ⅴ-4. Variations of nitrite content in the Yellow Sea in recent 20 years (February)



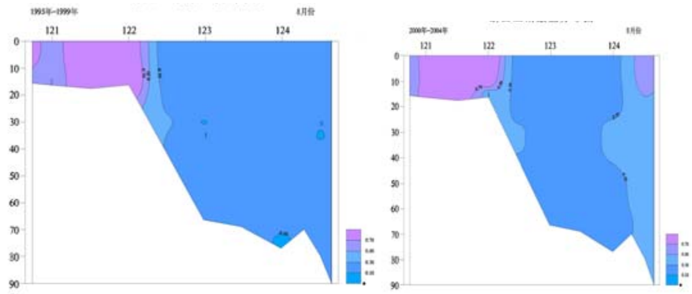


Fig. Ⅴ-5. Variation of nitrite content in the Yellow Sea in recent 20 years (August)

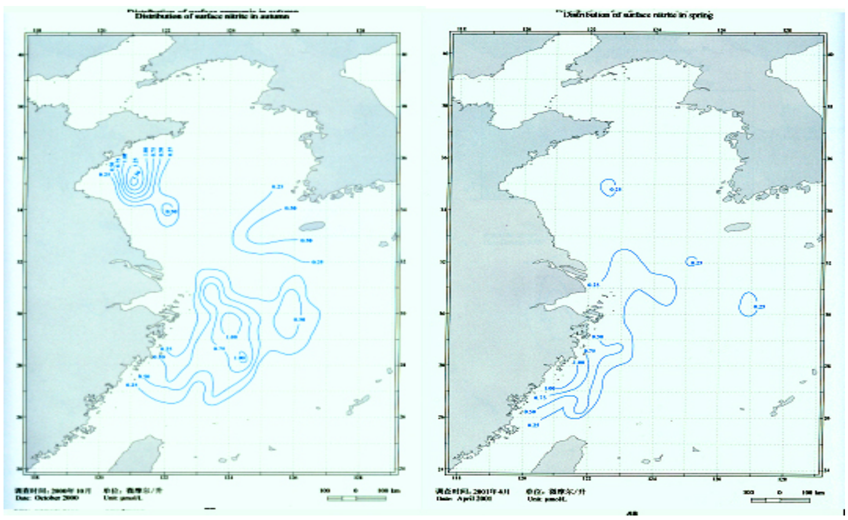
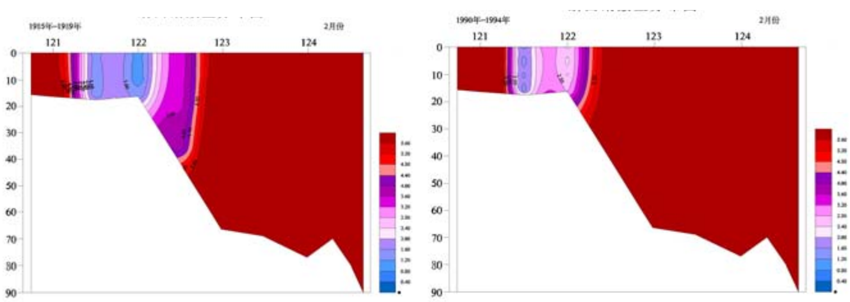


Fig. Ⅴ-6. Distribution of nitrite content in the surface seawater of the Yellow Sea (left: autumn 2000, right: spring 2001)

### 1.1.3. Nitrate

Variations of 20 years of nitrate content in the section located in thirty and four degrees north latitude in Yellow Sea are shown in Fig.Ⅴ-7 and Ⅴ-8. Distribution of nitrate content in the seawater of the Yellow Sea in autumn 2000 and spring 2001 is shown Fig.Ⅴ-9.



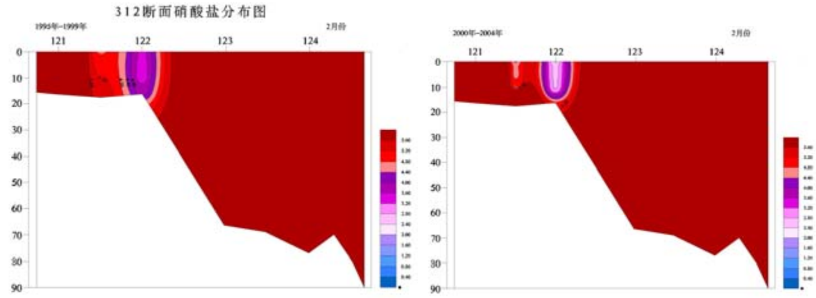



Fig. Ⅴ-7. Variations of nitrate content in the Yellow Sea in recent 20 years (February)

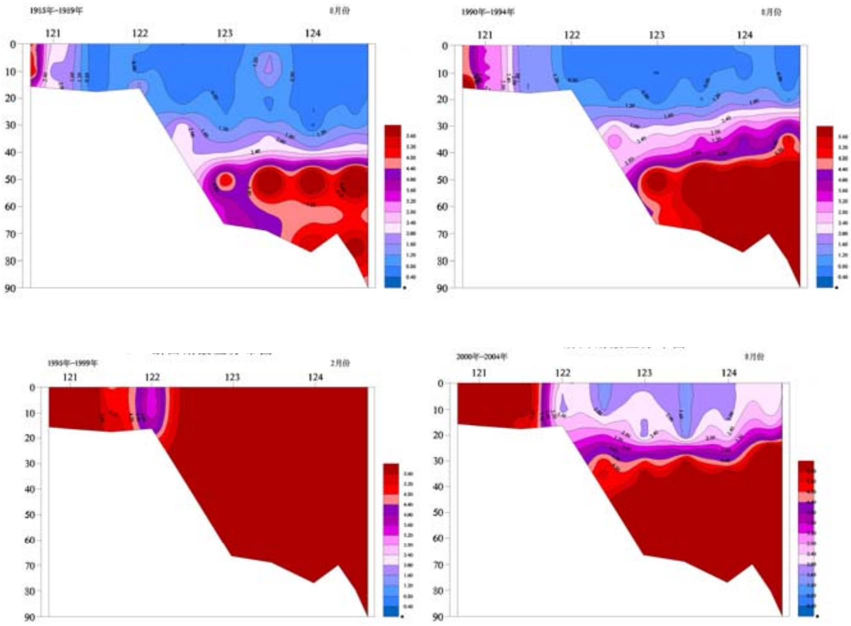



Fig. Ⅴ-8. Variation of nitrate content in the Yellow Sea in recent 20 years (August)

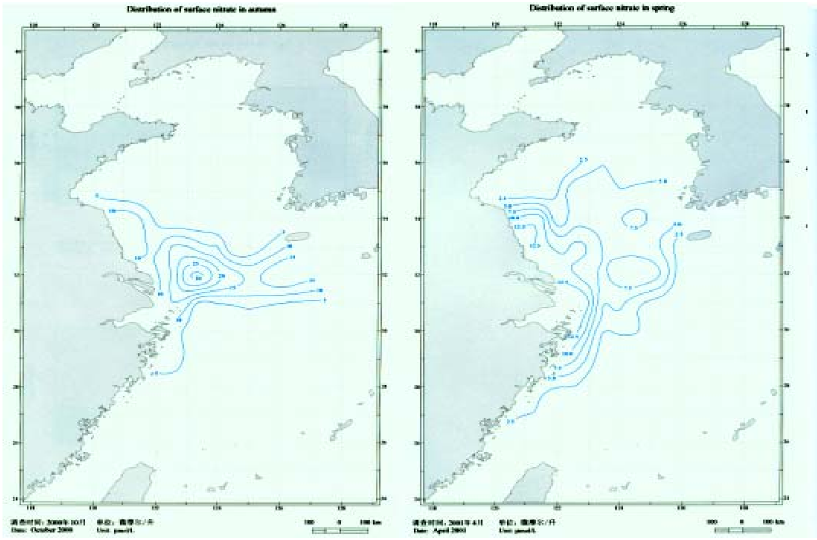



Fig. Ⅴ-9. Distribution of nitrate content in the surface seawater of the Yellow Sea (left: autumn 2000, right: spring 2001)

### 1.1.4. Phosphate

Variations of 20 years of phosphate content in the section located in thirty and four degrees north latitude in the Yellow Sea is shown in Fig.Ⅴ-10 and Ⅴ-11. Distribution of phosphate content in the seawater of the Yellow Sea of in autumn 2000 and spring 2001 is shown in Fig.Ⅴ-12.

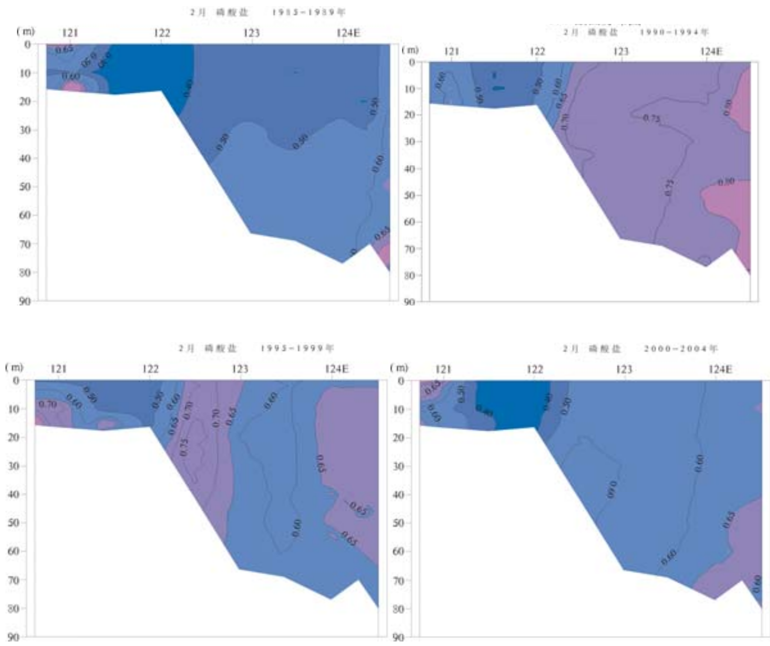


Fig.Ⅴ-10. Variations of phosphate content in the Yellow Sea in recent 20 years (February)

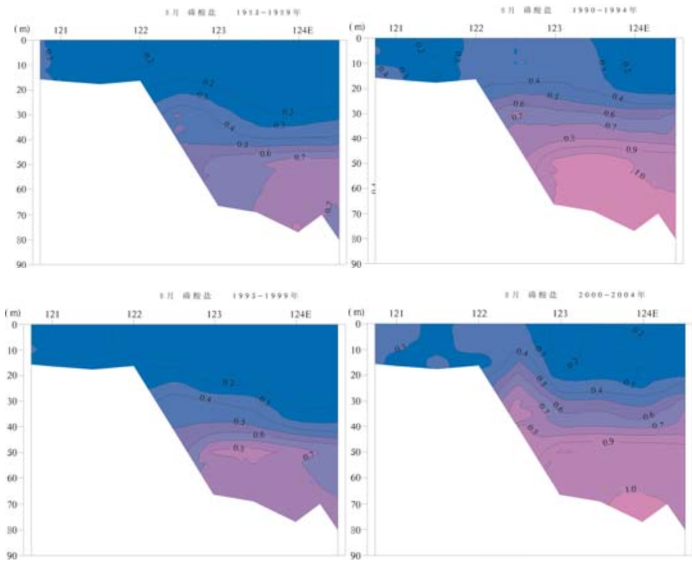



Fig. Ⅴ-11. Variations of phosphate content in the Yellow Sea in recent 20 years (August)

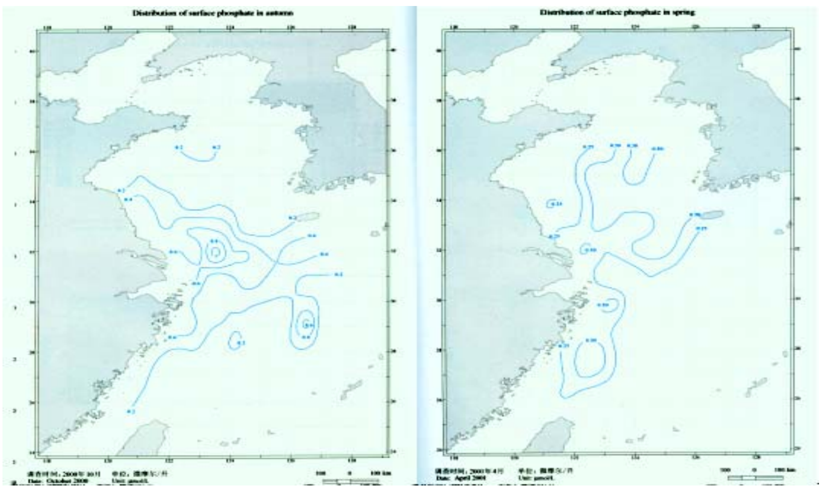



Fig. Ⅴ-12. Distribution of phosphate content in the surface seawater of the Yellow Sea (left: autumn 2000, right: spring 2001)

**1.1.5. Silicate**

Variations of 20 year of silicate content in the section located in thirty and four degrees north latitude in the Yellow Sea are shown in Fig.Ⅴ-13 and Ⅴ-14. Distribution of silicate content in the seawater of the the Yellow Sea in autumn 2000 and spring 2001 is shown in Fig. Ⅴ-15.

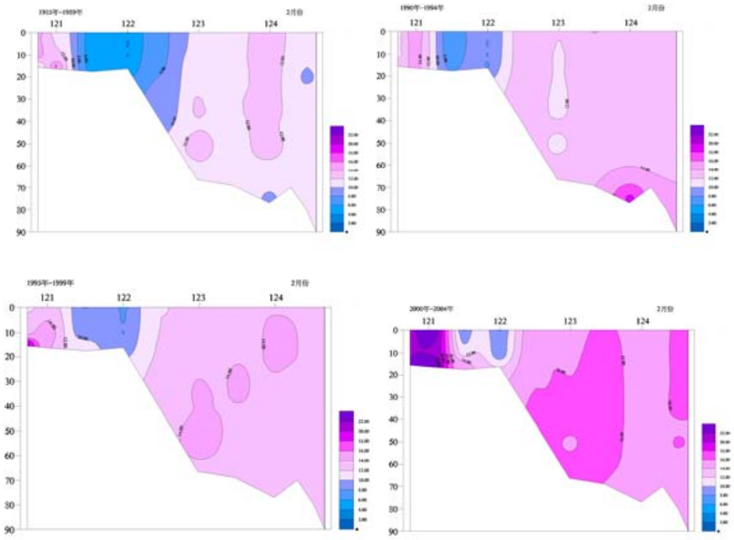


Fig. Ⅴ-13. Variations of silicate content in the Yellow Sea in recent 20 years (February)

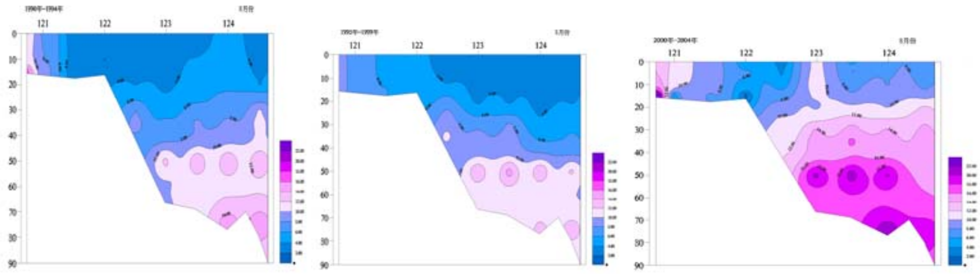


Fig. Ⅴ-14. Variations of silicate content in the Yellow Sea in recent 20 years (August)

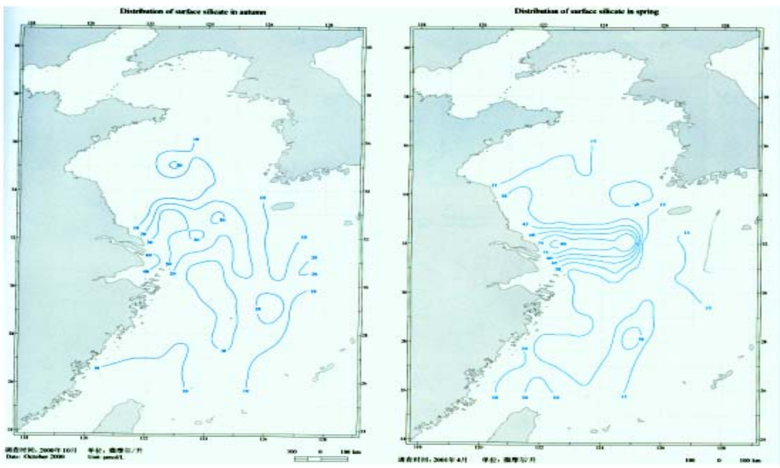



Fig. Ⅴ-15. Distribution of silicate content in the surface seawater of the Yellow Sea (left: autumn 2000, right: spring 2001)

Variation tendency of nutrients in the section located in thirty and four degrees north latitude in the Yellow Sea is shown in Fig.Ⅴ-16 to Ⅴ-20. Variation tendency of nutrients in the section from the Changjiang river estuary to the Chejudo Island is shown in Fig.Ⅴ-21 toⅤ-22.

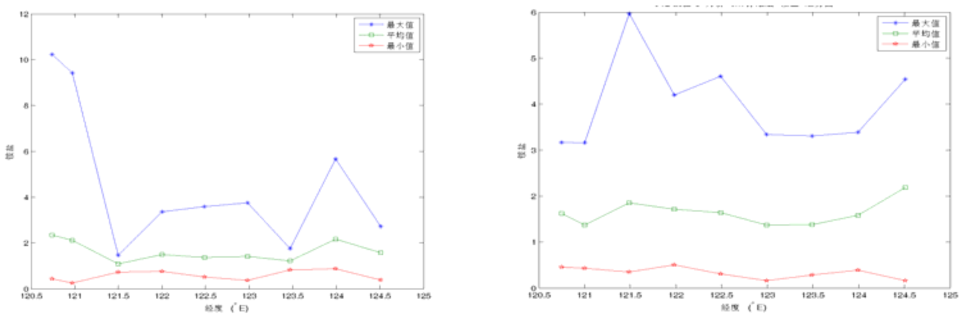


Fig.Ⅴ-16. Variation tendency of ammonium content in the section located in thirty and four degrees north latitude in the surface seawater of the Yellow Sea (1985-2004, left: February, right: August)

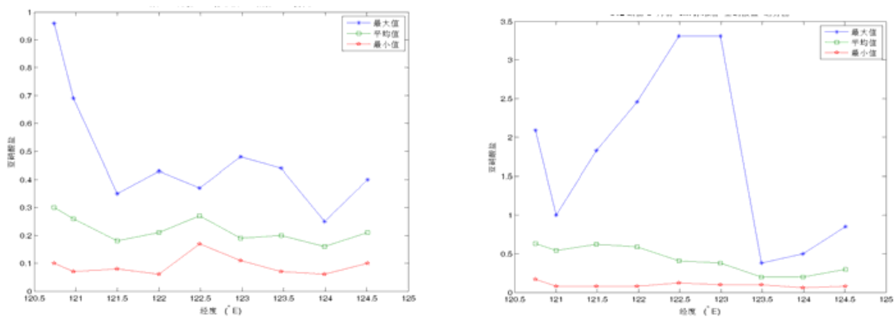


Fig. Ⅴ-17. Variation tendency of nitrite content in the section located in thirty and four degrees north latitude in the surface seawater of the Yellow Sea (1985-2004, left: February, right: August)

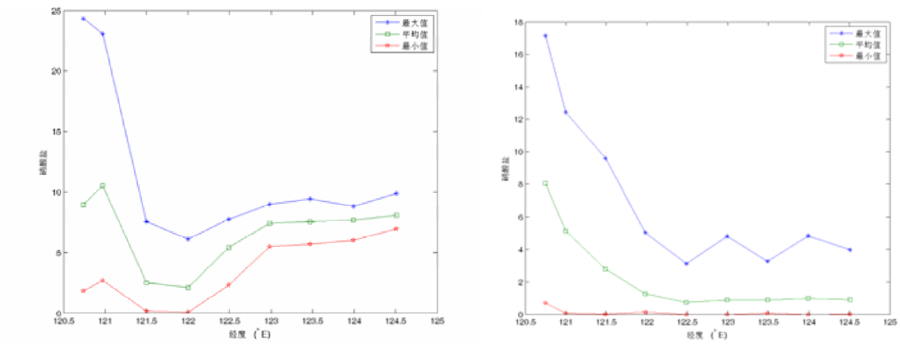


Fig. Ⅴ-18. Variation tendency of nitrate content in the section located in thirty and four degrees north latitude in the surface seawater of the Yellow Sea (1985-2004, left: February, right: August)

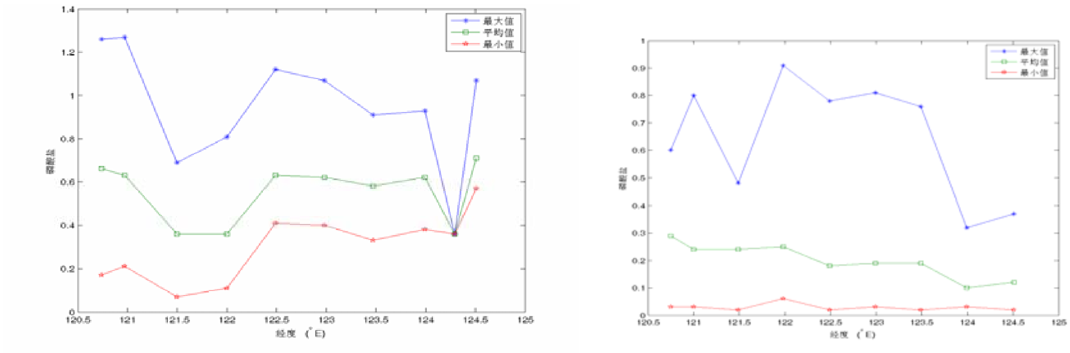



Fig. Ⅴ-19. Variation tendency of phosphate content in the section located in thirty and four degrees north latitude in the surface seawater of the Yellow Sea (1985-2004, left: February, right: August)

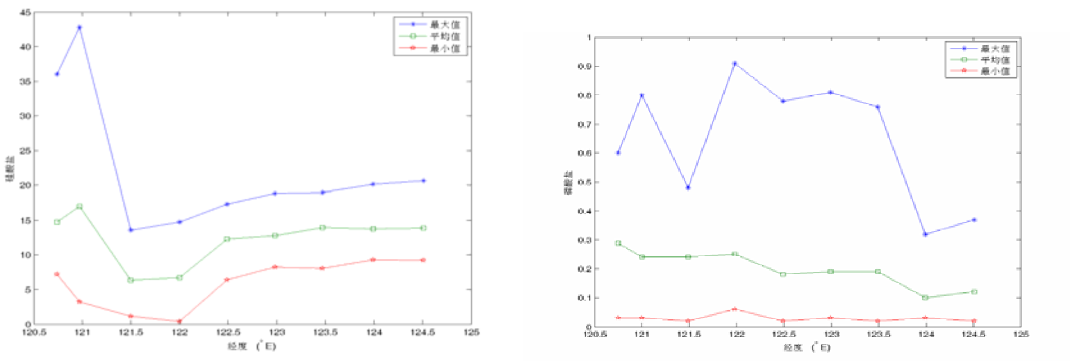



Fig. Ⅴ-20. Variation tendency of silicate content in the section located in thirty and four degrees north latitude in the surface seawater of the Yellow Sea (1985-2004, left: February, right: August)

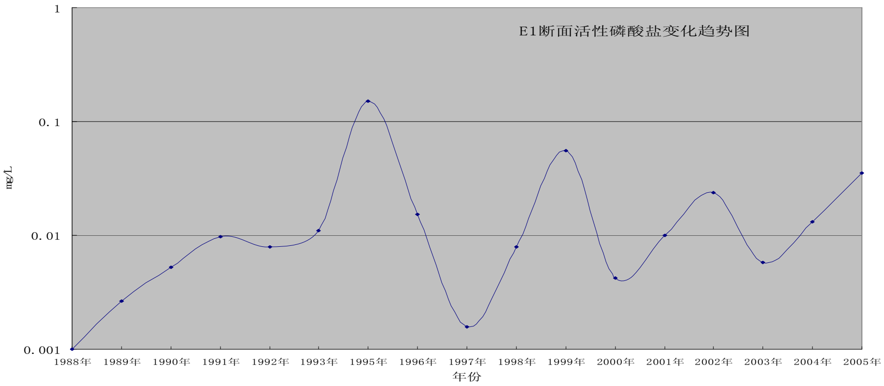



Fig. Ⅴ-21. Variation tendency of phosphate in the section from the Changjiang river estuary to the Chejudo Island (annual mean)

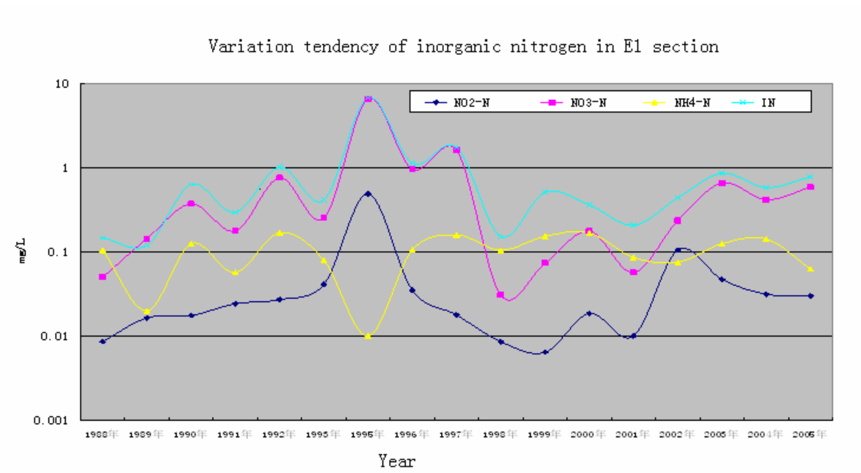



Fig. Ⅴ-22. Variation tendency of inorganic nitrogen content in the section from the Changjiang river estuary to the Chejudo Island (annual mean)

## 1.2. Chlorophyll-a

In recent years, the variations of Chlorophyll-a concentration in the coastal waters of the Yellow Sea, China are shown in Fig. Ⅴ-23.

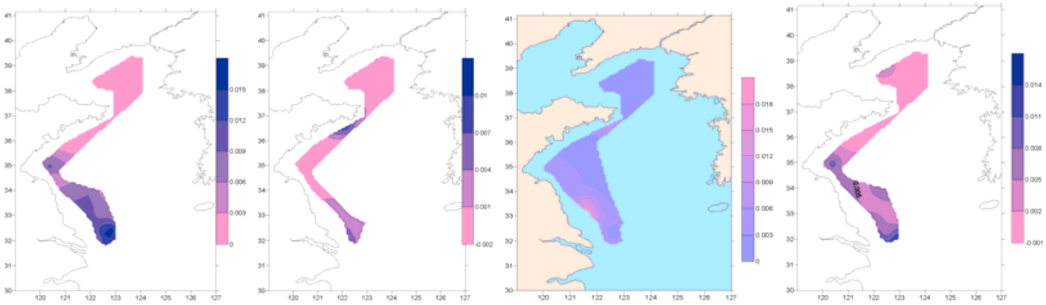


Fig. Ⅴ-23. Distribution of Chlorophyll-a concentration in the coastal waters of the Yellow Sea, China (Aug., 2002-2005)

## 1.3. Chemical oxygen demand (COD)

In recent years, variation tendency of COD in the coastal waters of the Yellow Sea, China is shown in Fig. Ⅴ-24.

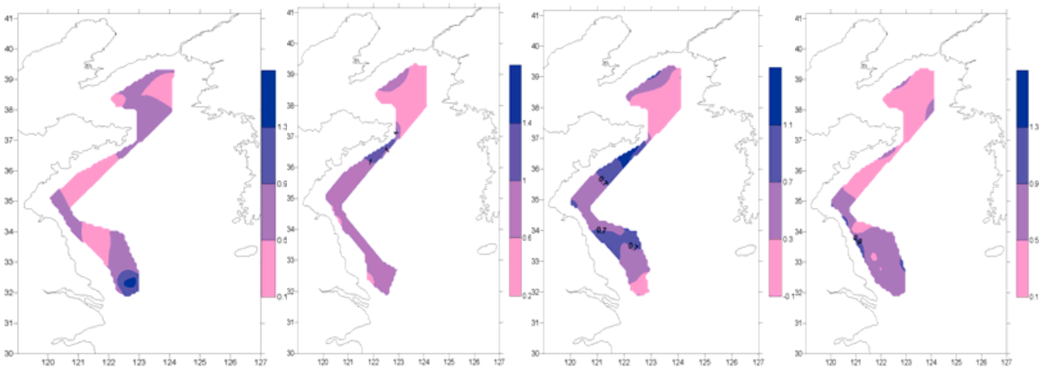


Fig. Ⅴ-24. Distribution of COD in the coastal waters of the Yellow Sea, China (Aug., 2002-2005)

## 1.4. Suspended substances (SS)

The strong influence of rivers on the The Yellow Sea brings about the high contents of suspended substances in the The Yellow Sea. Fig. Ⅴ-25 shows the distribution of the contents of suspended substances in the The Yellow Sea influenced by rivers.

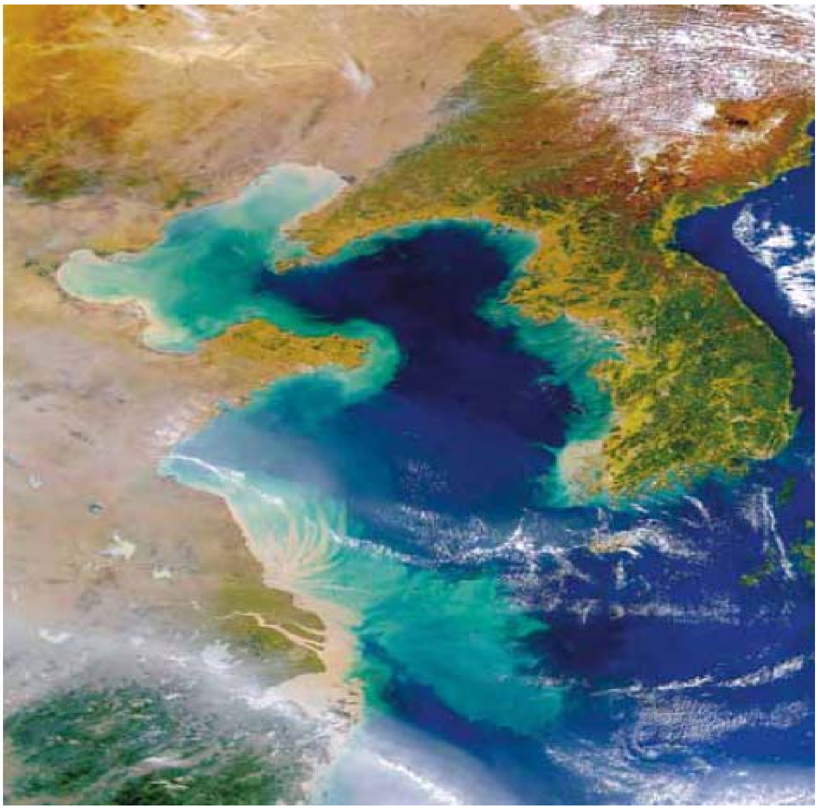


Fig.Ⅴ-25. Distribution of the suspended substances in the coastal waters of the Yellow Sea influenced by rivers

The contents of suspended substances in the surface seawater of the The Yellow Sea from 2000 to 2003 are shown in Fig. Ⅴ-26.

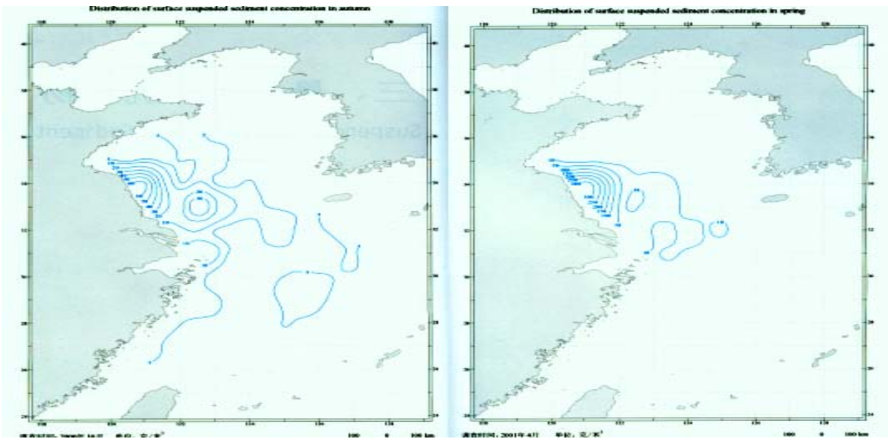



Fig. Ⅴ-26. Distribution of the concents of suspended substances in the Yellow Sea (left: Autumn, 2000, right: Spring, 2001)

## 2. Oil pollution

### 2.1. Oil spill, refinery waste water and offshore operations

Oil spill is one of the pollutants that man discharges into the Yellow Sea as a result of operational, faulty breakdown and carelessness. This oil spill attracts great public attention because it is visible and most people encounter it, either at first hand on bathing beaches, or from pictures on television. Oil the petroleum hydrocarbon can be spilled into Yellow Sea through tanker accidents, bilge and fuel oils, offshore oil production, coastal oil refineries, municipal and industrial wastes, and urban and river run-off. Water-soluble components of crude oils and refined products are toxic to a wide spectrum of marine plant and animals. Some polycyclic aromatic hydrocarbons (PAH) are more toxic than aliphatics, and middle-molecular-weight constituents are more toxic than high-molecular-weight tars. A spillage of diesel fuel, with a high aromatic content, is therefore much more damaging than bunker fuel and weathered oil, which have a low aromatic content. To assess the impacts of oil, it needs to estimate the spilled oil into the Yellow Sea, but it is difficult to estimate the total quantity of petroleum hydrocarbons entering the Yellow Sea.

#### 2.1.1. Chinese coast - needs data and information

As China are developing the marine industries, we can estimate the spilled oil is increasing year by year.

#### 2.1.2. Korean coast

In Korean coast, most of the big oil spill has been taken place in the South Sea of Korea for the last three decades. In the Yellow Sea, the total number of oil spill events was 1,869 with 18,634㎘ of spilled oil in 1987-2005 period. The average number of events and quantity of spilled oil are 98 and 980㎘ respectively. However generally speaking, the oil spill event has been increasing trends year by year even in the Yellow Sea.

Table Ⅴ-1. The number of oil spill events and quantity of spilled oil in the Yellow Sea in 1987-2005 period.

| Area | Numbers of oil spill events | Quantity of spilled oil(㎘) |
|---|---|---|
| Total | 1,869 | 18,634 |
| Incheon | 770 | 7,495 |
| Taean | 373 | 9,228 |
| Kunsan | 259 | 737 |
| Mokpo | 467 | 1,174 |

.

## 2.2. Ecological impacts of oil pollution

# 3. Heavy metals and persistent organic pollutants (POPs)

## 3.1. Heavy metals and POPs in sediments

### 3.1.1. Quality conditions of marine sediments in Chinese coast

The monitoring results of marine sediment in 2005 indicated that the marine sediment quality in the coastal waters of China was at good condition, and the potential ecological risk of integrated sediment pollution was low.

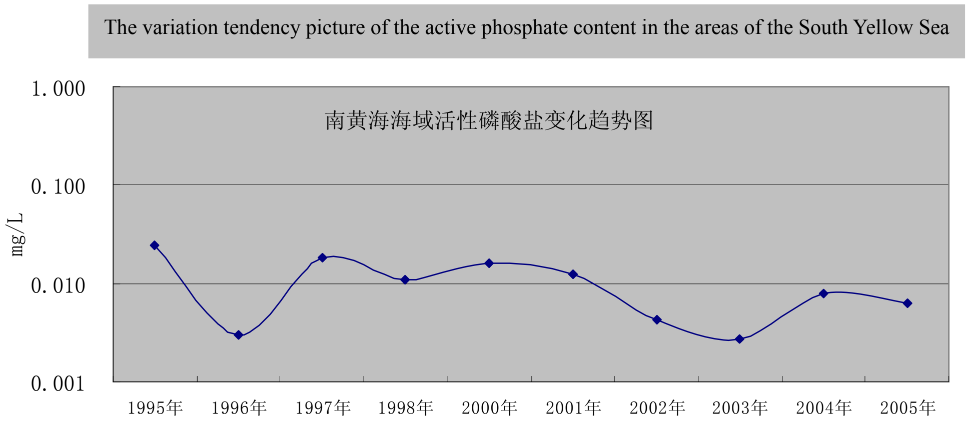



Fig.Ⅴ-27. Changes of the active phosphate concentration in the waters of the southern Yellow Sea

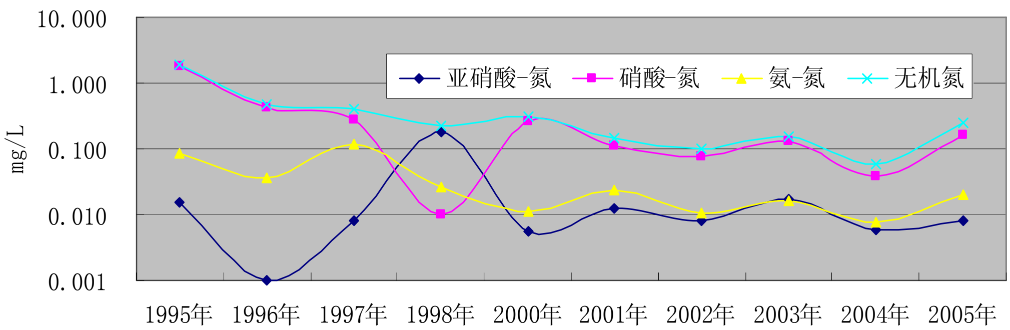



Fig.Ⅴ-28. Changes of the inorganic nitrogen concentrations in the waters of the southern Yellow Sea

However, such pollutants as cadmium, PCBs, arsenic, copper and oils polluted marine sediments in some coastal areas. Fig.Ⅴ-29 shows the environmental quality conditions of marine sediments in the offshore waters of China and the results of risk assessment. Among them, the environmental quality of marine sediments in the Yellow Sea was at fair condition, and the ecological risk was comparatively low.

The sediment quality in the waters of Liaoning was at good condition with low potential ecological risks compared with other coastal waters in china. The marine sediments in the Liaodong Bay were polluted by oils and arsenic, the marine sediments in the Dalian Bay were polluted by oils. The sediment quality in the waters of Shandong was at good condition with low potential ecological risks, the marine sediments in the coastal areas of Yantai and the Laizhou Bay were polluted by mercury. The sediment quality in the waters of Jiangsu was at good condition with low potential ecological risks, the marine sediments in the shallow waters in the north of Jiangsu were polluted by cadmium.

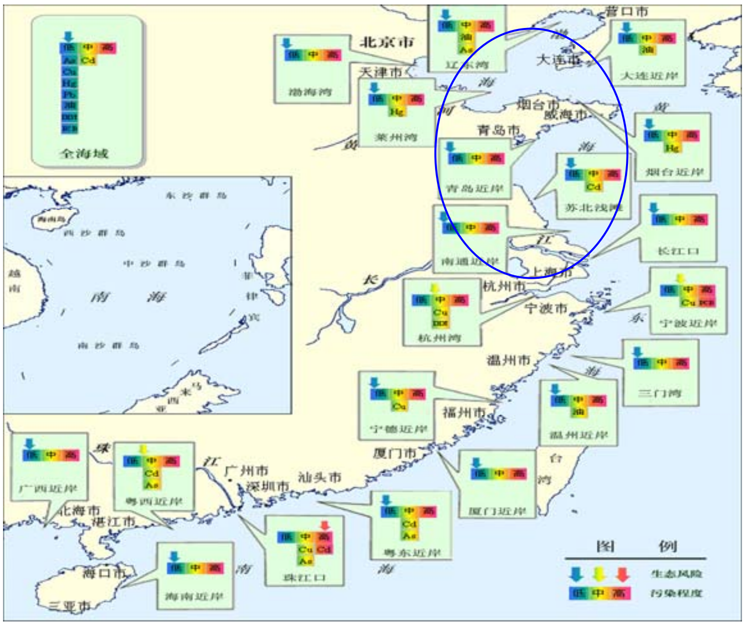



Fig. Ⅴ-29. Marine sediment quality and ecological risk assessment

**3.1.2. Quality conditions of surface sediments in Korean coasts**

Korea has determined the level of persistent organic pollutants such as organochlorine compounds and polycyclic aromatic hydrocarbons (PAHs) in seawater and sediment collected from the southeastern part of the Yellow Sea in 2000 (Oh et al., 2001). The total PCBs concentrations in the sediments were ranged from 0.17ng/g to 1.37ng/g. The most abundant PCB congeners were the congeners PCB 18, PCB 66, and PCB 110. These congeners constituted from 17% to 33% of total PCBs. Most PCB congeners were below detection. The total pesticide concentrations in the sediments were ranged from 0.63ng/g to 14.94ng/g, which revealed the levels were in low and some of them being below detection. The level of PAHs, PCBs, and pesticides in the sediments collected from the Yellow Sea were very low as in Fig.Ⅴ-30.

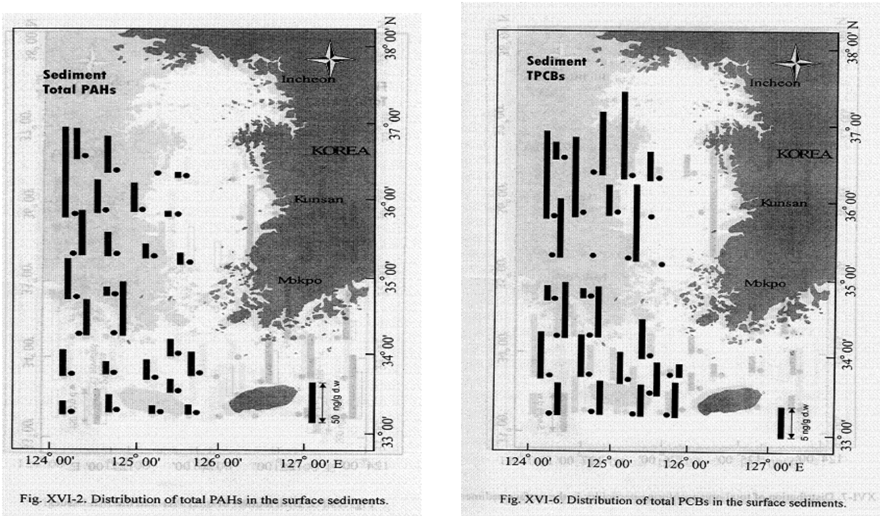



Fig. Ⅴ-30. The distribution of PAHs, PCBs, and pesticides concentrations in the surface sediments (Oh et al., 2001).

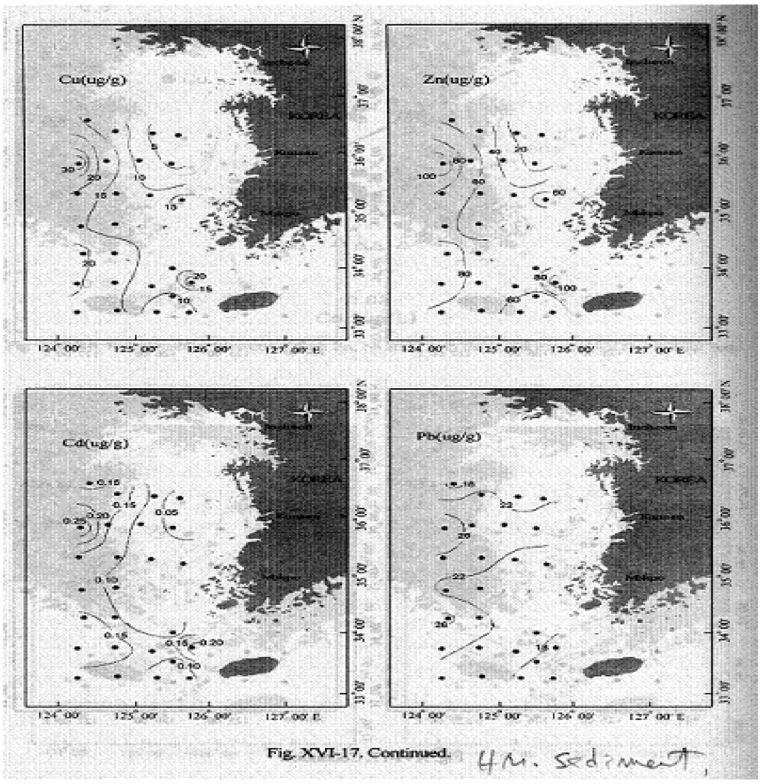



Fig.Ⅴ-31. The distribution of mean grain size and metals in the surface sediments of the Yellow Sea (Oh et al., 2001).

# 4. Radioactivities

# 5. Marine litters and heat

# 6. General status of marine pollution – An overview

## 6.1. General status of water quality in Chinese seas

According to the Chinese national report, an integrated evaluation of the coastal environment condition in China has been done at the end of the 20th century. The overall trend was that the rapid spread of marine pollution was controlled to a certain extent, but the deteriorative trend of the marine environment has not yet been effectively curbed. Generally speaking, the pollution level has been increased in most of the estuaries, the gulfs, and the waters adjacent to large and medium cities. In 1998, the area of offshore waters in China, which exceeded Category I National Seawater Quality Standards, was up to about 200,000 sq. km, almost doubled in comparison with 1992.

It was found that nutrients and organic compounds were major components of coastal water pollution, and their pollution level became more and more serious. The oil and heavy metal pollution caused significant deleterious effects in some regions. Anthropogenic pollutants such as synthetic organic and toxic substances were detected widely in the coastal water, sediment, and marine organism. The red tides occurred frequently. The marine ecosystems were destroyed aggravatingly. Over the past 50 years, the total area of the land reclaimed from tidal flats and seas was up to more than 700,000 hectares, and nearly 50% of the coastal wetlands have lost.

In 2005, the area of the waters, which didn't reach the quality standards of clean water, was about 139,000 sq. km, and the overall conditions had not improved actually. The pollution of the coastal waters remains serious. The main polluted waters were distributed over estuaries, bays and some waters adjacent to large and medium cities. The main pollutants in the coastal waters were inorganic nitrogen, active phosphate and oils. The coastal sediment quality was in fair condition in general. The offshore and ocean sediment quality was in good condition. The pollutants in some shellfishes collected from coastal waters were found at high levels. The concentrations of the pollutants from most discharge outlets into the sea exceed the limits of water quality standards. The water quality in the sea areas adjacent to pollutants discharge outlets didn't accord with the quality standards of marine functional zones, the environmental pollution was very serious in the waters adjacent to some pollutants discharge outlets. The amount of pollutants discharged from rivers into the sea was still enormous, and the atmospheric pollutant concentrations and deposition flux into the sea have been steady increasing.

In recent years, there were large fluctuations and variations in the environmental quality conditions of the Bohai Sea. The area of polluted waters expanded unceasingly, especially in 2004 and 2005, The area of waters which exceed Category I National Seawater Quality Standards almost doubled, compared with 2001. The area of polluted waters increased rapidly in the coastal waters of Jiangsu. Table 1-2-1 shows the change of the area of the waters failing to reach the quality standards of clean water in the Yellow Sea in recent years. Figure 1-2-1 shows the spatial distribution and change of the waters failing to reach the quality standards of clean water in the Yellow Sea in recent years.

### 6.1.1 Annual and regional water quality conditions and variation trends

According to “Bulletin of Marine Environmental Quality of China” in recent years, environmental quality conditions and variation tendency of the Yellow Sea were as follows:

In 2001, the area of medium and heavily polluted waters in the Yellow Sea was about 1,850 sq. km. The area of slightly, medium and heavily polluted waters in the coastal regions of Liaoning was about 1,700 sq. km, 1,080 sq. km and 2,590 sq. km respectively. The main polluted waters were distributed over the Yalu River Estuary and the Dalian Bay. The main pollutants were inorganic nitrogen, heavy metals and oils. The coastal waters of Shandong were mostly clean or comparatively clean except the coastal areas of Yantai and the Jiaozhou Bay. The main pollutants were inorganic nitrogen, phosphate and heavy metals. The coastal waters of Jiangsu were mostly clean or relative clean. The main pollutants were inorganic nitrogen and phosphate.

Table Ⅴ-2. The area of the non-clean waters f in the Yellow Sea (unit: sq. km)

| Year | Comparatively clean | Slightly polluted | Medium polluted | Heavily polluted | Total |
|---|---|---|---|---|---|
| 2001 | 28,110 | 1,160 | 590 | 1,260 | 31,120 |
| 2002 | 27,110 | 560 | - | - | 27,670 |
| 2003 | 14,440 | 5,700 | 3,520 | 3,200 | 26,860 |
| 2004 | 15,600 | 12,900 | 11,310 | 8,080 | 47,890 |
| 2005 | 21,880 | 13,870 | 4,040 | 3,150 | 42,940 |

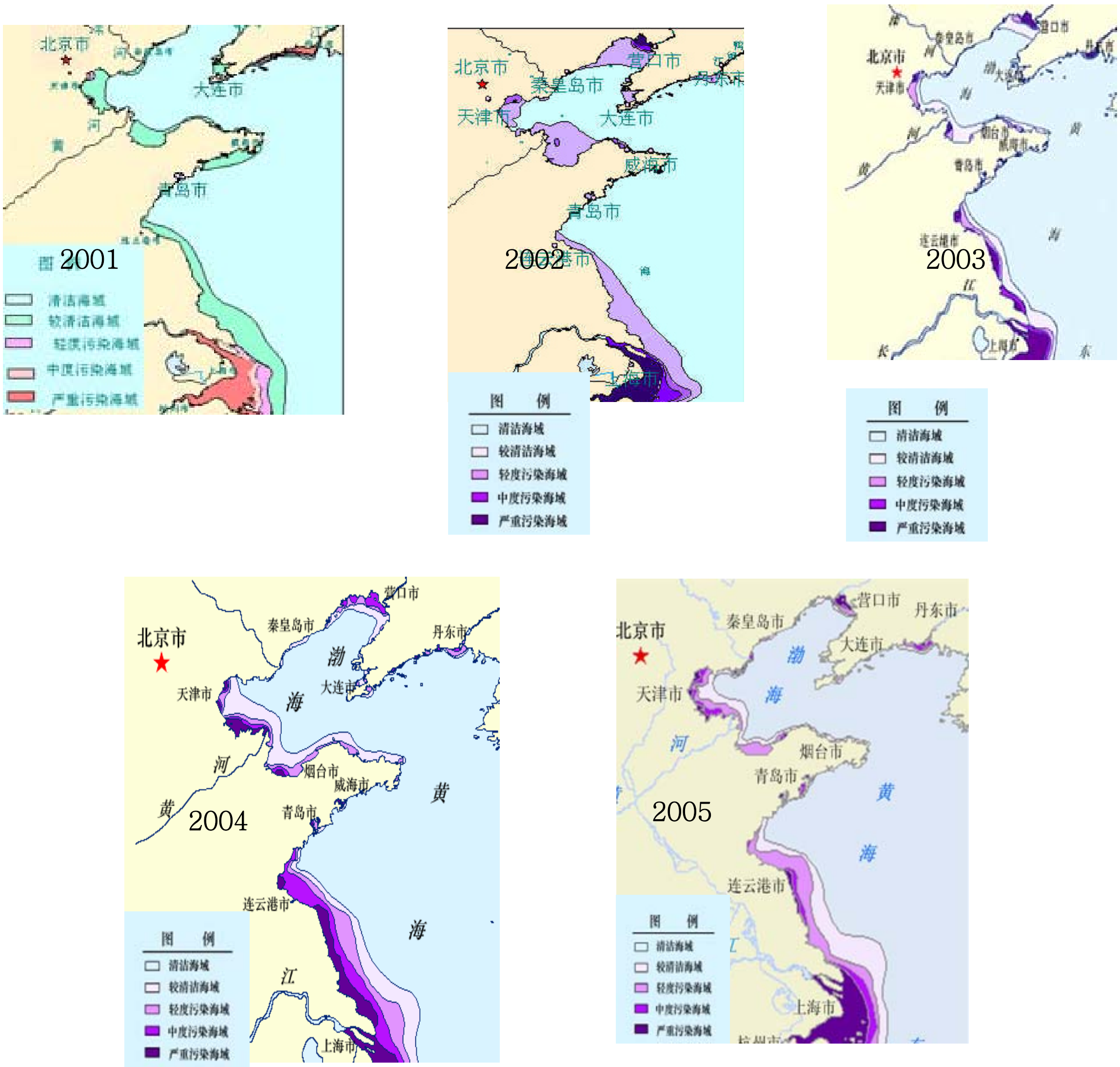



Fig. V-32. Sketch map illustrating the conditions and change of the non-clean waters in the Yellow Sea (2001-2005)

In 2002, the water quality of the Yellow Sea was at good conditions. The area of slightly polluted waters was about 600 sq. km. The area of medium polluted waters and heavily polluted waters reduced compared with 2001. The main pollutants were inorganic nitrogen, phosphate and lead. The area of the waters in the coastal areas of Liaoning, which did not reach the quality standards of clean water, amounted to about 14,270 sq. km. Among them, the area of comparatively clean waters, slightly polluted waters, medium polluted waters and heavily polluted waters was 12,260 sq. km, 580 sq. km 420 sq. km and 1,010 sq. km respectively. The area of slightly polluted waters, medium polluted waters and heavily polluted waters reduced compared with 2001. The main polluted waters were distributed over the Dalian Bay and other sea areas, the main pollutants were inorganic nitrogen, phosphate and lead. The coastal waters of Shandong were mostly clean or comparatively clean except the coastal areas of Yantai which was slightly polluted. The main pollutants were inorganic nitrogen, phosphate and lead. The coastal waters of Jiangsu were mostly clean or comparatively clean. The area of the contaminated waters, which didn't meet the quality standards of clean water, amounted to about 23,310 sq. km. The main polluted waters were distributed over the Xinyi River Estuary, the Sheyang River Estuary, the Changjiang River Estuary. The main pollutants were inorganic nitrogen and lead.

In 2003, the area of the polluted waters in the Yellow Sea reduced slightly. The area which didn't accord with the quality standards of clean water amounted to about 27 thousand sq. km. Among them, the area of slightly polluted waters was about 5.7 thousand sq. km, the area of medium polluted waters and heavily polluted waters was 3.5 thousand sq. km and 3.2 thousand sq. km respectively, mainly located in the Yalu River estuary, the Haizhou Bay and the Dalian Bay. The main pollutants were inorganic nitrogen, active phosphate and lead. The area of the polluted waters in coastal areas of Liaoning decreased, the medium polluted waters and heavily polluted waters were mainly distributed over the Yalu River estuary and the Dalian Bay. Among them, the medium polluted waters and heavily polluted waters in the Yalu River estuary increased in comparison with 2002, the main pollutants were inorganic nitrogen, active phosphate and lead. The area of the polluted waters in the coastal waters of Shandong reduced, the medium polluted waters and heavily polluted waters were mainly located in some sea areas of the Jiaozhou Bay. The main pollutants were inorganic nitrogen, lead and oils. The area of the polluted waters in the coastal waters of Jiangsu slightly reduced, the polluted waters were mainly distributed over some coastal waters from the Sheyang River estuary to the Doulong Port and the Haizhou Bay. The main pollutants were active phosphate, inorganic nitrogen and lead.

In 2004, the polluted sea areas in the Yellow Sea slightly increased, the area which did not reach the quality standards of clean water amounted to about 48 thousand sq. km. Among them, the area of slightly polluted waters and medium polluted waters was about 13 thousand sq. km and 11 thousand sq. km respectively, the area of heavily polluted waters was 8 thousand sq. km, mainly located in the coastal waters of Jiangsu. The main pollutants were inorganic nitrogen and active phosphate. The polluted areas in coastal waters of Liaoning slightly increased in comparison with the year before, the coastal areas, which did not reach the quality standards of clean water, were about 8.6 thousand sq. km. The area of medium polluted waters increased by 1,300 sq. km compared with pervious year. The polluted waters were mainly distributed over the Yalu River estuary and the Dalian Bay. The main pollutants were inorganic nitrogen, active phosphate and oils. The polluted areas in the coastal waters of Shandong slightly increased in comparison with the year before, the medium polluted waters and heavily polluted waters increased by 1,250 sq. km and 340 sq. km respectively. The polluted waters were mainly located in some waters of the Jiaozhou Bay and the south of the Bohai Sea, the Main pollutants were inorganic nitrogen, active phosphate and oils. The polluted areas in coastal waters of Jiangsu slightly increased in comparison with the year before, the medium polluted waters and heavily polluted waters increased by 4,980 sq. km and 5.070 sq. km respectively. The heavily polluted waters were mainly distributed over the sea areas adjacent to pollutants discharge outlets and extended to the offshore waters. The main pollutants were inorganic nitrogen and active phosphate.

In 2005, the area of polluted waters in the Yellow Sea, which did not reach the quality standards of clean water, amounted to about 43 thousand sq. km. Among them, the area of comparatively clean waters, slightly polluted waters, medium polluted waters and heavily polluted waters was 22 thousand sq. km, 14 thousand sq. km, 4 thousand sq. km and 3 thousand sq. km respectively. The heavily polluted waters were mainly located in the Yalu River Estuary, the Jiaozhou Bay and the coastal areas of Jiangsu, the main pollutants were inorganic nitrogen and active phosphate. The area of the polluted coastal waters in Liaoning, which wasn't up to the quality standards of clean water, amounted to about 5,070 sq. km with a decrease of 3,580 sq. km in comparison with the year before. The area of heavily polluted waters increased by 1,100 sq. km compared with pervious year, the main polluted waters were distributed at the sea waters adjacent to the Yalu River Estuary. The main pollutants were inorganic nitrogen, active phosphate and oils. The area of the polluted coastal waters of Shandong, which did not reach the quality standards of clean water amounted to about 11,380 sq. km. The polluted waters were mainly distributed at the Jiaozhou Bay, the main pollutants were inorganic nitrogen, active phosphate and oils. The pollution conditions of the coastal waters of Jiangsu had been improved slightly, the area that did not reach the quality standards of clean water was about 16,320 sq. km. The medium polluted waters and heavily polluted waters decreased by 5,980 sq. km and 4,970 sq. km separately in comparison with 2004. The heavily polluted waters were distributed over estuaries, pollutants discharge outlets and adjacent waters, the main pollutants were inorganic nitrogen, active phosphate.

According to the monitoring data of the Yellow Sea in the past years, the concentrations of active phosphate decreased year after year (shown in Fig.1-2-2). The maximum concentration of active phosphate in the Yellow Sea was about 0.024mg/L, found in 1995. The minimum concentration of active phosphate in the Yellow Sea was about 0.003 mg/L, found in 1996 and 2003 separately.

The concentrations of inorganic nitrogen decreased also year after year (shown in Fig. 1-2-3). The maximum concentration of inorganic nitrogen in the Yellow Sea was about 1.90mg/L, found in 1995 The minimum concentration of inorganic nitrogen in the Yellow Sea was about 0.58 mg/L, found in 2004.

# Ⅵ. Water pollution and biology

## 1. The trend of Harmful algal blooms (HABs)

Recent harmful algal blooms (HABs) in the coast and sea cause socio-economic problems due to its persistency and widespread. This, so called red tide formed by proliferations of microalgae in marine or brackish waters, can cause massive fish kills, contaminate seafood with toxins, and alter ecosystems in ways that humans perceive as harmful. Although HABs occurred long before human activities began to transform coastal ecosystems, a survey of affected regions and of economic losses and human poisonings throughout the world demonstrates very well that there has been a dramatic increase in the impacts of HABs over the last 20th century and that the HABs problem is now widespread, and serious. It must be remembered, however, that the harmful effects of HABs extend well beyond direct economic losses and impacts of human health. When HABs contaminate or destroy coastal resources, the livelihoods of local residents are threatened. Clearly, there is a pressing need to develop effective responses to the threat of HABs through management and mitigation. It was proved that the nature of dinoflagellate blooms have changed over the last four decades. With respect to the geographical scaling in the Asian countries, China is the biggest, and Korea and Japan are the next. In recent, the red tides or HABs can be utilized as one of biological indicators to assess the marine pollution especially due to its connection with coastal eutrophication and easy access of wide coverage.

### 1.1. West side of the Yellow Sea (China)

For long term statistics point of view (Lu and Zhou, 2005), the HABs occurrences in coastal China have been increased all the time, with a sharp increase after 2000 as shown in Fig.Ⅵ-1. They found that the magnitude, frequency, and geographic extent of these occurrences have increased significantly over the last several decades.

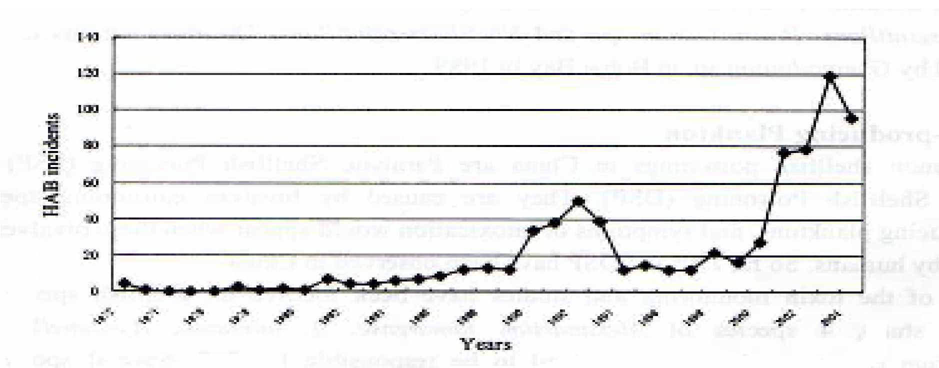



Fig. Ⅵ-1. HAB incidents in coastal China from 1972 to 2004 view (Lu and Zhou, 2005).

Along the Chinese coast, Zhu et al.,(2005) had reported there have been three areas of frequent HABs events. There were Bohai Sea, Changjiang estuary and Zhejiang coast in the East China Sea (ECS), and Guangdong coast, and Dapeng Bay in the South China Sea (SCS) (Chen, 1998, Zhu et al., 2005) as shown in Fig.Ⅵ-2.

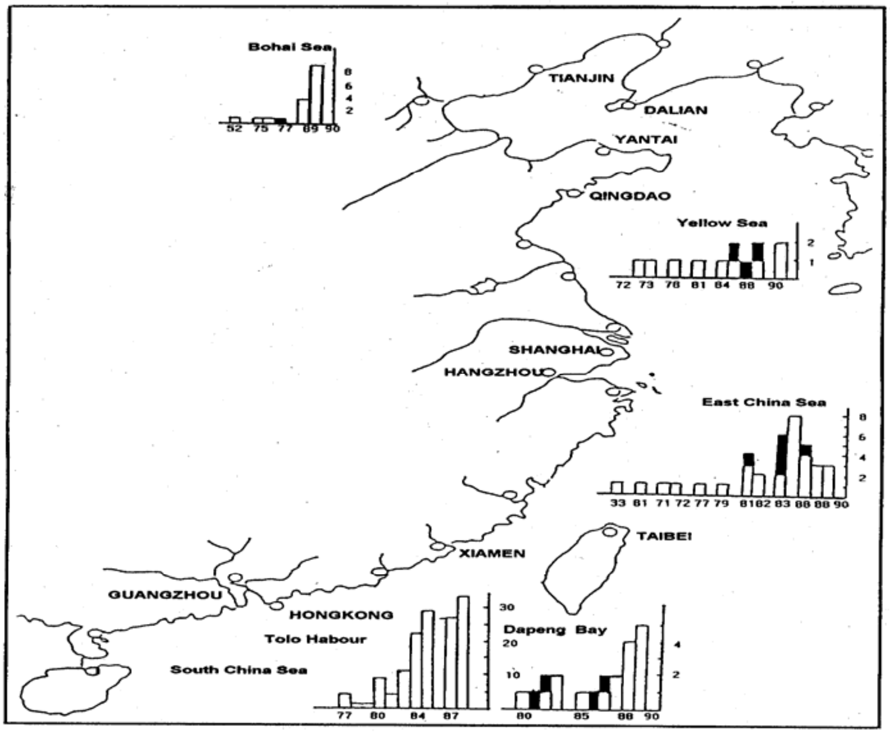



**Fig. 1. Red Tide incidences in China(Filled colums=toxic)**

Fig. Ⅵ-2. Red tide incidences in China (filled colums=toxic) if period 1970-1990. (Source, Chen, 1998)

According to the report (Zhu et al., 2005), there were 123 recorded HABs in the Bohai Sea, 354 in ECS, and 182 in SCS for the period 1952-2004. The main season of HABs occurrence in the Bohai Sea was June to September, April to October in ECS, and November to June in SCS respectively (Zhu et al., 2005),. In the ECS, the first red tide caused by *Noctiluca scintillans* had been occurred in the coastal water of Zhejiang Province in 1933 (Lu, 2004). Before 1980s, there found a few red tides in this area, but it became more frequent and widespread in the last two decades in the Zhejiang coast. Till 1997, about 91 species of red tide organisms have been recorded in China coastal water, of which 19 species are toxic (Chen, 1998). In recent, the main HAB species in the ECS are belonged to dinoflagellates, diatoms, Raphidophyte, Haptophyte etc. (Lu, 2004). Before 1980s, diatom and non-toxic dinoflagellates such as *Skeletonema costatum* and *N. scintillans* were the dominant species in the ECS. But in recent, they were changed into potentially toxic species such as *Alexandrium catenella, A. leei, Dinophysis acuminate, K.*

*mikimotoi, K. brevis* (Lu, 2004). Especially since 1955, *P. donghaiense* bloom has been recurred in the plume front between coastal waters of Zhejiang and Taiwan warm current. It has been formed massive blooms in the convergence zone of the Yangtze (Changjiang ) river estuary and coastal waters of Zhejiang province. In the Bohai Sea and the Yellow Sea. the locations of the most frequent red tide occurrence are Dalian Bay, Liaodong Bay, Bohai Bay, Laizhou Bay, Jiaozhou Bay, and Donggang waters (Lu and Zhou, 2005).. Of which, Liaodong Bay and Bohai Bay are the most frequent occurred areas.

HAB in the ECS showed a rapid increase, but slow in the Bohai Sea and in Guangdong coast due to strengthening of pollution control (Zhu et al., 2005). In recent, large scale blooms caused by *Prorocentrum donghaiense* (synonym of *P. dentatum*) has been occurred along the east Chinese coast, near Changjiang river estuary and Zhejiang coast (Zhou. 2005). In the ECS, a huge bloom of *Karenia mikimotoi* with *P. donghaiense* have been recorded in the coast of Zhejiang Province (Lu, 2005). The bloom covered an area of 15,000 ㎢ and lasted about one month. The species succession at the bloom season in this coastal area has been changed from *Karenia mikimotoi* with *P. donghaiense* to *Noctiluca scintillans* finally (Lu, 2005).

With respect to the impacts of HABs, a total of 6 red tides out of 112 cases caused mass mortality of fish and shellfish during 1998-2004 in Chinese waters of the Yellow Sea and Bohai Sea (Lu and Zhou, 2005). They found that the other 106 cases were harmless. In the Bohai Bay and the Yellow Sea, they reported that seven species such as *Ceratium furca, Exuviaella cordata, Gymnodinium* sp*., G. sanguineum, N. scintillans* have brought mass mortalities of fish, shrimp, and shellfish. The PSP and DSP are widely distributed in whole coast of China. The toxin occurrence, frequency, and shellfish toxin levels in southern parts of Chinese coast are greater than those in northern areas (Lu and Zhou, 2005).

## 1. 2. East side the Yellow Sea (Korea)

In the east side of the Yellow Sea (Korea), the red tides had been occurred sporadically in Kyunggi Bay, Chunsu Bay, and Kunsan coast during 1980s (Kim, 2005) . But in recent years, they became widespread encompassing entire coast since 1990s. The bloom have been occurred from May to October with the peak of June to August. Most of the blooms have been lasted for about one or two weeks at least. The prevailing phytoplankton species responsible for the blooms were diatoms till 1980s and then dinoflagellates such as Noctiluca scintillans, Prorocentrum micans, and Heterosigma akashiwo in recent coastal waters. The fish-killing dinoflagellate, Cochlodinium polykrikoides, had formed blooms in October of 1998 and 1999(Kim, 2005). But there was no fish kill due to the absence of farmed fish over there. Such species as Heterosigma akashiwo, Akashiwo sanguinea(=Gymnodidnium sanguineum) and Noctiluca scintillans have caused detrimental blooms. Besides, the death and decay of algal blooms can lead anoxia through decompositional oxygen demand, resulting in mortalities of fish and shellfish.

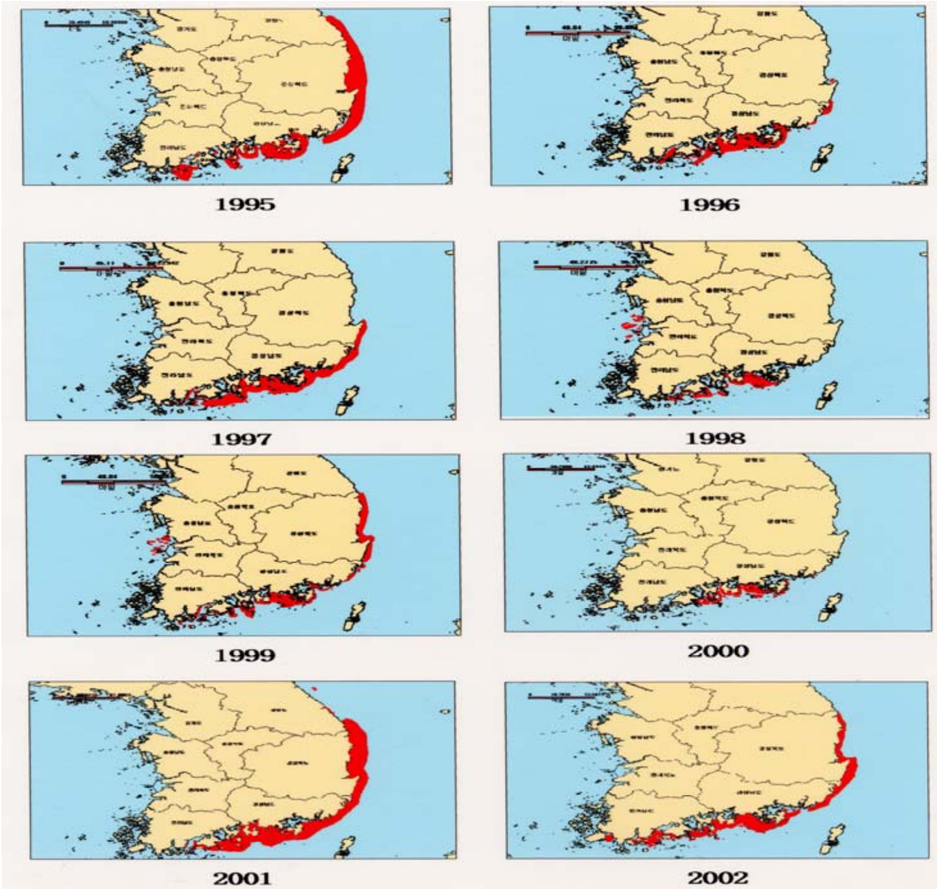



Fig.Ⅵ-3. Red tide affected by *Cochlodinium polukrikoides* blooms in Korean waters in period 1995-2002 (Kim, 2005)

## 2. Pathogenic microorganisms – virus and bacteria

### 2.1. Viruses and bacteria in the Chinese coastal waters

The viruses in the coastal waters of the Yellow Sea required further studies. In 1988, hepatitis A virus outbroke in the coastal areas of Shanghai, Zhejiang and Jiangsu, caused by the consumption of Scapharca subcrenata. The conclusion of investigation indicated that Scapharca subcrenata carried hepatitis A virus. There were several studies on the bacteria in the Yellow Sea and the Bohai sea, such as “Distribution of coliform in the waters of Dalian Coastal Scenic Area”, “Ecology of autotrophic bacteria and heterotrophic bacteria in the waters of the north of the Yellow Sea” and “Ecological distribution of fecal coliform and heterotrophic bacteria in the waters of the Changjiang River Estuary”. In recent years, detections and analysis of the bacteria in shellfishes and their living Environment including water and sediment have been developed.

The density of the fecal coliform in the coastal surface waters of the Yellow Sea and the Bohai Sea ranged from 40 ind/L to more than 48000 ind/L. 56.3% of the water samples accorded with the Category I National Seawater Quality Standards. The water samples that surpassed the standards were mostly collected from the tourist areas where human activities were frequent. In summer, the amount of fecal coliform in surface water of bathing beach may exceed the standards to a large extent.

The density of the heterotrophic bacteria living in the coastal surface water of the Yellow Sea and the Bohai Sea ranged from $2.5\times10^5$ cfu/L to $1.0\times10^8$ cfu/L, the average density for the whole area was$1.2\times10^7$ cfu/L. The density of the heterotrophic bacteria in surface sediment ranged from $2.8\times10^3$ cfu/ g to $7.5\times10^5$ cfu/ g, the average density for the whole area was $1.3\times10^5$ cfu/ g. There were more heterotrophic bacteria living in coastal waters than in offshore areas

# 3. Bioassay monitoring

## 3.1. The health of coastal animals in Chinese coast

According to the monitoring results of the mid and late 1990s, the average concentrations of heavy metals (mercury, cadmium, lead, arsenic) in the fishes, shellfishes and algae collected from the Yellow Sea were shown in TableⅥ-1. The average concentrations of oils in fishes, shellfishes and Crustaceans collected from the Yellow Sea and the Bohai Sea were shown in Table Ⅵ-2.

Persistent organic pollutants (POPs ) in the fishes, shellfishes and algae collected from the Yellow Sea mainly include organochlorine pesticides, PCBs, PAHs and DDT. PAHs include naphthalene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, chrysene, benzo(a)anthracene, benzo(a)pyrene, benzo(e)pyrene ect and their average concentrations were shown in Table Ⅵ-3. The average concentrations of DDTs and PCBs in the fishes, shellfishes and algae collected from the Yellow Sea were shown in TableⅥ-4.

According to the hygienic standards for food issued by the People’s Republic of China and the World Health Organization and derived from some scholar’s finds, the standard-exceeding rates of the residual contents of Hg、Cd、Pb、As、DDTs、PCBs and oils in fishes and shellfishes collected from the Yellow Sea were shown in Table Ⅵ-5.

We used the statistical method of t-test for two correlated samples to analyze the historical data of 1997 and 1990 (shown in TableⅥ-6), and found that the concentration of Hg in the shellfishes increased, the concentrations of Cd in the shellfishes reduced and the concentrations of Pb and As in the shellfishes reduced significantly ($\alpha$=0.05) in the Yellow Sea. The decrease of the concentrations of PCBs, DDTs and oils in the organisms in the Yellow Sea indicated that the pollution of PCBs, DDTs and oils was reduced.

TableⅥ-1. Average contents of heavy metals in organisms collected from the Yellow Sea

| Biological categories or types | Heavy metals contents ($10^{-6}$ wet weigh) |
|---|---|

| | Hg | Cd | Pb | As |
|---|---|---|---|---|
| Ruditapes philippinarum | 0.008 | 0.14 | 0.12 | 0.489 |
| Scapharca subcrenata | 0.008 | 1.14 | 0.12 | 0.397 |
| Shellfishes | 0.011 | 0.56 | 0.11 | 0.423 |
| Uiva pertusa | 0.006 | 0.04 | 0.27 | 0.370 |
| Fishes | 0.024 | 0.02 | 0.08 | 0.340 |

Table Ⅵ-2. Average contents of oils in marine organisms collected from the Yellow Sea and the Bohai sea

| Biological categories or types | The average contents of petroleum hydrocarbons ($10^{-6}$ wet weigh) |
|---|---|
| Ruditapes philippinarum | 20.4 |
| Scapharca subcrenata | 13.7 |
| Shellfish | 19.5 |
| Fish | 2.01 |

Table Ⅵ-3. Average contents of PAHs in the in the shellfishes, fishes and algae colleted from the Yellow Sea

| Types of pollutants | Average pollutants contents ($10^{-9}$ wet weigh) | | |
|---|---|---|---|
| | Shellfishes | Fishes | Uiva pertusa |
| Naphthalene | 1.7 | 6.1 | 2.5 |
| Fluorene | 1.0 | 2.0 | 0.7 |
| Phenanthrene | 3.3 | 3.5 | 3.5 |
| Anthracene | 2.0 | 1.5 | 2.5 |
| Fluoranthene | 4.2 | 1.4 | 1.7 |
| Pyrene | 3.9 | 0.7 | 3.1 |
| Chrysene | 39.4 | - | 21.2 |
| Benzo(a)anthracene | 82.7 | - | - |
| Benzo(a)pyrene | - | - | - |
| Benzo(e)pyrene | - | - | - |
| PAHs | 22.0 | 13.2 | 18.9 |

Table Ⅵ-4. Average contents of DDTs and PCBs in the organisms colleted from the Yellow Sea

($10^{-9}$ wet weigh)

| Biological types | DDTs | p.p'-DDE | p.p'-DDT | p.p'-DDD | o.p'-DDT | PCB |
|---|---|---|---|---|---|---|
| Ruditapes philippinarum | 6.1683 | 0.7393 | 3.6362 | 2.7228 | 0.0874 | 1.6331 |
| Scapharca subcrenata | 1.0486 | 0.8391 | 0.2489 | 0.2805 | 0.2320 | 5.2587 |
| Shellfishes | 16.9342 | 1.3370 | 1.5650 | 1.5848 | 1.4646 | 1.8243 |
| Fishes | 8.2660 | 2.3527 | 1.6233 | 4.7879 | 0.3067 | 0.9346 |

Table Ⅵ-5. Standard-exceeding rates of pollutants in fishes and other organisms collected from the Yellow Sea and the Bohai Sea

| Pollutants | Biological categories | Standard 1) ($10^{-6}$ wet weigh) | Standard-exceeding rate (5) |
|---|---|---|---|
| Hg | Shellfishes | 0.3 | 0 |
| | Fishes | 0.3 | 0 |
| Cd | Shellfishes 2) | 2.0 | 6.5 |
| | Fishes | 0.1 | 0 |
| Pb | Shellfishes | 1.0 | 0 |
| | Fishes | 1.0 | 0 |
| As | Shellfishes | 1.0 | 0 |
| | Fishes | 0.5 | 0 |
| DDTs | Shellfishes | 0.1 | 15.2 |
| | Fishes | 0.1 | 10 |
| PCBs3) | Shellfishes | 0.1 | 0 |
| | Fishes | 0.1 | 0 |
| Petroleum Hydrocarbons 4) | Shellfishes | 20 | 21.4 |
| | Fishes | 20 | 0 |

Note: 1) Hygienic standards for food issued by China; 2) Standards issued by world health organization; 3) IJC Aquatic Life Guideline; 4) Biological standard study group under Third Institute of Oceanography, SOA of China.

TableⅥ-6. The t-test results of the contents of the pollutants in shellfishes in the Yellow Sea and the Bohai Sea in 1997 and 1990

| Pollutants | The Yellow Sea and the Bohai | The Yellow Sea |
|---|---|---|
| Hg | Decreased | Increased |
| Cd | Decreased | Decreased |
| Pb | Remarkably decreased | Decreased |
| As | Remarkably decreased | Remarkably |
| PCBs | Decreased | Decreased |
| DDTs | Decreased | Decreased |
| Petroleum | Decreased | Decreased |

### 3.2. The health of coastal animals in Korean coast

Korea has collected the fish samples from the southeastern area of 33° -37°N and 124°-126°N in the Yellow Sea in 2000 to investigate how is the status of non-degradable pollutants such as heavy metals and PCBs (Oh et al., 2001). Most of the Yellow Sea fish samples had very low concentrations of total PCBs and chlorinated pesticides. The total PCBs concentrations ranged from 0.05ng/g to 26.75ng/g in fish tissue. The chlorinated pesticide concentration were quite low, and most of them ranged from undetected to 35.4ng/g in tissue (Oh et al., 2001). The PAHs concentration in the fish tissues ranged from 45.0 to 330.8ng/g. The concentrations of heavy metals in the fish muscles showed variations to the ranges of the followings : Cr. 0.81-2.99 (avg. 1.35)㎍/g, Cu.0.54-1.82 (avg.1.09)㎍/g, Cd. 0.002-0.030 (avg.0.008) ㎍/g, Pb. 0.007-0.494 (avg.0.056) ㎍/g, and Hg. 0.035-0.319(avg. 0.116) ㎍/g (Oh et al., 2001). The average concentration of Cr and Cu in the fish muscle tissues are relatively higher than those of other metals and the order of average concentration of metals is Zn>Cr>Cu>Ni>Hg>Pb>Cd.

This study shows us that the concentration of heavy metals and persistent organic pollutants in fish were not contaminated compared to the other coastal areas and other regions of the world. The heavy metal concentration in fish tissue from the Yellow Sea is relatively low and below the criteria set by Europe and Korea.

TableⅥ-7. Average contents of heavy metals in organisms collected from the southwestern part of Korean peninsula in the Yellow Sea

# Ⅶ. Environmental risk assessment of the Yellow Sea

## 1. Why is risk assessment necessary for the Yellow Sea?

Korea and China are responsible for protecting people from adverse health effects that arise from environmental exposure to contaminants, and also for protecting flora and fauna in the Yellow Sea. The practical approach of environmental risk assessment (ERA) is to remove any contaminant that has the potential to cause harm to human health and the Yellow Sea marine ecosystem (MPP-EAS, 1999). The other approach, on the other hand, searches for levels of industrial activity and hence contamination, that minimizes harm. It provides a basis for the Korean and Chinese environmental management that balances the responsibilities to protect Korean and Chinese people and the environment of Yellow Sea with economic realism. To implement ERA, the first thing is to detect the likelihood environmental condition caused by human activity that will cause harm the Yellow Sea marine ecosystem and human health, and then estimate the level of harm to a target. Then, we should understand the potential factors causing harm with an understanding of the likely levels of exposure in targets. The final goal is to conserve high quality of the Yellow Sea marine ecosystem to secure the sustainable productivity and balanced biodiversity.

### 1.1. What is the suspected agent and target?

Here, the interesting target of ERA is the Yellow Sea marine ecosystem rather than human health. It can be achieved to keep a high water quality that can secure the ocean sustainable productivity and balanced biodiversity in the Yellow Sea. We must select the susceptible agents to implement this risk assessment. The suspected agent may be chemical, biological, physical, or a combination of the three. As far as the agents of environmental risk are concerned, chemical contaminants are the main focus of the ERA (MPP-EAS, 1999). The chemical agents can identify as bio-degradable and non-biodegradable pollutants. Most of data used in this risk assessment of chemical agents were from the measured concentration in the field. It is also necessary to prioritize which chemicals to address in a risk assessment program. There are various international initiatives involved with prioritization of existing chemical. Conforming to Hedgecott (1944) and International Lists of Hazardous Substances, likelihood of chemical factors causing an adverse effect on the productivity and biodiversity in the Yellow Sea include high biomass of bio-degradable pollutant, and heavy metals and persistent organic pollutants (POPs) of toxic non-biodegradable substances.

Table Ⅶ-1. The available environmental date compiled for the ERA for the Yellow Sea

| Environment | National report submitted | | Select agents |
|---|---|---|---|
| | China | Korea | |
| Water quality | ○ Biodegradable<br>- Oils, Chlorophyll-a, SS, COD, Nutrients, pH, DO<br>○ Non-biodegradable<br>- Heavy metals : Hg, Cd, $Cr^{+6}$, | ○ Biodegradable<br>- Oils, Chlorophyll-a, SS, COD, Nutrients, pH, DO<br>○ Non-biodegradable<br>- Heavy metals : Hg, Cd, $Cr^{+6}$, | COD,<br>Chrolophyll-a<br>Nutrients |

| | | | |
|---|---|---|---|
| | Pb, As, CN,<br>- POPs : DDT, BHC, PCB,<br>Volatile phenolic compounds | Pb, As, CN,<br>- POPs : DDT, BHC, PCB,<br>Volatile phenolic compounds | |
| Sediment | ○ Biodegradable<br>- Oils,<br>○ Non-biodegradable<br>- Heavy metals : Al, As, Cd, Fe, $Cr^{+6}$, Cu, Hg, Mg, Pb,<br>- POPs : Aldrin, Benzppyrene, Cyanide, DDT, PAHs, PCB | ○ Biodegradable<br>- Oils,<br>○ Non-biodegradable<br>- Heavy metals : Al, As, Cd, Fe, $Cr^{+6}$, Cu, Hg, Mg, Pb,<br>- POPs : Aldrin, Benzppyrene, Cyanide, DDT, PAHs, PCB | Cd, Hg, Cu, Zn, PCB |
| Marine organisms | ○ Non-biodegradable<br>- Heavy metals : As, Cd, Hg, Pb,<br>- POPs : DDT, PAHs, PCBs | ○ Non-biodegradable<br>- Heavy metals : As, Cd, Hg, Pb,<br>- POPs : DDT, PAHs, PCBs | |
| HABs | | | |

Based on the present available environmental data compiled from China and Korea (table ), chemical oxygen demand (COD), chrolophyll-a, and nutrients can be the representative parameters to assess the quantity of high biomass. The events of harmful algal bloom (HAB) could be also one of the important parameters to assess the high biomass. Fortunately, both Korean and China are analyzing COD and HAB in their national environmental monitoring schemes.

As for heavy metals and POPs, cadmium (Cd), mercury (Hg), copper (Cu), zinc (Zn), PCB can served as chemical agents for the risk assessment for the Yellow Sea.

### 1.2. What are the sources of the risk agents?

### 1.3. What are the likely routes of exposure and exposure level?

### 1.4. What are the critical levels?

Table Ⅶ. National standards and critical levels of agents for ERA in the Yellow Sea

| Items | Factors | Water quality standard (㎎/ℓ) | | | | Critical level | RQ |
|---|---|---|---|---|---|---|---|
| | | China | Korea | Japan | | | |
| Bio-degradable | DIN | | 0.1 | 0.2 | | | |
| | DIP | | 0.015 | 0.02 | | | |
| | COD | | 2 | 2 | | | |
| | Chlorophyll-a | | | | | | |
| Heavy metal | Cd | | 0.01 | 0.01 | | | |
| | Hg | | nd | 0.0005 | | | |
| | Cu | | 0.02 | - | | | |
| | Pb | | 0.1 | 0.01 | | | |
| | Zn | | 0.1 | - | | | |
| POPs | Dioxin | | | | | | |
| | PCB | | nd | nd | | | |
| | TBT | | | | | | |
| | | | | | | | |

### 1.5. Prospective risk assessment

From the identified agents and targets hitherto, one can predict likely effects. The main question is to detect key suspected agents in the Yellow Sea, and then identify marine pollution hot spots over there.

Table Ⅶ. Applying criteria to designate marine pollution hot spots

# Ⅷ. Conclusions

## 1. Expected outcome

☐ **Provide scientific basis for the ecosystem based management**

It can identify the principal driving forces introducing the changes of biomass and biodiversity by assessing the status of pollution and their biological impacts. It can provide scientific basis for the ecosystem based management of the driving forces to ensure the intergenerational sustainability of Yellow Sea ecosystem productions such as fisheries and ecosystem services like marine tourisms.

☐ **Designation of pollution hot spots and sensitive areas for SAP**

The Strategic Action Programme (SAP) will be a action-oriented YSLME initiative to tackle and eliminate the terrestrial pollutants by facilitating and accelerating the implementation of national environmental goals. It needs to identify pollution hot spots and sensitive areas where are responsible for the effluent of toxic, persistent and liable to bio-accumulate pollutants into the Yellow Sea. Based on the available pollution data and information generated through the national and cooperative study cruise reports, a determination of the Yellow Sea's pollution hot spots and ranking can be implemented. These determinations will address the areas to be specially managed, and to be protected for the conservation of marine ecosystem and secure public health.

☐ **Baseline contaminants levels essential to protect the safety of marine life**

Threshold concentration of safety level of conservative pollutants is to be compiled to assess their toxicity. Priorities will be given to the impacts of those pollutions to the marine environment and commercially important plants and animals living there. In addition, clarify the implications.

## 2. Recommendations for TDA

☐ **Recommendations for the stewardship agencies and organization**s

○ Develop management strategies from simple to comprehensive, and from short-term to long-term management practice focusing on sustainable production and safety of marine products.

○ Urge to use these scientific findings and assessment to identify and evaluate management options that are both scientifically credible and economically practical with regard to the use of ecosystem goods and services of the Yellow Sea.

○ Recommend countries to undertake a transboundary diagnostic analysis (TDA) to provide the science-based assessments for priority setting on threats to the ecosystem and root causes.

○ Science-based assessments should lead interested countries to advance new policies and actions for eliminating root caused of transboundary environmental and resources use practices leading to serious degradation of coastal environments and losses in biodiversity and food security from overexploitation of fish population in the Yellow Sea Large Marine Ecosystem.

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